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ABSTRACT

This proceedings contains a copy of the conference program and more than 75 papers and presentation summaries from the meeting, placed in order by conference session. Paper topics include science assessment issues; science for special needs students; science teachers' self-efficacy; teaching science to at-risk students; online inquiry instructional systems; strategies for equity in science education; teacher-researcher collaboration strategies; the nature of science; national science standards; portfolio development; teacher professional development; school-professional partnerships; learning theories; problem-based learning; student attitudes toward science; science, technology and society; elementary and secondary science teacher preparation; integrated approaches to curriculum; scheduling effects on science learning; constructivism; strategies for technology integration; writing-to-learn science; action research; distance education; preservice teachers' science knowledge; science teacher preparation in foreign countries; family science activities; multicultural science; student-centered science; and virtual field trips. (WRM)

Proceedings of the 1999 Annual International Conference of the Association for the Education of Teachers in Science

Edited by:

Peter A. Rubba, The Pennsylvania State University
James A. Rye, West Virginia University
Patricia F. Keig, California State University – Fullerton

Preface

We are pleased to have had the opportunity to edit these proceedings of the 1999 Annual International Conference of the Association for the Education of Teachers in Science, held in Austin, Texas, January 14-17, 1999. Over 75 papers and summaries of presentations from the conference are included here, along with a copy of the conference program. The papers and presentation summaries are ordered herein by the corresponding conference session and by the first author's last name if it did not appear in the printed conference program.

Each paper and presentation summary submitted for inclusion in the proceedings was reviewed by one of the editors. Because these proceedings are to serve as a record of the 1999 AETS annual meeting, the papers and presentation summaries were not heavily edited and were not refereed. Those papers and presentation summaries that were revised and returned by a designated date were included.

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Peter A. Rubba, The Pennsylvania State University
James A. Rye, West Virginia University
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1999 AETS Conference Program

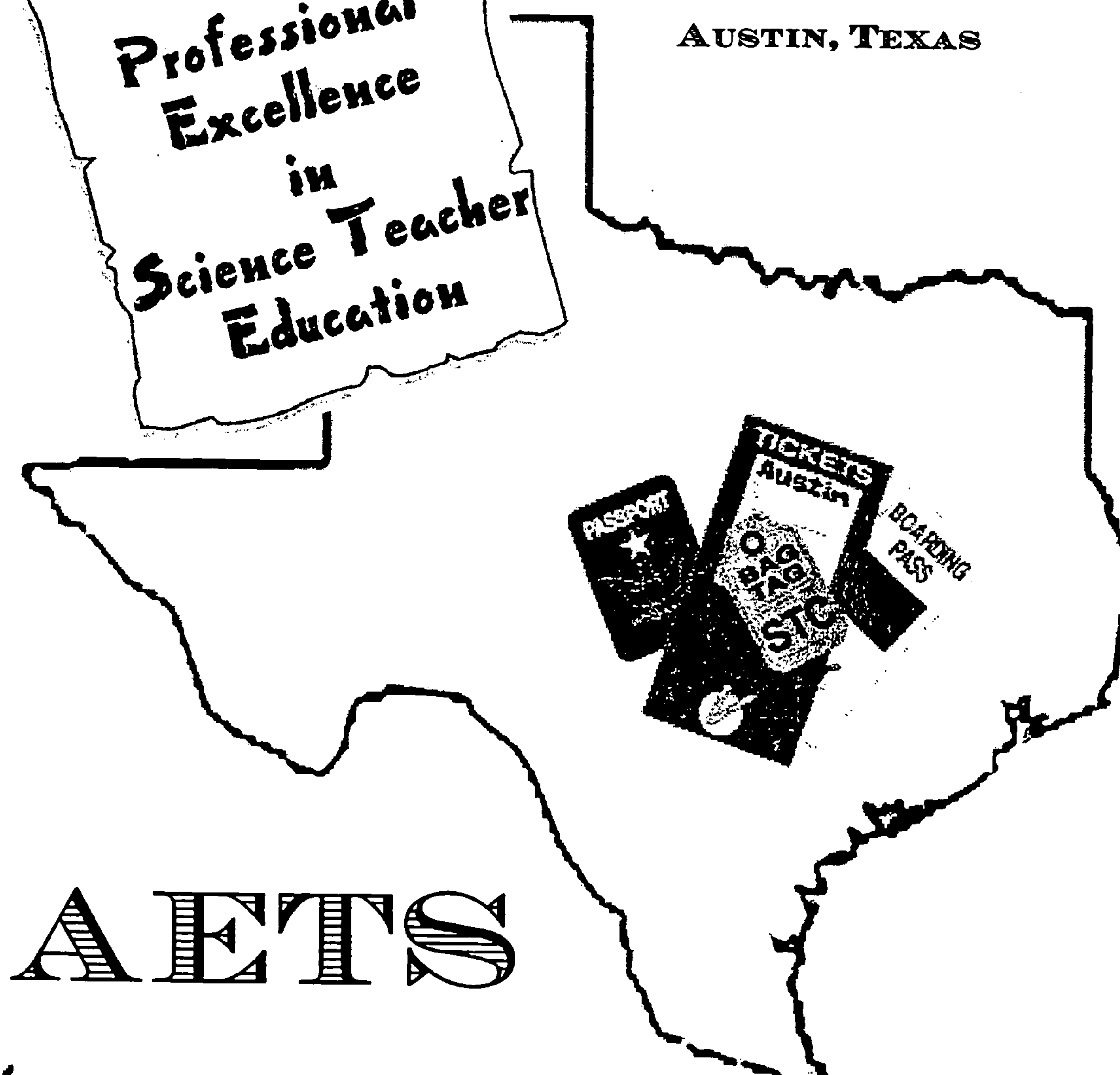
Association for the Education of Teachers in Science, 1999 Annual International Conference, January 14-17, 1999: Austin, Texas

Association for the Education of Teachers in Science

1999 Annual International Meeting

Passport to Professional Excellence in Science Teacher Education

January 14-17, 1999
Omni - Austin Hotel
Austin, Texas



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Texas Regional Collaboratives for Excellence in Science Teaching

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Conference Theme: Passport to Professional Excellence in Science Teacher Education

Welcome to the 1999 Annual AETS International Meeting in Austin, Texas. The Omni Austin Hotel is conveniently located in downtown Austin in the heart of business, shopping, and the 6th Street entertainment district. It is a few blocks from the Texas State Capital and one mile from The University of Texas. A 200-foot tall atrium is the center point of the Omni, which houses a cafe, dining room, lobby and lounge areas. The facilities include an outdoor roof top pool, exercise room, outdoor heated whirlpool, and sauna. We are certain you will enjoy your stay.

The theme for this year's conference is "Passport to Professional Excellence in Science Teacher Education." You will have opportunities to attend numerous presentations including papers, poster sessions, panel discussions, workshops and three general sessions. We have outstanding speakers for the general sessions: Dr. Jere Confrey, Dr. Alberto Rodriguez and Dr. Steven Rakow. They will address three very important questions: "Where are we going in science teacher education? How do we get there? How do we know if we have arrived?" During our 1999 meeting, you will enjoy a tour and buffet dinner at the Lyndon B. Johnson Library and Museum, as well as an evening "out on the town" which includes a performance at one of the more colorful spots on 6th Street, Esther's Follies.

The corporate sponsors for the event are Casio, Inc. and Delta Education. Additional support has been provided by the Biological Sciences Curriculum Study, Texas Instruments, Houghton Mifflin, and the Texas Regional Collaboratives for Excellence in Science Teaching. As a member of AETS and a conference attendee, please let these organizations know how much you appreciate their support of AETS. We would also like to thank Lynn Jones Eaton and Sherry Nichols, program co-chairs, and all committee members who worked during the past year to help make this event successful. A special thanks to John Cannon, Director of Electronic Services, for making all conference information, registration forms and the advance program available through the AETS Web Site and the listserve. We would also like to thank Jon Pedersen for assuming the responsibility of Executive Secretary early in order to conduct registration and provide for fiscal arrangements. Additional thanks are provided to the 1998 Minneapolis committee members who provided ideas and advice on various aspects of organizing an AETS conference.

We hope you will enjoy Austin and our 1999 AETS meeting. If you have questions, concerns or comments please let us know.

Jim Barufaldi and Kathy Norman, Conference Co-Chairs

Conference Committees

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Registration Location and Hours

Registration is located on the Mezzanine level of the hotel. In addition to matters directly related to conference registration, the staff will be able to answer any questions you have about the conference. Registration will be open during the following hours;

Wednesday evening	7:00 pm - 9:00 pm
Thursday	7:00 am - 5:00 pm
Friday	7:00 am - 5:00 pm
Saturday	7:00 am - 5:00 pm

Amenities

As part of registration fees, a continental breakfast will be available on Friday, Saturday, and Sunday, 6:30 am - 9:00 am in the Atrium. Breaks will be provided on Thursday, 2:30 pm, Friday and Saturday at 10:20 am and 3:20 pm, and on Sunday at 10:20 am, on the Mezzanine level.

Special Events

There are several special events that have been included with your conference registration fee. These include the buffet dinner at the LBJ Library and Museum, a "night out" at Esther's Follies, two luncheons including the Annual Awards Ceremony/Business Meeting Luncheon, and three invited guest speakers. The specific times, dates, and locations of these events follow.

Thursday General Session — 5:00 pm - 6:00 pm — Ballroom A & B
Speaker, Dr. Jere Confrey: Where are We Going in Science Teacher Education

Thursday Buffet Dinner — 7:00 pm - 10:00 pm — LBJ Library and Museum
This event is sponsored by Casio, Inc. Bus transportation provided; hotel main entrance beginning at 6:45 pm.

Friday Luncheon — 12:00 noon - 2:00 pm — Longhorn Room
Speaker, Dr. Alberto Rodrigues: How Do We Get There?

Friday Evening — 8:00 pm — Esther's Follies
This event is sponsored by Delta Education. Esthers is located on 6 th Street; a short walk from the hotel. Ticket required.

Saturday Luncheon — 12:00 noon - 2:30 pm — Longhorn Room
Annual Awards Ceremony/Business Meeting
Speaker, Dr. Steven J. Rakow: How Do We Know if We Have Arrived?

1999 AETS International Meeting
Schedule of Events

Wednesday, January 13

Board Meeting	6:00 pm - 10:00 pm	Austin Room
Registration	7:00 pm - 9:00 pm	Mezzanine

Thursday, January 14

Registration	7:00 am - 5:00 pm	Mezzanine
Pre-conference workshops	8:30 am - 12:00 noon	Hotel and University*
*A van will transport participants attending workshops at the University, 7:30 am, main entrance of hotel.		
Coffee Break	3:20 pm	Mezzanine
Paper Sessions	1:00 pm - 4:40 pm	Hotel
General Session	5:00 pm - 6:00 pm	Ballroom A & B
Speaker, Dr. Jere Confrey: Where Are We Going in Science Teacher Education?		
Buffet Dinner	7:00 pm - 10:00 pm	LBJ Library
Bus transportation provided; hotel main entrance beginning 6:45 pm.		

Friday, January 15

AETS Committee Meetings	6:30 am - 8:00 am	Hotel
Registration	7:00 am - 5:00 pm	Mezzanine
Continental Breakfast	6:30 am - 9:00 am	Atrium
Paper Sessions	8:00 am - 11:40 am	Hotel and University*
*A van will transport participants attending workshops at the University, 7:30 am, main entrance of hotel.		
Coffee Break	10:20 am	Mezzanine
Luncheon	12:00 noon - 2:00 pm	Longhorn Room
Speaker, Dr. Alberto Rodriguez: How Do We Get There?		
Paper Sessions	2:20 pm - 5:40 pm	Hotel
Coffee Break	3:20 pm	Mezzanine
Dinner	On your own	
Esther's Follies (a short walk from hotel)	8:00 pm	6th at Red River Street

Saturday, January 16

AETS Committee Meetings	6:30 am - 8:00 am	Hotel
Registration	7:00 am - 5:00 pm	Mezzanine
Continental Breakfast	6:30 am - 9:00 am	Atrium
Paper Sessions	8:00 am - 11:40 am	Hotel
Coffee Break	10:20 am	Mezzanine
Award Luncheon/ Business Meeting	12:00 noon - 2:30 pm	Longhorn Room
Speaker, Dr. Steven J. Rakow: How Do We Know If We Have Arrived?		
Paper Sessions	2:40 pm - 6:00 pm	Hotel
Coffee Break	3:40 pm	Mezzanine
Dinner	On your own	

Sunday, January 17

Continental Breakfast	6:30 am - 9:00 am	Atrium
AETS Board Meeting	8:00 am - 12:00 noon	Lone Star Room
Paper Sessions	8:00 am - 12:00 noon	Hotel
Coffee Break	10:20 am	Mezzanine

1999 AETS Preconference Workshops

All Preconference Workshops will be held at 8:30 am on Thursday, January 14, 1999

Achieving Inclusion in K-12 Science Classes: Adapting Instruction for Students with Learning and Other Disabilities
Presenters are Richard Villa, Jacqueline Thousand, and Pat Kurtz
Held in Executive Room

Applications of the Internet to Connect Communities of Learners to Improve the Quality of Science Teacher Educators
Presenters are Kenneth Tobin and Nancy Davis
Held on the University of Texas at Austin Campus, SZB Building, Collaborative Learning Lab (*van will transport participants at 7:30am, main entrance of hotel)

Designing Professional Development for Teachers of Science: An Interactive Forum
Presenters are Susan Loucks-Horsley and Paul Kuerbis
Held in Congress Room

Developing Physical Science Concepts in the Primary Grades-the OPPS Approach
Presenters are M. Janice French, Tim Cooney, and Karen Ostlund
Held in Ball Room A

Forms Follows Function: Web Page Architecture for Educational Telecomputing Projects
Presenter is Judi Harris
Held on the University of Texas at Austin Campus, SZB Building, Mac Lab (*van will transport participants at 7:30am, main entrance of hotel)

On-Line Access Supporting Quality Searches for Science Materials
Presenters are Tom Gadsden, Stephen Marble, and Donna Berlin
Held at the Southwest Educational Development Laboratory, 211 East 7th Street

Preparation and Classroom Applications of Virtual Field Trips for Use in Elementary, Middle School, and Secondary Education
Presenters are Robert L. Hartshorn, J. Preston Prather, Kueh Chin Yap, Reo Prulett, Janet J. Woerner, Terry Cook, Betsy Jones, and Roger L. Davis
Held in Ball Room B

Multicultural Science Pedagogy: Practical Approaches for the Classroom
Presenters are Leslie S. Jones, University of N. Iowa; Will Letts, University of Delaware; Alberto J. Rodriquez, New Mexico State University; and Aldrin E. Sweeney, University of Central Florida
Held in Senate Room

Thursday, January 14, 1:00-2:00pm Session 1

T 1.1 Austin North **general** **Interactive Session (60 min.)**
Sherry Nichols East Carolina State University
Deborah Tippins University of Georgia

Theoretical Frameworks: What Are They, Where Do They Come From?
Participants will explore questions including: What is a theoretical framework? How many frames are needed for a study? Where do we "get" a framework(s)?

T 1.10 Longhorn **general** **panel (60 min.)**
Joanne K. Olson University of Southern California
Anne Marshall Cox California State University, Fullerton
William F. McComas University of Southern California

The Inclusion of Informal Environments in Teacher Preparation
We wish to discuss with participants successful strategies which enable preservice and inservice teachers to effectively use informal environments with their own students.

T 1.11 Rotunda **general** **contributed paper (30 min.)**
Jeffrey Weld Oklahoma State University

Effects of Science Teaching Awards on Recipients and their Peers
Do awards improve science teaching? What are the after-effects of awards on winners? Are awards a valued incentive? Five national cash awards comprised this study--their winners and a sample of science teachers who have yet to win such an award.

T 1.11 Rotunda **general** **contributed paper (30 min.)**
Vaughan Prain La Trobe University, Bendigo
Larry D. Yore University of Victoria
Brian Hand La Trobe University, Bendigo

Barriers and Breakthroughs in Implementing Writing for Learning in Secondary School Science
This presentation addresses the concerns and success of Australian science teachers during a 5-year implementation of innovative writing-to-learn tasks in secondary science.

T 1.12 Senate **elementary** **contributed paper (15 min.)**
Jennifer Karpel Purdue University

Understanding Assessment in Bilingual/Biliterate Science Classrooms
This study examined the types, uses and roles of science assessment in a bilingual/biliterate (Spanish/English) elementary classroom in Central America.

T 1.12 Senate **general** **contributed paper (15 min.)**
Mary Kay Kelly Miami University
Jane Butler Kahle Miami University
Kate Scantlebury University of Delaware

Performance Assessment as a Tool to Enhance Teacher Understanding of Student Conceptions of Science
Science achievement was measured by both performance and paper-pencil questions. Student scores were better on the performance questions than on the paper-pencil questions.

T 1.2 **Austin South** **college** **seminar (60 minutes)**
Patricia E. Simmons University of Missouri-St. Louis

Outside the Hotel: A Challenging and Continuing Discourse

Come participate in a continuing dialogue and discourse about science teacher education, where we focus on "making a difference."

T 1.3 **Ball Room A** **college** **contributed paper (30 min.)**
Kathie Owens The University of Akron

Project "Getting Up to Spe-ed"

Undergraduate students' attitudes toward inclusion in K-12 classrooms were analyzed to determine changes following a workshop for faculty where revisions to methods courses occurred.

T 1.3 **Ball Room A** **college** **contributed paper (30 min.)**
Mary E. Wingfield University of Houston
John Ramsey University of Houston

Improving Science Teaching Self-efficacy of Elementary Preservice Teachers

Experiences of the site based education program had a statistically significant increase in the science teaching self-efficacy of elementary preservice teachers as measured by the STEBI. Factors identified by Bandura as sources of information for building efficacy are discussed.

T 1.4 **Ball Room B** **college** **demonstration (30 min.)**
Marcia K. Fetters The University of Toledo
Michael E. Beeth The Ohio State University
R. Paul Vellom The Ohio State University
Betsy McNeal The Ohio State University

Moving from Student to Teacher: Three Strategies that help pre-service teachers move from a student role to teacher role

This panel will describe three strategies that help pre-service teachers develop proactive plans for addressing: the nature of science and mathematics; at-risk students; and assessment.

T 1.4 **Ball Room B** **college** **demonstration (30 min.)**
George E. O'Brien Florida International University
Scott Lewis Florida International University
Craig Williams Florida International University

Implementing a New Elementary Science Methods Course Framework

The purpose of this presentation is to demonstrate a course framework which consists of four major strands of knowledge (i.e., Content Knowledge, Nature of Science Knowledge, Pedagogical-Content Knowledge, and Knowledge of Children's Knowlege).

T 1.5 **Bouquets** **elementary/middle** **hands-on workshop (60 min.)**
Susan Stehling Region 3, Yorktown ISD
Karlton Land Region 3, Victoria ISD

Hands on Science for Elmentary and Junior High School

Teachers will receive handouts and participate in hands on science activities for elementary and junior high students. Fun with chemistry and toys will help make real connections in science. All activities are taken from the Steve Spangler Institute for Hands on Science (Regis University, Denver, Colorado). A supply list will be given to each person attending so they may go back and use these activities as soon as possible.

T 1.6 **Cellar** **college** **contributed paper (15 min.)**
Jackie Wilcox University of North Dakota

Stories from the Field: A Case Study of Six Elementary Student Teachers Initial Experiences Teaching Science

The qualitative study was conducted to find out how preservice elementary teachers make meaning of science teaching during their student teaching experience.

T 1.6 **Cellar** **college** **contributed paper (15 min.)**
Scott Watson East Carolina University

Problems Encountered by Novice Science Teachers

The purpose of this project was to explore the various problems and dilemmas faced by science teachers in their first three years of teaching.

T 1.6 **Cellar** **college** **contributed paper (15 min.)**
Alynn J. Gentry Purdue University-North Central

Preservice Elementary Teachers Visualization and Self-Efficacy of Their Learning: Reflection as a Tool for Self-Evaluation

Preservice teachers use reflections on their future classroom and drawing themselves teaching science to evaluate their learning in an elementary science methods course.

T 1.6 **Cellar** **college** **contributed paper (15 min.)**
Mark Seals Purdue University

Caring and its "Role" to Effective Teaching

The qualitative inquiry (case study) was to explore, analyze, and describe the reciprocity of "caring" as it is embedded in and shapes the culture of the high school science classroom in regards to the teaching and learning of science. The findings show the need to develop ways pre-service teachers can learn to build caring relationships and learn to teach to the "individual rather than the student."

T 1.7 **Congress** **college** **contributed paper (15 min.)**
Kevin D. Finson Western Illinois University
Iris M. Riggs Univ. California-San Bernardino
Joseph Jesunathadas Cal-State Univ-San Bernardino

The Relationship of Preservice Elementary Teachers' Self-Efficacy to Self Image as a Science Teacher

This presentation will examine possible relationships between preservice teachers' self images as revealed through drawings of themselves and self efficacy as measured using the STEBI-B.

T 1.7 **Congress** **college** **contributed paper (15 min.)**
Karen Laba University of New Hampshire
Eleanor Abrams University of New Hampshire

Changing Teachers' Minds

Teachers' beliefs influence their curricular choices in complex and intricate ways. A simple interview protocol used to probe exemplary teachers' beliefs also holds promise for use with preservice teachers.

T 1.7 **Congress** college contributed paper (15 min.)
John W. Tillotson Syracuse University

The Impact of a State Mandated Science Curriculum on Teachers' Beliefs and Decision-making

Learn how preservice and inservice science teachers' beliefs and actions in the classroom are influenced by a state science curriculum. Implications for teacher education programs and strategies for overcoming these constraints will be shared.

T 1.7 **Congress** general contributed paper (15 min.)
Kueh Chin Yap Nanyang Tech University

Perceptions of Pre-Service Science Teachers about Themselves as Science Teachers: The Singapore Experience

This session will look at the use of DASTT-C in comparing the drawings of various groups of pre-service science teachers in Singapore.

T 1.8 **Executive** college panel (60 min.)
Christine S. Jones Colorado State University
Barbara J. Nelson Colorado State University
Frederick M. Stein Colorado State University
Terrence O'Donnell Colorado State University
Sreedevi Bringi Colorado State University

Rocky Mountain Teacher Education Collaborative: Preservice Reform Results

Results of Rocky Mountain Teacher Education Collaborative, NSF five-year CETP, Colorado multi-institution collaboration: major institutional changes for preservice science and mathematics teacher preparation.

T 1.9 **Liberty** college panel (60 min.)
Lynn M. Burlbaw Texas A&M University
Robert K. James Texas A&M University
Janice Robinson Texas A&M University

Integrating Science & Social Studies Methods in an STS Project

Integrating secondary science and social studies methods courses via an STS unit. Topics will include cross disciplinary contents team building and collaboration and issues oriented curriculum within a resource unit.

T 2. **Austin North** college hands-on workshop (60 min.)
Dean Becker Austin Community College

Work, Energy and Power on a Rowing Ergometer

Participants will gain a kinesthetic sense of the concepts through hands-on and minds-on exploration on a rowing ergometer. Appropriate for physics, physical science and secondary methods classes.

T 2.10 **Longhorn** middle panel (60 min.)
Barbara A. Crawford Oregon State University
P. Elizabeth Pate The University of Georgia
Robin McGrew-Zoubi Sam Houston State University
Claudia T. Melear University of Tennessee

Where is the SCIENCE in Middle Level Science Teacher Education?

An interactive panel addresses the dilemmas and special considerations for teacher education at the middle school level. Bring your own issues to debate..

T 2.11 Rotunda **general** **contributed paper (30 min.)**
Alec M. Bodzin North Carolina State Univ.

An Online Inquiry Instructional System for Science Education

This paper presents the design and development process of creating a science curricular website that incorporates an authentic inquiry simulation for student learning.

T 2.11 Rotunda **general** **contributed paper (30 min.)**
William H. Robertson Los Alamos National Laboratory

TOPS (Teacher Opportunities to Promote Science): Vertical Curriculum Alignment through aWeb Based Teacher Network

TOPS participants form vertical teacher teams representing elementary, middle and high school levels to promote vertical curriculum alignment and communication through networking and skill development.

T 2.12 Senate **general** **contributed paper (30 min.)**
Robin Lee Harris Freedman Buffalo State College

Variety in Assessment: A Closer Look

NSES promotes the use of variety in assessment. What does it look like? This session attempts to define and describe variety.

T 2.12 Senate **college** **contributed paper (30 min.)**
J. Preston Prather University of Tennessee-Martin
Ronald D. Simpson University of Georgia
Rebecca E. Irwin University of Tennessee-Martin

Faculty Perspectives on Reform of Undergraduate Science and Mathematics Curriculum and Teaching

The results of a program for development of a prototype laboratory for intra-institutional reform of undergraduate science and mathematics education will be reviewed and discussed.

T 2.2 Austin South **college** **contributed paper (30 min.)**
David T. Crowther University of Nevada, Reno
John R. Cannon University of Nevada, Reno

How Much is Enough? Preparing Elementary Science Teachers Through Science Practica: The third year of a longitudinal study

This paper reports the results of a three year study investigating the effectiveness, or lack thereof, of various lengths of elementary science practica. The unit of measure used was Science Teaching Self-Efficacy (STEBI) Beliefs Inventory scores.

T 2.2 Austin South **contributed paper (30 min.)**
Elva G. Laurel The University of Texas at Brownsville
Reynaldo Ramirez The University of Texas at Brownsville
Celvia Rodriguez The University of Texas at Brownsville

Como Que No Puedo? Strategies for the Recruitment and Retention of Hispanic Females into Mathematics and Science Post-secondary Programs and Careers

A search of literature and first hand experience with Mexican-American female youth entering post-secondary science, engineering, and mathematics programs has provided insights to best practice models. Recruitment, retention and assistance strategies for minorities, expecially females entering institutions of higher education are the focus of the presentation. An overview of two projects will provide the audience with action research features that can be emulated by institution of higher ed.

T 2.3 Ball Room A Sponsor
BSCS

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Corporate Sponsored Presentation

T 2.4 Ball Room B college panel (60 minutes)
Gil Naizer Texas A&M University, Commerce
Carol Stuessy Texas A&M University
Kim Dooley Texas A&M University

Distance Science Education

This roundtable session will include several instructors who have used distance education sharing their experiences, frustations, and solutions and addressing audience questions.

T 2.5 Bouquets secondary/college hands-on workshop (60 min.)
Norman Thomson University of Georgia

Knowledge Changes of Second Grade Children Following an Instructional Television Program - "Plant Changes"

"Plant Changes" is one of 13 instructional public television programs in a science inquiry based series called "Let Me See" designed for first and second grade children. The purpose of this study was to determine what detailed knowledge changes occurred in second grade children as a consequence of viewing one 25-minute program independent of any accompanying activities designed for instruction.

T 2.6 Cellar contributed paper (30 min.)
Steven B. Case KanCRN/Univ of Kansas

New and Emerging Technologies and their Impact on School Reform, Teaching and Learning

The session will explore the activities and research potential of the Kansas Collaborative Research Network (KanCRN). Participants will explore the underlying curriculum model, the coordinating website for the students, teachers, and mentors, and web-design principles applied to the project. The evaluation plan for the project serves as a springboard for research into curriculum design, standards implementation, professional development and the use of technology in science education reform.

T 2.7 Cellar general contributed paper (15 min.)
Larry Flick Oregon State University

The Role of Teacher-Researcher Collaboration on Inquiry-Board

The role of collaborative research is analyzed in the context of new assumptions about the professionalization of teachers and the NSES focus on science as inquiry.

T 2.7 Cellar middle contributed paper (15 min.)
Joseph Krajcik University of Michigan
Jonathan Singer University of Michigan

Supporting Middle School Teachers with Developing and Enacting Extended Inquiry Projects

This presentation describes our collaboration approach to develop and enact extended inquiry projects.

T 2.7 Congress general contributed paper (15 min.)
Kevin D. Finson Western Illinois University

Collaborative Relationships Between Science and Special Education Teachers: Pitfalls and Benefits

This presentation will look at the salient points necessary for effective collaboration to occur between science and special education teachers.

T 2.7 Congress — elementary/college — contributed paper (15 min.)
Penny L. Hammrich Temple University

Sisters in Science: An Intergenerational Science Program for Elementary School Girls

This paper describes the Sisters in Science Program that was conceived to increase the interest and literacy of elementary school age females in science and mathematics.

T 2.7 Congress — general — contributed paper (30 min.)
Rita Coombs Richardson Southeastern Louisiana University

A Multicultural Approach to Teaching Science & Math to Minority Students Receiving Special Education

The presentation will familiarize participants with strategies to teach science and mathematics to minority culture students with learning disabilities. A paper, describing strategies will be distributed.

T 2.8 Executive — college — panel (60 min.)
Charlene M. Czerniak The University of Toledo
Jodi J. Haney Bowling Green State University

Project-Based Science Methods Course

An overview of a project-based approach, used in undergraduate science methods, is presented. Discussion focuses on the utility of the project-based approach in methods courses.

T 2.9 Liberty — elementary — panel (60 min.)
Suzanne Shaw Drummer The Ohio State University
John R. Mascazine The Ohio State University
Dawn Healy McCary The Ohio State University
Wendy Sherman McCann The Ohio State University

Innovative Science Content Courses for Preservice Elementary Teachers

Our panel will discuss innovative ideas used in preservice elementary teacher courses, including individualized field experiences, user-friendly labs, and integrated curricula.

Thursday, January 14, 3:40-4:40pm Session 3

T 3.1 Austin North — general — hands-on workshop (60 min.)
Lloyd H. Barrow University of Missouri

Helping Graduate Students Becoming a Successful Professor

The session will discuss potential types of positions; interview tips, and professor activities that lead to tenure.

T 3.10 Senate — college — contributed paper (30 min.)
Huey-Por Chang National Changhua Univ. of Education

Contributed Paper: Teacher Education and Evaluation

Teacher education and evaluation have been drastically changed in the last four years. The development of systematic instruments to assess beginning teachers' competency is urgent.

T 3.2 Austin South — college — contributed paper (15 min.)
Alan Colburn California State Univ-Long Beach
John Tillotson Syracuse University

Inquiry & Constructivism for Science Methods Students

We explain an innovative learning cycle based approach to help prospective teachers explore constructivism, and then apply the ideas within an inquiry-based classroom.

T 3.2 **Austin South** **general** **contributed paper (15 min.)**
Amy B. Palmeri Vanderbilt University

Using HyperNews Technology to Enhance Professional Dialogue between Preservice Elementary Teachers

This paper examines the professional dialog generated between preservice teachers seeking to link theory and practice as a result of using HyperNews technology.

T 3.2 **Austin South** **general** **contributed paper (30 min.)**
Julie Saam Indiana University
William J. Boone Indiana University
Valerie Chase National Aquarium, Baltimore

A Snapshot of Upper Elementary and Middle School Science Teachers' Self-Efficacy and Outcome Expectancy

Presenters collected self-efficacy/outcome expectancy data from a national teacher sample. Analysis suggests differences only in self-efficacy regarding students' SES. Presenters will discuss outreach implications.

T 3.2 **Austin South** **general** **contributed paper (15 min.)**
Michael R. Vitale East Carolina State University
Nancy R. Romance Florida Atlantic University

A Knowledge-based Typology for Classroom Assessment in Science

Presented is a knowledge-based model for the design of assessment instruments that focus on student understanding of and capability to apply conceptual relationships in science.

T 3.3 **Bouquets** **general** **hands-on workshop (60 min.)**
Vickie Harry Clarion University of Pennsylvania
Maggie Niess Oregon State University
John McCullough Clarion University

Promoting the Teaching and Learning of Gender Equity

This session will engage participants in activity designed to raise awareness of gender equity issues in mathematics, science, and technology in teacher education programs.

T 3.4 **Cellar** **college** **contributed paper (30 min.)**
Ron Good Louisiana State University
Catherine L. Cummins Louisiana State University
Gary Lyon Louisiana State University

Nature of Science Assessment Based on Benchmarks and Standards

Reform documents, Benchmarks and Standards, identify nature-of-science ideas that can be used to assess teachers' and students' understanding of the nature of science.

T 3.4 **Cellar** **secondary** **contributed paper (30 min.)**
Julie F. Westerlund Southwest Texas State University
Sandra S. West Southwest Texas State University

The Use of the National Science Education Standards as a Tool to Critique the Texas Biology I End-of-Course Examination

A study which uses the National Science Education Standards in assessment to critique a Texas state-mandated high school biology end of course examination.

T 3.5 **Congress** **college** **contributed paper (30 min.)**
Richard J. Bryant Southwestern Oklahoma State Univ.

Gender Equity: One University's Efforts Toward Systemic Change

A team of education and arts and sciences faculty members designed and implemented a plan to promote gender equity instruction throughout the teacher education program.

T 3.5 Congress — elementary/college — contributed paper (15 min.)

Penny L. Hammrich Temple University
Greer Richardson Temple University

The Sisters in Science Program: Teachers Reflective Dialogue on Confronting the Gender Gap

This paper describes teachers conceptions of science/mathematics teaching and their perceptions of confronting the gender gap as they participated in the Sisters in Science Program.

T 3.5 Congress — contributed paper (15 min.)

R. Lynn Jones Eaton The University of Texas at Austin
Violetta Lien The University of Texas at Austin

MSEC: A Model of Reform for Elementary Science Teachers

This presentation will focus on the MSEC (Math and Science Education Cooperative) model of reform and its impact on elementary science teaching.

T 3.6 Executive — college — panel (60 min.)

Julie Gess-Newsome University of Utah
Deborah Tippins University of Georgia
Bill Baird Auburn University

Using Matrices for Understanding, Designing and Assessing Science Curricula

We will describe how we each use matrices as planning tools to generate ideas, design good tests, organize course content, and examine changes in teachers' thinking. Examples will illustrate some of the ways this approach has been useful to us. A dialogue with the audience will follow.

T 3.7 Liberty — elementary — panel (60 min.)

Michael R. Cohen Indiana Univ Purdue University-Indianapolis
William John Boone Indiana University
Lynn A. Bryan University of Georgia
Valarie Dickinson Washington State University
Roy Lee Foley University of Houston - Victoria
Yoshisuke Kumano Shizuoka University
Karen Lind University of Louisville
Francis Broadway Univ of Akron
Ron Brown Mankato State University
Jennifer Karpel Purdue University
George O'Brien Florida International University

What's Elementary About Elementary School Science Education? Sharing and Expanding the Work of the Ad Hoc Committee on the Education of Elementary

This proposal is from the Ad Hoc Committee on Elementary Science Teacher Education. Our intent is to engage AETS members in discussions about several areas identified in our report. Our session will provide a brief general overview of our report and then break into smaller discussion groups to share specific ideas. We will end with reports from the individual groups.

T 3.8 Longhorn — general — panel (60 min.)

Carol L. Fletcher The University of Texas at Austin
James P. Barufaldi The University of Texas at Austin
Kamil Jbeily The University of Texas at Austin

Barriers and Facilitators to Including Student Data in the Evaluation of Professional Development for Science Teachers

This discussion will focus on the on-going experiences of program coordinators and evaluators in attempting to include student-centered data in an NSF funded science teacher professional development program called Project ESTT.

T 3.9 **Rotunda** **general** **contributed paper (30 min.)**
Marianne B. Barnes University of North Florida
Barbara Spector University of South Florida

Creating Contexts for Inquiry in Science Teacher Preparation: How we do it?

Research methodology, grounded theory, and a model to promote inquiry in science teacher preparation will be discussed, with further research direction.

T 3.9 **Rotunda** **general** **contributed paper (30 min.)**
Michael P. Clough The University of Iowa
Craig A. Berg Univ of Wisconsin-Milwaukee
Paul Numedahl The University of Iowa

Preparing Science Teachers Who Can Persuasively Explain Their Teaching Strategies

Fullan (1996) charges that teachers are constantly defending themselves because they cannot adequately explain their practices. We will address how we prepare teachers who can persuasively explain themselves.

T 3.10 **Senate** **college** **contributed paper (30 min.)**
Huey-Por Chang National Changhua Univ. of Education

Contributed Paper: Teacher Education and Evaluation

Teacher education and evaluation have been drastically changed in the last four years. The development of systematic instruments to assess beginning teachers' competency is urgent.

Friday, January 15, 1999 8:00-10:00am Session 1

F 1.0 **UT Austin (College of Education,** **general** **panel (2 hours)**
Judith K. Sweeney Natural History and Planetarium Museum
George Davis Moorehead State University
Walter Smith University of Akron
Linda Ramey Wright State University
Eric Pyle West Virginia University
Charlie Walter FWMSH
Colleen Blair FWMSH
Norman Lederman Oregon State University
Janet Kelly Texas Christian University
Vanessa Westbrook Elementary Science Specialists, Texas SSI
Huey-Por Chen Changua University, Taiwan
Mann-hsi Tao National Museum of Science, Taiwan

Informal Science Education: The Full Monty!

This presentation will attempt to "expose" an array of issues that focus on informal science education including: Current research on the teaching and learning of science through informal resources; Models of successful collaborations between formal and informal educators; State level involvement of the informal science education community in the Texas SSI.

F 1.0 **UT Austin (College of Education,** **hands-on workshop (3 hours)**
Paul Kuerbis Colorado College
James Ellis University of Kansas
Don Maxwell BSCS (COSTEP)

Inquiry as a Means and an End in Staff Development

The presenters will share data and their reflections on the role of inquiry in science staff development they found in the projects. We will examine some of the many views of inquiry, ideas on helping teachers move from cookbook activities in inquiry, and how classroom or action research may help teachers transition from traditional investigations to greater use of inquiry in their teaching.

F 1.0 **UT Austin (College of Education,** **college** **hands-on workshop (4 hrs.)**
Jo Ellen Roseman AAAS/Project 2061

Learning to Evaluate Curriculum Materials in Pre-Service Classes

Participants will learn to use Project 2061's curriculum materials evaluation procedure to evaluate how well a curriculum material addresses science literacy goals on conservation of matter outlined in Benchmarks for Science Literacy. Discussion of the instructional design and how this design can be adapted for use in pre-service and in-service sessions.

F 1.1 **Austin North** **elementary** **hands-on workshop (60 min.)**
Marilyn Fowler The University of Texas at Austin

Family Learning Events and Kits: Passport to Parental Involvement

Thematic family events bring people into your schools with a spirit of learning. Modeled after Family Math, our approach involves science and math activities through a literacy approach.

F 1.10 **Longhorn** **general** **panel (60 min.)**
S. Maxwell Hines Hofstra University
Bill Baird Auburn University
Don Duggan-Haas Michigan State University

CASE Network Standards: Preliminary Conceptions & Implementation

This session welcomes diverse voices (panelists and attendees) interested in solidifying their own conceptions of the CASE Network standards with an eye toward future implementation.

F 1.11 **Senate** **elementary/college** **contributed paper (15 min.)**
Gerald Wm. Foster DePaul University
Dan Heuser Westbrook School

Relationships Between Teaching Strategies and Children's Learning

Year long study of children who experienced different teaching strategies and their understanding of classificaiton, number, and ordering. Teaching and learning implications will be presented.

F 1.11 **Senate** **college** **contributed paper (15 min.)**
Lee Meadows University of Alabama at Birmingham
Tommy Smith University of Alabama at Birmingham

Effective Fifth-Year Preparation During Full-Time Teaching

We revised our 5th-year program to target full-time teachers. We'll report program design, including web-based instruction and faculty collaboration, and initial evaluation results.

F 1.11 **Senate** **college** **contributed paper (15 min.)**
Paul E. Adams Fort Hays State University

A Case Study of Unifying K-9 Teacher Preparation

A project to provide K-9 preservice teachers with teaching models in undergraduate science and mathematics will be discussed.

F 1.12 **Senate** **general** **contributed paper (15 min.)**
Michael Bentley Virginia Tech University

A Post-Final Assignment for the Methods Course: An Incentive to Professional Growth for Future Teachers

An exit interview has been substituted for a final exam on the last day of my method courses, and have introduced a new "post-final" assignment as part of each interview. Session participants will learn how to organize post-final assignments that entice students to stay engaged with professional development.

F 1.2 **Austin South** college contributed paper (15 min.)
Warren J. DiBiase Univ. of North Carolina at Charlotte

Have Journal Will Travel

This session describes the use of traveling journals in a science methods class.

F 1.2 **Austin South** college contributed paper (15 min.)
John Settlage Cleveland State University

Strategies for Supporting Reflection within Methods Courses

Learn about successfully used strategies for encouraging reflection within methods courses. No gimmicks, just practices rooted in sound educational theory.

F 1.2 **Austin South** college contributed paper (15 min.)
Keith McElroy University of Wisconsin-Milwaukee

Improving Teaching Practices

Instructional strategies typically employed in elementary science methods courses may not be achieving their desired goals. This author shares his innovative instructional strategy, and seeks feedback from members of the field.

F 1.3 **Ball Room A** college contributed paper (30 min.)
Lesley Blair Oregon State University

Student, Teaching Assistant, and Faculty Learning in the Context of Curricular Innovation

What influences the success of a curricular innovation in a university science course? We will discuss a model of student, teaching assistant, and faculty learning.

F 1.3 **Ball Room A** college contributed paper (30 min.)
Julie A. Thomas Texas Tech University
Jon E. Pedersen East Carolina University
Ron Bonnstetter University of Nebraska-Lincoln

Experience is the Best Teacher: A Study of Episodic Memory in Science Teacher Preparation

Teachers enter science methods courses with a fixed image of themselves as science teachers. These images are held in episodic memory and greatly affect learning.

F 1.4 **Ball Room B** general demonstration (30 min.)
William R. Kubinec College of Charleston

Science, Society and Values: Responsible Citizenship

Science and society are the ingredients of structured controversy. Participants prepare arguments, debate an issue, and then engage in value based discussions which produce solutions.

F 1.4 **Ball Room B** college demonstration (30 min.)
Norman Thomson University of Georgia

Traditional and Contemporary Keiyo (Kenyo) Understanding of Chance and Probability and Use of Strategies in Traditional Games: Identifying Their

Research results presented comparing Keiyo traditional and contemporary use and understanding of chance/probability and use of strategies in traditional games and solving transmission genetics problems. Further comparison made between biology students in Kenya/U.S. Slides/video will introduce Keiyo culture, Kenyan biology classrooms, and the research study. Copies of the Kenyan biology syllabus examinations will be available.

F 1.5 **Bouquets** hands-on workshop (60 min.)
Robin Lee Harris Freedman Buffalo State College

Mapping Research Agendas

This workshop will be spent first on mapping out our research agendas (areas of strength, needs, methodologies, and areas for growth) and second discovering areas where we can collaborate. A network of collaborators will be started.

F 1.6 **Cellar** college contributed paper (30 min.)
Karen Williams East Central University
Edmund Marek University of Oklahoma

Contributed Paper: Ausubel and Piaget - A Contemporary Investigation

An investigation of meaningful understanding and effectiveness of the implementation of piagetian and ausubelian theories in college physics instruction.

F 1.6 **Cellar** college contributed paper (30 min.)
Genevieve Bardwell West Virginia University
John Lewis Greenbrier West High School
Cathy Morton-McSwain Webster Springs Elementary
James A. Rye West Virginia University
G. Jill Hyde Appalachian Rural Systemic Initiative
Priscah Simoyi West Virginia University

Partnerships to Promote Professional Development and Inquiry Learning in the Health Sciences

The Health Sciences and Technology Academy provides opportunities for science teachers to gain professional development, as well as collaborate with biomedical experts and science educators.

F 1.7 **Congress** college demonstration (30 min.)
Delena Norris-Tull University of Alaska, Dillingham
Claudette Bradley-Kawagley University of Alaska, Fairbanks
Roger Norris-Tull University of Alaska

Distance Delivery of an Integrated Mathematics/Science Methods Course for Elementary Teachers

Materials and techniques used for teaching an integrated mathematics/science methods course by distance delivery in rural Alaska. A math/science lab kit will be displayed, videotapes shown, and innovative teaching techniques demonstrated.

F 1.7 **Congress** general demonstration (30 min.)
Ronald F. Pauline Juniata College
Peter Mecca Educational Consultant

A Drop of Water: An Interactive and Multimedia Approach to Teaching

A hands-on demonstration of an interactive, multimedia CD-ROM program which includes movies, animation, case studies, virtual laboratory simulations. An accompanying teacher's manual discussed.

F 1.8 **Executive** general panel (60 min.)
Greg Stefanich University of Northern Iowa
Lawrence A. Scadden National Science Foundation
Jacqueline Thousand California State University San Marcos
Rich Villa California State University San Marcos

A Research Agenda Leading to Appropriate Policy Development and Implementation with Regard to Instructional Practices to Implement Science for All

Each of the panel members will share insights and research relating to Policy Development and Implementation of Instructional Practice in areas of equity and disability.

F 1.9 **Liberty** **elementary** **panel (60 min.)**

Michael Kamen Auburn University
Malcolm B. Butler Texas A&M University-Corpus Christi
Bruce Johnson Gustavus Adolphus College
Sandra K. Enger The University of Alabama in Huntsville
M. Gail Jones University of North Carolina at Chapel Hill

Bringing the Outdoors In: Integrating Environmental Education in Teacher Education

The novel format will combine short presentations, a poster session format, and a panel discussion to share how environmental education is integratedinto elementary education at a number of universities.

Friday, January 15, 1999 9:20-10:20am Session 2

F 2.1 **Austin North** **general** **hands-on workshop (60 min.)**

Alan Colburn California State Univ-Long Beach

Web Page Construction for Science Teacher Educators

If you can do simple word processing and web browsing, you can make a web page. I will give you everything you need to start.

F 2.10 **Bouquets** **elementary/middle/hig** **hands-on workshop (2 hrs.)**

Piyush Swami University of Cincinnatti

SCASS Model for Implementaing Science Portfolios in Classrooms

A hands-on experience to participants who would like to learn about a model developed by SCASS (Science Consortium of Assessment and Student Standards) project for using Science Portfolios at the elementary, middle, and high school levels as one strategy for authentic assessment. The model has been piloted in various states, and the materials are now available for wider distribution.

F 2.2 **Austin South** **elementary** **contributed paper (30 min.)**

Michael E. Beeth The Ohio State University

A Continuum for Assessing Science Processes

Presentation of a continuum for assessing science process knowledge in grades K-6 by several elementary teachers and a university professor.

F 2.2 **Austin South** **college** **contributed paper (30 min.)**

Dawn R. Parker Texas A&M University
Carol L. Stuessy Texas A&M University

From Guidelines to Profiles: Exemplary Programs for Elementary Teacher Preparation

Profiles of exemplary elementary teacher preparation programs are presented based on researcher-constructed typologies devised from new guidelines for elementary certification programs.

F 2.3 **Ball Room A** **general** **contributed paper (30 min.)**

Ann Marshall Cox California State University at Fullerton
HsingChi A. Wang University of Southern California

Problem-based Learning: Implications for Science Teacher Education

This study presents approaches to science methods courses and to in-service programs for science teachers using problem-based learning.

F 2.3 **Ball Room A** **general** **contributed paper (30 min.)**

HsingChi A. Wang University of Southern California
Patricia Thompson University of Southern California
Charles F. Shuler University of Southern California

Effects of Problem-Based Learning as Applied to the Professional Development for Science Teachers

Findings of how the Problem-Based Learning (PBL) as it applied to professional development for the science teachers at the Los Angeles Unified School District (LAUSD) will be reported in this study.

F 2.4 **Ball Room B** **general** **contributed paper (30 min.)**

Steven W. Gilbert Indiana University, Kokomo

The Model as a Vehicle for Understanding the Nature and Processes of Science

Describes the use of models and model-building to describe science and the results of applying this approach in an elementary science methods course.

F 2.4 **Ball Room B** **college** **contributed paper (30 min.)**

Thomas LaPorta University of South Florida
Barbara S. Spector University of South Florida

Bridging Science Education and Content Courses: Subculture Matter

A qualitative study of students enrolled in an STS course is presented revealing why bridging disparate subcultures in science education and content courses is important.

F 2.5 **Cellar** **elementary** **contributed paper (30 min.)**

Starlin D. Weaver Salisbury State University

Using Children's Literature Books and Storytelling to Initiate the Inquiry Process in Elementary School Science

This interactive session will demonstrate how trade books and traditional stories can be used as catalysts for starting the inquiry process in elementary science teaching.

F 2.5 **Cellar** **general** **contributed paper (30 min.)**

M. Faye Neathery Southwestern Oklahoma State University

Elementary/Secondary Students' Attitudes with Correlations of Gender, Ethnicity, Ability, and Achievement

This paper presents the significant relationships between the variables and four of the attitudes examined in the study of students in grades 4 through 11.

F 2.6 **Congress** **college** **contributed paper (30 min.)**

Pradeep M. Dass Northeastern Illinois University

An STS Approach to Organizing a Secondary Science Methods Course: Prelimary Findings

Preliminary findings regarding student understanding of reform-oriented science instruction resulting from an STS approach in a methods class will be shared and constructive critique invited.

F 2.6 **Congress** **secondary** **contributed paper (30 min.)**

William H. Leonard Clemson University
John E. Penick North Carolina State University

Preparing High School Biology Teachers for Standards-based Curricula

A preparation program in which sixteen high school biology teachers in widely diverse settings have successfully implemented a new, standards-based biology curriculum is described.

F 2.7 **Executive** college panel (60 min.)

Pamela Fraser-Abder New York University
Nina Leonhardt New York University
Shindy Jones New York University
Maria Davis Community School District 13

Science Teacher Enhancement Models (STEM): A Model for University - Non-Formal Science Instituiton and Urban Community School District Collaboration

An in-depth description of a successful Teacher Enhancement model, a tour of the newly developed STEM web site, and a videotape are presented.

F 2.8 **Liberty** college panel (60 min.)

Robin Lee Harris Freedman Buffalo State College
John Penick University of North Carolina, Charlotte
Pradeep M. Bass Northeastern Illinois University
Ron Bonnstetter University of Nebraska
John W. Tillotson Syracuse University
Peter Veronesi State University of New York, Brockport
Sandy Enger The University of Alabama in Huntsville

Rationale Papers in Methods Courses: A Discussion

Panel discussion on the development and use of rationale papers by pre-service teachers. Audience participation encouraged.

F 2.9 **Senate** college contributed paper (30 min.)

George R. Davis Moorhead State University
Patricia Simpson St. Cloud State University

Preparing K-12 Teachers for Standards-Based Science and Math Instruction through a Statewide Reform Project

We will present how a multi-year state-wide K-12 science-math initiative has engaged education and science faculty into improving the preparation of math and science teachers.

F 2.9 **Senate** general contributed paper (30 min.)

Kenneth Tobin University of Pennsylvania

Learning to Teach Science: Use of an internet application to create communities of learners

The paper describes research on applications of an interactive internet application that connects communities of learners engaged in courses for prospective and practicing science teachers.

F 3.10 **Senate** general demonstration (30 min.)

Robert L. Hartshorn University of Tennessee at Martin

Monitoring Students' Use of an Internet Browser with Webwhacker

Using Webwhacker allows teachers to monitor students' use of the internet by previously downloading sites for subsequent off-line accessing.

F 3.10 **Senate** middle/secondary demonstration (30 min.)

Raymond Francis Central Michigan University

Connecting the Curriculum: Integrating through the National Mathematics and Science Standards

General overview of an effective process for integrating the curriculum. Includes handouts, activity, and resources.

F 3.6 **Austin South** — general — contributed paper (30 min.)

Sandra K. Enger Univ. of Alabama in Huntsville

Concept Mapping: A Passport to Understanding

Concept mapping has great versatility for both instruction and assessment. Quantitative and qualitative results from a concept mapping study will be reported.

F 3.6 **Austin South** — secondary — contributed paper (30 min.)

Maureen M. McMahon University of California, Davis
William G. Holliday University of Maryland, College Park
Elizabeth Gibson University of California, Davis
Bernadette McCormack University of California, Davis
Susan P. O'Hara University of California, Davis
Christine Kelly Austin Independent School District

Fifth Grade Teacher Team's Journey into Community Science-Based Integrated Curriculum

This project documents the journey of six fifth grade teachers as they plan, design and implement a community-based science-themed integrated curriculum for 150 fifth graders.

F 3.7 **Ball Room A** — general — contributed paper (30 min.)

Rebecca Monhardt Utah State University

The Compatibility of the Navajo World View and the Nature of Science: Implications for Science Education

This study examines the compatibility of Navajo traditional cultural beliefs to the philosophy of Western science and the implications for Navajo students in science.

F 3.7 **Ball Room A** — general — contributed paper (30 min.)

Pamela Fraser-Abder New York University
Therese Shields New York University
Rebecca Mace New York University
Vanessa Go New York University

The Educational and Social Value of Non-Formal Science Institutions

An analysis of teacher, student and adults responses to questionnaires that examined the educational and social value of non-formal science institutions.

F 3.8 **Ball Room B** — college — contributed paper (30 min.)

Tracey Cascadden University of New Mexico
Debra Tull University of New Mexico
Marcy Wood University of New Mexico

The Natural Sciences Program: Personalizing Science for Elementary Education Majors

The Natural Sciences Program provides pre-service elementary school teachers with the understanding of science content and processes necessary to teach science confidently and competently.

F 3.8 **Ball Room B** — college — contributed paper (30 min.)

John A. Craven Queen's College/CUNY
Brian Hand La Trobe University
Vaughan Prain La Trobe University

Developing the Language of Science and Scientific Literacy: Implications from a study of preservice elementary science teachers

A study of preservice elementary teachers' conception of science and the changes thereof following instructional practices. Findings provide implications for the development of scientific literacy.

F 3.9 **Rotunda** elementary contributed paper (30 min.)
Andrea Foster Texas A&M University

Seeing Things Through Science Eyes: A Case Study of an Exemplary Elementary Teacher

This paper highlights the essential features of a qualitative study of an exemplary elementary teacher who happens to view teaching and learning through science eyes. The paper presents a model of an expert science pedagogue.

F 3.9 **Rotunda** college contributed paper (30 min.)
Judith Johnson University of Central Florida

Transforming Science Education: Defining and Developing Teacher Leadership

The purpose is to describe a science teacher development project's approach to "teacher leadership" that is multifaceted, intentional, and focused on building an infrastructure for real changes in science education in the schools in a diverse urban area.

Friday, January 15, 1999 10:40-11:40a Session 3

F 3.1 **Austin North** elementary hands-on workshop (60 min.)
Betty Crocker The University of North Texas
Sandra Garrett Southern Methodist University
Laura Trammell Edison Project, Dillingham Intermediate

Earthworm Magic

Workshop participants engage in hands-on "play" or exploration of earthworms. Exemplary teaching practices and methods (Language Arts and Science) facilitate the use, construction, and reflection of knowledge.

F 3. **Cellar** college demonstration (30 min.)
John R. Cannon University of Nevada, Reno
David T. Crowther University of Nevada, Reno

Electronic Publishing in the 21st Century: Its Impact on Scholarly Writing

This sectional will provide an overview of the current and changing state of electronic publication. Many issues surrounding it and scholarly writing, specifically promotion and tenure in higher education, will be questioned and discussed. A demonstration of how easy it is to write for electronic publication will follow.

F 3. **Cellar** general demonstration (30 min.)
Deborah Hall University of Wisconsin-Whitewater

Students with Learning Disabilities: Keeping the Science Classroom Accessible

Demonstration focuses on instructional approaches increasing accessibility of science classrooms for students with learning disabilities. Will introduce strategies for students in university coursework and science teacher education.

F 3.3 **Congress** general panel (60 min.)
J. Preston Prather University of Tennessee-Martin
Kuen Chin Yap Nanyang Tech Univ/Natl Inst of Education
Geraldine T. Farmer Metropolitan Nashville Public Schools
Susan Bunch Henderson County Board of Edu
Joseph P. Riley University of Georgia
Linda Jordan State of Tennessee, Dept of Edu

An International Dialogue on the TIMSS: Tennessee and Singapore Science Teachers Seek Insights for Better Teaching

Results of face-to-face discussions among teachers from Tennessee and Singapore, a top performer in the Third International Mathematics and Sciences Study (TIMSS), will be presented.

F 3.4 **Executive** **college** **panel (60 min.)**

Robert K. James Texas A&M University
Caroline Beller University of Arkansas
Warren DiBiase University of North Carolina at Charlotte
Joneen Hueni Bellville High School
Julie Luft University of Arizona
Patti Nason Stephen F. Austin State University

Using Rubrics and Performance Assessment in Science Teacher Education

The session will draw on the expertise of experienced science teacher educators and science teachers who have been developing and using rubrics in science teacher education and science teaching.

F 3.5 **Liberty** **college** **panel (60 min.)**

Paul Kuerbis Colorado College
Valerie Olness Augustana College
Julia McArthur Bowling Green State University
Patricia Morrell University of Portland
Bill Baird Auburn University
Richard Bryant Southwestern Oklahoma State University
Don Wilson Southwestern Oklahoma State University

A Novel Approach to Dissemination of Successful Professional Development

Representatives from ten national teams describe a novel dissemination and outreach effort across the country, including action plans, and barriers and solutions to professional development.

F 3.7 **Ball Room A** **general** **contributed paper (30 min.)**

Pamela Fraser-Abder New York University
Therese Shields New York University
Rebecca Mace New York University
Vanessa Go New York University

The Educational and Social Value of Non-Formal Science Institutions

An analysis of teacher, student and adults responses to questionnaires that examined the educational and social value of non-formal science institutions.

Friday, January 15, 1999 2:20-3:20pm Session 4

F 4. **Ball Room B** **college** **seminar (30 minutes)**

Paul Jablon University of Massachusetts at Lowell

Doctoral Programs in Science Education: Components, Accessibility and Numbers

A brief description of the Rutherford (1966) and Yager (1980) reports on doctoral programs in Science Education will be given in addition to the presenter's recent findings. Participants will then discuss thier views on what the components of a doctoral program for 1999 should be and what solutions there should be for the dearth of graduates.

F 4. **Cellar** **secondary** **contributed paper (30 min.)**

Donald W. Aguillard Louisiana State University
Ron Good Louisiana State University

An Analysis of Evolution Instruction in Louisiana Public High Schools

What is the status of evolution instruction in Louisiana schools a decade after the Supreme Court in Edwards vs. Aguillard declared that "creationism" is a religious idea and that its teaching cannot be mandated in public schools?

F 4. **Cellar** — general — contributed paper (30 min.)

Denise Crockett The University of Georgia
Elizabeth Doster East Carolina University
Allen Emory The University of Georgia

Addressing Critical Educational Issues in Pernambuco, Brazil: An Indigenous Thematic Approach

The purpose of this study was to design a science education curriculum using indigenous herbal plants as a thematic device for elementary science classrooms in Pernambuco, Brazil

F 4. **Executive** — general — panel (60 min.)

Katherine C. Wieseman Western State College
Mary Atwater University of Georgia
Lynn Bryan University of Georgia
David Jackson University of Georgia
Sharon Lynch George Washington University
J. Randy McGinnis University of Maryland
Eric Pyle West Virginia University
Penny Hammrich Temple University

Addressing Equity within Science Education Courses: Sharing Approaches and Ideas

Panelists will contribute approaches and ideas "in use" in their science education courses as springboards for discussion in a forum-type session.

F 4.1 **Austin North** — elementary/middle — hands-on workshop (60 min.)

Shawn Stanley National Wildlife Federation

Environmental Science Across the Curriculum

A hands-on workshop offering cross-curricular environmental education activities for K-8 educators through National Wildlife Federation's Classroom Program, "Animal Tracks". Teachers will be provided with complimentary copies of the Animal Tracks books and more.

F 4.10 **Senate** — Sponsor

Casio

Casio

Corporate Sponsored Presentation

F 4.2 **Austin South** — college — panel (60 min.)

Virginia Anderson Towson University

Reciprocal Science Success: Urban Action Discussions

Urban projects and collaboration strategies developed in an innovative NSF grant for teams of university science educators and scientists experience will be presented.

F 4.3 **Ball Room A** — general — contributed paper (30 min.)

Sharon H. Harwell University of Alabama in Huntsville
Sandra K. Enger University of Alabama in Huntsville

Passport to Excellence: Embedding Inquiry in Professional Development

Evaluation of Exploring Space: The Classroom Connection which mapped NSES professional development standards and curriculum to provide in-service experiences to enhance classroom science inquiry.

F 4.3 **Ball Room A** college contributed paper (30 min.)
G. Nathan Carnes University of South Carolina

Encouraging Professional Excellence through Knowledge of Science Standards

This paper presentation will focus on the experience of an advanced science methods course designed to increase teacher knowledge of national and state science standards.

F 4.6 **Congress** general contributed paper (30 min.)
Lawrence A. Scadden National Science Foundation

Laboratory Accessability for Students with Disabilities

The presenter will help dispel myths associated with students with disabilities in science class and will provide recommendations on lab accessibility for students with disabilities.

F 4.6 **Congress** general contributed paper (30 min.)
Bradford L. Lewis University of Pittsburgh
Karen L. Sadler University of Pittsburgh

Teaching Deaf and Hard-of-Hearing Students in Science Classes

Many public schools are experiencing an influx of Deaf and HOH student into general science educaiton classes. General science teachers often do not know how to go about accomodating these students into their classes and this session will provide general rules for accomodations.

F 4.8 **Liberty** general panel (60 min.)
Kueh Chin Yap Nanyang Tech University
J. Preston Prather University of Tennessee-Martin
Joseph P. Riley University of Georgia
Michael J. Padilla University of Georgia
Hideo Ikeda Hiroshima University
Thomas R. Koballa, Jr. University of Georgia

Professional Development for Science Teachers in the United States, Singapore, Malaysia, Japan and Germany

Comparisons of principles and practices in science teacher education in the United States, Japan, Malaysia, Singapore and Germany will provide insights into teacher induction and retention.

F 4.9 **Rotunda** college panel (60 min.)
Penny J. Gilmer Florida State University
Chris Muire Florida State University

Web-based Portfolios in University-level Science and Science Education Courses

Interactive session showing how students and instructors use an electronic portfolio in university-level science and science education courses.

Friday, January 15, 1999 3:40-4:40pm Session 5

F 5. **Congress** general contributed paper (15 min.)
Linda K. Ramey Wright State University

Using Environmental Science Education Curricula and Experience to Enhance Science Teaching for All Students: Creating an Integrated, Inclusive Learning Environment

This presentation will focus on results and implementation strategies for two long-term environmental science education projects designed to enhance teachers' and their students' conceptual understanding and environmental literacy.

F 5. **Executive** general panel (60 min.)
Janice Koch Hofstra University
S. Maxwell Hines Hofstra University
Molly Weinburgh Georgia State University
Virginia Epps Univ of Wisconsin-Whitewater
Pamela Fraser Fraser-Abder New York University

Images of Inclusive Science Education: Involving Diverse Learners in School Science
This panel discussion addresses the connections between the 'personal' and the 'scientific' as panelists strive to engage historically marginalized students in school science. This discussion moves away from 'fixing' the students and toward 'fixing' traditional science education.

F 5.1 **Austin North** elementary hands-on workshop (60 min.)
Carolyn B. Dickman Radford University
Meta Van Sickle College & University of Charleston

Activity Sequences for Conceptual Development
Presentation of a paradigm through activities that early childhood educators can use to develop activity sequences to teach science process skill and related math skills.

F 5.10 **Rotunda** college panel (60 min.)
Patricia L. Nason Stephen F. Austin State University
Tom Callaway Stephen F. Austin State University
Troy Cuniff Mike Moses Intermediate School

Collaborative Leading to Exellence in Science Education
Professors from the departments of education and physics collaborate with a school district to design a TEKS related program for teacher interns, their mentors and intermediate students to learn science content.

F 5.11 **Senate** secondary contributed paper (15 min.)
Frank J. Giuliano Westfield State College

Problem-Solving in a Non-traditional Chemistry Course: Implications for Instruction
This session will provide the results of recent research regarding students' problem-solving strategies in a ChemCom course and the implications of this research for instruction.

F 5.11 **Senate** general contributed paper (15 min.)
Young-soo Kim University of Missouri-Columbia

Several Ways of Using Concept Mapping in Science Classroom
Six different ways of using concept mapping will be presented to discuss as an alternative assessment tool in teaching science.

F 5.11 **Senate** secondary contributed paper (15 min.)
William R. Veal Indiana University

Hybrid Scheduling Effects on Science Teaching and Learning
This presentation will present a case study using mixed methods to determine the effects of a hybrid class schedule on science teachers' abilities to instruct and students' achievement.

F 5.11 **Senate** general contributed paper (15 min.)
Norma Moreno Molina High School

Working with Power Point and Video Presentations
The laws of reflection and refraction will be demonstrated with a lap top computer, Power Point animation and video tape.

F 5.2 **Austin South**
Delta Education **Sponsor**

Delta Education

Corporate Sponsored Presentation

F 5.3 **Ball Room A** **general** **contributed paper (30 min.)**
Michael Bentley Virginia Tech University
Steven Fleury LeMoyne College

Professional Development for Teachers in Urban Schools: Model for Reform

Professional development projects in Syracuse, Chicago, and Waukegan share a collaborative professional development process aimed at mitigating the isolation of institutions from the needs of students and in referring to current national and state frameworks for local curriculum design.

F 5.3 **Ball Room A** **general** **contributed paper (30 min.)**
Hedy Moscovici Science Education Consultant (self-employed)

Shifting Toward Inquiry Science Teaching: A Helpful Model for Change

This study explores the use of a four-stage model representing the shift from teaching textbook science to facilitating students' inquiries in professional enhancement activities.

F 5.4 **Ball Room B** **general** **contributed paper (30 min.)**
Ann C. Howe North Carolina State University
Myra Halpin North Carolina School of Science & Math

Teachers and Technology: Outcomes of a Three-Year Project

A three-year technology implementation project is described and discussed in terms of teacher reactions, attitudes and outcomes.

F 5.4 **Ball Room B** **elementary** **contributed paper (30 min.)**
Larry G. Enochs University of Wisconsin Milwaukee
William Kean University of Wisconsin Milwaukee

Field Geology for Elementary Teachers: A Teacher Enhancement Study

This session will be centered around the evaluation and staff development model used to prepare elementary teachers to take earth science field trips. Project provided 21 elementary teachers with a three week field oriented geology program. We provided instruction and activities on how to run a geology field trip which provides data collection and analysis - i.e., inquiry based science.

F 5.5 **Bouquets** **college** **hands-on workshop (60 min.)**
William H. Leonard Clemson University
John E. Penick North Carolina State University

Converting Preservice Science Teachers to Constructivism

Role play the effects of different variables on the population growth of a hypothetical family over 100 years. Take with you a complete set of student and teacher instructions.

F 5.6 **Cellar** **general** **contributed paper (30 min.)**
Barbara Rascoe University of Georgia

Achievement of Gifted Black Males in America: Implications for Teachers and Teacher Educators

This paper is an explication of reasons black males in middle and high school choose not to achieve in classrooms.

F 5.6 **Cellar** — general — **contributed paper (30 min.)**

Kenneth Tobin University of Pennsylvania

Learning to Teach Science in Urban Settings

The paper addresses learning to teach in urban settings characterized by ghetto schools, diverse sociocultural histories of students and minorities

F 5.7 **Congress** — general — **contributed paper (15 min.)**

Burnette Hamil Mississippi State University

GLOBE Enhances Interdisciplinary Scientific Research

GLOBE Environmental Education activities provide skills needed in Elementary and Secondary Science classrooms. Preservice teachers and veteran teachers are benefiting from training sessions.

F 5.7 **Congress** — college — **contributed paper (15 min.)**

J. Steve Oliver The University of Georgia
B. Kim Nichols The University of Georgia

Pre-service Teachers, Microteaching and "How We Know": An ongoing study

This presentation will report on the ongoing use of organizers which are used to focus microteaching experiences. Particular attention is paid to "How We Know" Organizers.

F 5.7 **Congress** — college — **contributed paper (15 min.)**

Theresa M. Arburn Palo Alto College
Lowell J. Bethel The University of Texas at Austin

Teaching Strategies Designed to Assist Community College Science Students' Critical Thinking

Many community college students in the sciences are in need of improvement in academic performance as well as in the use of critical thinking skills. A student-generated questioning technique applied within the context of a lecture class may provide some measure of success toward attaining positive outcomes in both areas of need.

F 5.9 **Liberty** — general — **panel (60 min.)**

Jo Ellen Roseman AAAS/Project 2061
Molly Weinburgh Georgia State University
Norm Lederman Oregon State University

Finding Textbooks That Meet Benchmarks and Standards

Participants will receive an overview of Project 2061's on-line database of curriculum materials evaluation reports and will learn how to use the database as a resource in pre-service methods course.

Friday, January 15, 1999 4:50-5:50pm Session 6

F 6. **Ball Room B** — general — **contributed paper (30 min.)**

James Tomlin Wright State University
Linda K. Ramey Wright State University
Beth Basista Wright State University

Implementation of a Performance-Based Comprehensive Science Education Program for Preparation of Pre-K to 12 Teachers

Session describes the design and implementation of a model science education program to better prepare teachers in professional development school sites. The overall framework and course examples are detailed.

F 6.1 **Austin North** **college** **hands-on workshop (60 min.)**
Bonnie McCormick University of the Incarnate Word
Christy MacKinnon University of the Incarnate Word

Learning Life Science through Space Science

Activities that integrate mathematics, space technology, and life science will be presented. The audience will participate in one activity, "Is There Life on Other Planets?"

F 6.10 **Rotunda** **poster presentation**
Margaret B. Bogan Jacksonville State University

Indigenous Traditions and Ecology: Implications for the Science Classroom in the 21st Century

Thoughts of selected Indigenous Peoples regarding spiritual/cultural desires for planetary health, improving humankind's relationship with "All That Is" and concomitant pedagogical strategies for interdisciplinary science.

F 6.10 **Rotunda** **secondary** **poster presentation**
Rhea Miles University of Virginia

Minorities in New Depths of Science (M.I.N.D.S.)

Poster will focus on Minorities in New Depths of Science (MINDS) Program. The objective of the program was to increase the number of high school minority students enrolled in advanced science class.

F 6.10 **Rotunda** **secondary** **poster presentation**
Ke-Sheng Chan The University of Texas at Austin

The Interactive Historical Vignettes: A Safe and Powerful Tool for "Smuggling" Some History and Nature of Science into the High School Science Classroom

Introducing the Interactive Historical Vignettes as a pedagogical tool for teaching the nature of science along with the results of a teaching experiment.

F 6.11 **Senate** **middle/secondary** **contributed paper (30 min.)**
Shelley Gross-Gray Shippensburg University
Elaine J. Anderson Shippensburg University
Kim Ferry Scotland School for Veterans Children

Preservice Science Teachers Expanding Science Lessons Using the Internet for Grades 7-12

Students and Teachers Using New Technologies, STUNT, allows preservice science teachers to develop and try out internet science lessons under the guidance of a cooperating science teacher.

F 6.11 **Senate** **middle** **contributed paper (30 min.)**
Ann F. Wright Washington State University
Valarie L. Dickinson Washington State University

Integrating Technology into the Middle School Science Classroom

This action research project studied the effects of using the Internet on middle school science students' performance, interest, and understanding of science and technology.

F 6.2 **Austin South** **college** **contributed paper (30 min.)**
Christine Moseley Oklahoma State University
Sarah Ramsey Oklahoma State University

Oklahoma Teacher Education Collaborative (O-TEC)

O-TEC is a state-wide network of higher education institutions, professional organizations, and public schools united to better prepare current and future teachers of science and mathematics

F 6.2 **Austin South** college contributed paper (30 min.)
Marti Schriver Georgia Southern University
Jim Darrell Georgia Southern University

Using Collaborations at the University Level

This presentation presents one model for teaching preservice teachers which emphasizes team teaching by science and education faculty.

F 6.3 **Ball Room A** elementary contributed paper (30 min.)
JoAnne Ollerenshaw University of Nebraska - Lincoln

An Elementary Science Education Methods Course with a Difference

Using a supplemental oral narrative strategy as a platform for elementary education majors to meaningfully learn and teach science.

F 6.3 **Ball Room A** general contributed paper (30 min.)
Isabel N. Quita College of Saint Rose
Julita Lambating California State University-Sacramento

A Case Study: Learning Maps in Science and Math

Focuses on how prospective teachers utilize "learning maps" to illustrate themselves as learners in an elementary science methods course.

F 6.4 **Ball Room B** college contributed paper (30 min.)
James A. Russett Purdue University, Calumet

Secondary Science Methods: A Professional Development School Approach

Description and analysis of a novel Professional Development School approach to the teaching of a pre-service secondary methods course.

F 6.5 **Bouquets** general hands-on workshop (60 min.)
Young-soo Kim University of Missouri-Columbia

Collaborative Concept Mapping for Teaching Science

This workshop is intended to provide concept mapping training model for non-expert teachers of concept mapping. Participants will practice concept maps with the friendly guidance as a group.

F 6.6 **Cellar** demonstration (60 min.)
Paul E. Resta The University of Texas at Austin

Our Eyes, Our Voices: Authentic Assessment with Digital Photography

Digital photography, especially when combined with Hyperstudio™, provides a powerful, inexpensive, and versatile tool for authentic assessment while teaching important higher-level thinking. This session provides instruction in the procedures, as well as student-produced models, hands-on experience, and example rubrics.

F 6.7 **Congress** college contributed paper (30 min.)
Rosalina V. Hairston University of Southern Mississippi

Bringing the Reality of Science Teaching by Using Field-Based Methods Course

A field-based science methods course to prepare preservice teachers for secondary school biology teaching through a 5-week mentoring program involving master teachers and science educators.

F 6.7 **Congress** **college** **contributed paper (30 min.)**

Patricia Morrell University of Portland
Alexander Casareno University of Portland
Syd Steinbock University of Portland

Reflective Journaling: A Way to Enhance Preservice Science Teachers' Field Experiences

The reflective journals of preservice science teachers can assess/enhance the student teachers' understanding of field experiences. Critical reflection on practices maximizes learning from the field.

F 6.8 **Executive** **elementary** **panel (60 min.)**

Catherine G. Yeotis Wichita State University
Gary F. Varrella George Mason University
Joseph Riley
Dee French
Faye Neathery
Barbara Spector
Gail Shroyer
Margaret Bolick
Patti Nason
Caroline Beller
Katherine Wieseman

Follow up to "An Exemplary Science Methods Course"

Participants and facilitators from the 1998 pre-conference session will share results and on-going progress toward the development of an Exemplary Elementary Science Methods Course.

F 6.9 **Liberty** **general** **panel (60 min.)**

Lloyd H. Barrow University of Missouri-Columbia
Meta Van Sickle College of Charleston
Michael Wavering University of Arkansas

Improving Preservice Secondary Science Programs: Salish II

The panel will share how three Salish II Institutions have improved their programs via action research.

Saturday, January 16, 8:00-9:00am Session 1

S 1.0 **Austin South** **college** **contributed paper (15 min.)**

Erica M. Brownstein Eastmoor High School

Application of Alternative Assessment in College Level Science: Using Contemporary Teaching Approaches in Existing Courses

Poems, artwork, concept maps, and even one family "history" are included in a series of summary projects developed by an upper-level physiology class.

S 1.0 **Austin South** **college** **contributed paper (30 min.)**

Karen R. Dawkins North Carolina State University
John Penick North Carolina State University

Teacher Preferences for an Advanced Master's Degree

A survey of North Carolina teacher provides data regarding their preferences for components to be included in the state's new Advanced Master's Degree programs.

S 1.1 **Ball Room A** general demonstration (30 min.)
Ron Browne Mankato State University
Scott Page Mankato State University

Using Digital Cameras to Enhance Interest in Science Education

This session will demonstrate several applications for using digital cameras for teaching and learning science. Limited hands on use of cameras will be included.

S 1.1 **Ball Room A** general demonstration (30 min.)
James A. Roberts The University of North Texas

The Laws of Physics

Several experiments with the laws of physics will be demonstrated. The glowing pickle, the magic pendulum and light properties will be explored.

S 1.2 **Ball Room B** college contributed paper (30 min.)
Angelo Collins Vanderbilt Univ., Peabody College

What is INTASC? And Why Should You Care?

This paper provides an overview of INTASC, the application of core principles to science teacher education, features of the portfolio process with scoring criteria.

S 1.2 **Ball Room B** college contributed paper (30 min.)
Francis S. Broadway University of Akron
Rowena Susan Habler Ohio Dept. of Education

Portfolio Assessment of Beginning Teachers: The Ohio Model

Ohio is exploring portfolio assessment for beginning science teachers. The legislative considerations will be presented along with state-specific findings from preliminary field testing.

S 1.3 **Bouquets** secondary hands-on workshop (60 min.)
Michael Shayer King's College, University of London

Cognitive Acceleration through Science Education

A simulation of the science teaching practice which has, in the U.K., led to permanent increases in high school students' learning ability and long-term achievement.

S 1.4 **Cellar** general contributed paper (30 min.)
Bruce H. Munson University of Minnesota, Duluth

Water on the Web: Curriculum Development and Real-Time Data

"Water on the Web" is a NSF funded curriculum project using near real-time data and the Internet. Project status, technologies, and curriculum are discussed.

S 1.4 **Cellar** middle/secondary demonstration (30 min.)
Jonathan Singer University of Michigan
Joseph Krajcik University of Michigan

Model-It: Integrating Technology to Facilitate Student Understanding

During this session a discussion of how a learning technology, Model-It, is utilized to support students in understanding of science concepts.

S 1.5 **Congress** college contributed paper (30 min.)
Robert Boram Morehead State University
Candace Glendening Morehead State University

Science Curriculum Improvements for Preservice Elementary Teachers

Two required science courses for elementary teachers were re-designed to bring them into alignment with the National Science Education Standards.

S 1.5 **Congress**
Sandra S. West — Southwest Texas State University — **college** — **contributed paper (30 min.)**
Melanie C. Lewis — Southwest Texas State University

Evaluation of a Standards-Based Pilot Life Science Course for Preservice Elementary Teachers, which included a School Component

Study compares preservice teachers' science teaching efficacy beliefs and science content knowledge in a course with a school component vs. traditional life science content course.

S 1.6 **Executive**
Nancy Finkelstein — Harvard-Smithsonian Ctr for Astrophysics — **general** — **panel (60 min.)**
Gordon Lewis — Annenberg/CPB Math & Science Project

Intelligent Television

Find out about the ANNENBERG/CPB CHANNEL, a free satellite/Web service carrying professional development programs and workshops for K-12 math and science educators, and a variety of programs from popular PBS series.

S 1.7 **Liberty**
Sandra Abell — Purdue University — **general** — **demonstration (60 min.)**

Publishing in Science Education Journals

This session is designed to provide insight and advice on the process of publishing in science education journals. Representatives of several science education journals are participants in the panel.

S 1.8 **Longhorn**
Beth Shiner Klein — St. Norbert College — **general** — **panel (60 min.)**
Reid Riggle — St. Norbert College
Mary Alyce Lach — St. Norbert College
Mark Bockenhauer — St. Norbert College

Ocean Voyagers Program: "Floating" Online and Onboard Inservices

This discussion will include a review of this unique teacher program including teacher experiences aboard U.S. Navy ships and their outcomes.

S 1.9 **Senate**
Bambi Bailey — Texas A&M International Univ — **elementary/college** — **contributed paper (15 min.)**
Cathy Sakta — Texas A&M International University

Margarita on the Rocks - with a twist?

Discusses complications that arise when elementary teachers along the border teach science to students whose vocabularies are blended English and Spanish.

S 1.9 **Senate**
Alan Colburn — California State Univ-Long Beach — **general** — **contributed paper (15 min.)**

Finding Useful Resources on the World Wide Web

This presentation summarizes the results of a study examining the strategies used by experts for finding resources and information via the web.

S 1.9 **Senate**
Laura Henriques — California State University, Long Beach — **college** — **contributed paper (15 min.)**
Beth Ambos — California State University Long Beach

Project ALERT (Augmented Learning Environment for Renewable Teaching): Improving Earth Science Instruction in the California State University System

Project ALERT combines rich databases of NASA, geology and science education faculty at CSU's and web technology to improve earth science classes for prospective teachers.

S 1.9 **Senate** college contributed paper (15 min.)
Kenneth P. King Northern Illinois University

100 Percent Efficiency: The Use of Technology in Science Education Since 1900
Present historical overview of the use of technology in support of science teaching from 1900 through the present.

S 1.10 **Austin North** general contributed paper (30 min.)
Eric J. Pyle West Virginia University
Lynn McMullen West Virginia University
Gretchen Butera West Virginia University

Inclusion in a Climate of Reform: A Convergent Approach to the Inclusion of Students with Special Needs in Science Instruction
ICOR is a collaborative project between science and special educators in West Virginia that has adopted a convergent approach to science inclusion by using student Individualized Education Plans (IEPs) the state science curriculum, and Coordinated and Thematic Science (CATS).

S 1.10 **Austin North** general contributed paper (30 min.)
Juanita Jo Matkins University of Virginia
Frederick J. Brigham University of Virginia

A Synthesis of Empirically Supported Best Practices for Students with Learning Disabilities
This paper summarized best practices research for learners with learning disabilities. Recent research has focused upon activity-based, inquiry-oriented instruction.

Saturday, January 16, 9:20-10:20am Session 2

S 2.1 **Austin North** general hands-on workshop (60 min.)
Vickie Harry Clarion University of Pennsylvania
Martha Ritter Clarion University of Pennsylvania

Inquiry into Science: Integrating Constructively (INSINC)
This session will engage participants in phases and strategies of constructivist style teaching presented at the INSINC summer institute at Clarion University of PA.

S 2.2 **Austin South** general contributed paper (30 min.)
Barbara S. Spector University of South Florida
Herbert K. Brunkhorst California State University

Collaboratively Studying the Efficacy of Science and Mathematics Teacher Preparation in the U.S.: A lesson in communication
Examples of communication gaps among science educators and their impact on teacher education research and development of a common theoretical framework will be presented.

S 2.2 **Austin South** general contributed paper (30 min.)
Tracy John Posnanski University of Wisconsin-Milwaukee

The Promotion of Self-efficacy Beliefs Through a Professional Development Model
The development of teacher self-efficacy beliefs are examined as elementary science teachers participate in an in-service experience designed to promote self-efficacy beliefs and effective elementary science instruction.

S 2.3 **Ball Room A** **elementary** **contributed paper (30 min.)**
J.M. Shireen Desouza Ball State University

Early Childhood Science - Adopting the Reggio Emilia Approach

Originating in Italy, the Reggio Emilia Approach is an exemplary early childhood program. This presentation shows how it can be adopted to teach young children science.

S 2.3 **Ball Room A** **college** **contributed paper (30 min.)**
Lucille Slinger University of Wisconsin - La Crosse

Combining Physical Science & Technology Enhancement for K-2 Teachers

The format and outcomes of a two year combination physical science and technology grant projects for K-2 level building team teachers will be presented.

S 2.4 **Ball Room B** **elementary** **contributed paper (30 min.)**
Carol Briscoe University of West Florida
David L. Stout University of West Florida

Prospective Elementary Teachers' Concepts of Variable as Represented in Solutions to a Lever Mechanics Problem

Elementary science and mathematics methods students describe their understanding of mathematical representations of relationships among variables in solutions to mechanics problem involving levers.

S 2.4 **Ball Room B** **college** **contributed paper (30 min.)**
Carolyn Dawson University of Northern Colorado
Gerald Saunders University of Northern Colorado

Teaching Biology to Preservice Elementary Teachers: Using the K-8 Content Standards as a Framework

This paper describes a biology course for preservice elementary teachers. Curriculum was based on K-8 content standards. Students gained both content knowledge and standards awareness.

S 2.5 **Bouquets** **general** **hands-on workshop (60 min.)**
William R. Kubinec College of Charleston

Powerful Ideas: Developing Physical Science Concepts for Pre-Service Teachers

This course uses an instructional technique that integrates a single hands-on, inquiry based model. During this session the model will be illustrated with actual course materials.

S 2.6 **Cellar** **middle/secondary** **contributed paper (30 min.)**
William J. Boone Indiana University
Kate Scantlebury University of Delaware
Jane Kahle Miami University
Arta Damnjanovic Miami University

An Instrument to Gauge Teachers' Attitudes Towards and Assessment of Parental Involvement in Middle School Classrooms

A 13-item attitudinal instrument was developed to evaluate teachers' attitudes towards and assessment of parental involvement in middle school classrooms throughout the state of Ohio. The instrument was administered to over 90 principals and 450 science teachers. Analysis results will be presented, and copies of the instrument distributed.

S 2.6 **Cellar** **elementary** **contributed paper (30 min.)**
Larry Yore University of Victoria
James A. Shymansky University of Missouri
Brian Hand Iowa State University

Empowering Families in Hands-on Science Program

The presentation reports on a school-home collaboration utilizing children's literature and science activities. It will provide useful insights and guidelines for empowering families in thier children's science learning.

S 2.7 Congress elementary/college contributed paper (30 min.)

Valarie L. Dickinson Washington State University
Fouad Abd-El-Khalick American University of Beirut
Norman G. Lederman Oregon State University

Changing Elementary Teachers' Views of the NOS: Effective Strategies for Science Methods Courses

The present study compared the effectiveness of two approaches to enhancing elementary teachers' views of the NOS, an explicit activity-based approach versus a similar approach that incorporated reflective elements.

S 2.7 Congress elementary contributed paper (30 min.)

Melissa George Purdue University
Sandra Abell Purdue University

Reconsidering Elementary Science: Teacher Beliefs and Understandings of a State Science Framework

How do elementary teachers operationalize a state science framework into curriculum, instruction, and instructional materials evaluation? Preliminary findings from a study of a teacher enhancement program will be reported.

S 2.8 Executive college panel (60 min.)

Robert K. James Texas A&M University
Ronald J. White Baylor College of Medicine
Virginia Heilman College Station Junior High
Debbie Jensen Texas A&M University
Marlene Y. MacLeish Morehouse School of Medicine
Nancy Moreno Baylor College of Medicine

Preparing Science Teachers and Other Citizens for the Trip to Mars: NSBRI

An overview of the science and education elements of the National Space Biomedical Research Institute.

S 2.9 Liberty college panel (60 min.)

Lesia C. Lennex Morehead State University
Joan M. Whitworth Morehead State University

Distance Learning: How, What and Why?

Panel Discussion of issues involved in teaching a science methods course via distance learning (compressed video and internet technology).

S 2.10 Senate college contributed paper (30 min.)

Thomas E. Thompson Northern Illinois University
Kenneth P. King Northern Illinois University

Project TEAM: Bridging Theory and Practice in Science Teacher Preparation

Project TEAM is a Northern Illinois University-based partnership dedicated to improving teacher knowledge of the physical sciences, science instruction, and preservice teacher education.

S 2.10 Senate college contributed paper (30 min.)

Teresa M. Carroll Dury College

Developing Partnerships: The Tie Between Beliefs & Practices

An investigation of the Kansas Collaborative Research Network concerning teacher beliefs about curriculum and instruction and the relationship of those beliefs to strategies and practices in the classroom.

Saturday, January 16, 10:40-11:40a Session 3

S 3.1 **Austin North** secondary hands-on workshop (60 min.)
James A. Rye West Virginia University
V. Star Campbell Creative Enterprises
Jenny Bardwell West Virginia University

A Model and Strategies for Realizing Secondary Level Interdisciplinary Instruction
Educational reform advocates interdisciplinary approaches. This workshop features a thematic multidisciplinary high school curriculum which has applications for science instruction and teacher professional development.

S 3.2 **Austin South** general contributed paper (30 min.)
Sandra Finley Southwest Educational Dev Lab (SEDL)

Collaboration Between a Researcher and Three Science Teachers: A Story of the Process
This paper tells the story of the evolution of a collaborative relationship between a novice researcher and three science teachers as they explored teaching practice.

S 3.2 **Austin South** secondary contributed paper (30 min.)
Susan Westbrook North Carolina State University
Tracy Jenkins North Carolina State University
Barbara L. Popovec North Carolina State University

The Science Teacher Education and Mentor Project: Voices in School-University Partnerships
Discussion of the roles and concerns of high school science teachers involved in the development of a school-university partnership to improve science teacher education.

S 3.3 **Ball Room A** elementary/college contributed paper (30 min.)
James D. Ellis University of Kansas

A Dilemma in Reforming Science Teacher Education: Responding to Students' Concerns or Striving for High Standards
A description of student concerns and needs, professional standards for science teachers, and their impact on the redesign of a teacher preparation program.

S 3.3 **Ball Room A** general contributed paper (30 min.)
Richard H. Audet Roger Williams University
Linda Jordan Tennessee Dept of Education

Strategies for Learning How to Use Standards Documents
This paper reviews activity-based approaches for gaining confidence in applying the uses to make curriculum and teaching decisions.

S 3.4 **Ball Room B** general contributed paper (30 min.)
Craig Berg Univ. of Wisconsin-Milwaukee
Michael Clough The University of Iowa

Research On, Activities to Facilitate Partnering in Field Experiences
Research describing the effects of partnering field experience students (on planning, teaching, reflection) and activities to facilitate partnering.

S 3.4 **Ball Room B** **general** **contributed paper (30 min.)**

Penny J. Gilmer Florida State University
Terrie L. Kielborn Belleview Middle School

Meaningful Science = Teachers Doing Inquiry + Teaching Science

Elementary and middle school teachers share their empowering experiences of their transition from teacher to scientist in a new monograph.

S 3.5 **Bouquets** **college** **panel (60 min.)**

Sam Spiegel National High Magnetic Field Lab
Pat Dixon National High Magnetic Field Lab

Preservice Learning Opportunities at a National Laboratory - Imagine the possibilities.

Following a presentation of a national laboratory's preservice opportunities, participants will discuss potential opportunities that could be developed through both in-site and distance learning strategies.

S 3.6 **Cellar** **secondary** **contributed paper (30 min.)**

Randy L. Bell Oregon State University
Lesley Blair Oregon State University
Norman G. Lederman Oregon State University
Barbara Crawford Oregon State University

The Effect of a Science Apprenticeship Program on High School Students' Understandings of the Nature of Science and Scientific Inquiry

The study assessed changes in 11 secondary students' understandings of the nature of science and scientific inquiry during an intensive 8-week university science apprenticeship.

S 3.6 **Cellar** **general** **contributed paper (30 min.)**

Barbara S. Spector University of South Florida

What's involved in developing a continuum of learning for science teachers from preservice through career-long inservice? Can we do it?

Findings from an NISE study, e.g., issues to resolve, mechanisms in use, common features of reform projects, and more addressing title questions will be described.

S 3.7 **Congress** **college** **contributed paper (30 min.)**

Marvin Druger Syracuse University

Preparing College Science Teachers

This presentation will concern science teacher preparation for college-level teaching. an exemplary program will be described, and problems and perspectives will be discussed.

S 3.7 **Congress** **general** **contributed paper (30 min.)**

Laura Henriques California State Univ, Long Beach
Joanne Olson California State Univ, Long Beach
Alan Colburn California State Univ, Long Beach

Beyond Outcomes: Standardizing Performance Assessments in a College Science Course

A team of professors worked together to create, test and implement course-wide standards-based performance assessments for multiple sections of a college science course.

S 3.8 **Executive**
Sharon Lynch George Washington University **general** **panel (60 min.)**

The National Board of Professional Teaching Standards for Secondary Science Teachers: Preliminary Discussions, Issues and Implications

This panel will discuss the National Board of Professional Teaching Standards (NBPTS) first efforts in area of Board certification for science teachers. In this session panelists will discuss the history and philosphy behind NBPTS, describe the process that science teachers must go through in order to achieve Natoinal Board certification, and discuss the implications of the process for science educators.

S 3.9 **Liberty**
William H. Robertson Los Alamos National Laboratory **general** **panel (60 min.)**
Richard Alexander Los Alamos National Laboratory

A Critical Thinking Curriculum Model

A demonstration of a multidisciplinary curriculum model that integrates effective educational components (constructivism, Socratic dialogue, critical thinking, collaborative environments, standards and benchmarks), computer technology, asssessment, and community building.

S 3.10 **Senate**
E. Barbara Klemm University of Hawaii **middle/secondary** **contributed paper (30 min.)**
Sandy Buczynski University of Hawaii

Metaphors and Images of Mentoring in an Initial Teacher Certification Program

Metaphors and images used by science teachers serving as mentors in an initial teacher certification program are compared with those appearing in research literature on mentoring.

S 3.10 **Senate**
Kathleen Sillman Bellefonte Area Middle School **college** **contributed paper (30 min.)**

Prospective Teachers' Use of Metaphors to Guide Teaching and Learning

Metaphor can be used as a vehicle of reflection for prospective teachers of science to examine and develop their understandings of learning, teaching, and science.

Saturday, January 16, 2:40-3:40pm Session 4

S 4.1 **Austin North**
Larry Enoch The University of Wisconsin-Milwaukee **secondary** **hands-on workshop (60 min.)**
Mike Smith American Geological Institute

Earth System in the Community: A New Earth Science Curriculum for the High School

This workshop will provide an overview of the EarthComm science curriculum. The workshop is designed as a participatory activity through which all of the components of the curriculum will be demonstrated.

S 4.2 **Austin South**
Roger L. Davis Escola das Nacoes **general** **demonstration (30 min.)**
J. Preston Prather University of Tennessee-Martin
Geraldine T. Farmer Metropolitan Nashville Public Schools
Carol Foster McMurray Middle School

An Internet-Based Model for Multicultural Science Education: Near-Peer Teaching Across the Equator through the Global Learning Cooperative

Benefits of internet-based teaching methods, employing global learning cooperatives for near-peer instruction among mentee and mentor classes in grades K-12, will be demonstrated and explained.

S 4.2 **Austin South** **general** **demonstration (30 min.)**
Eileen Carolton Parsons Lenoir-Rhyne College/UNC-Chapel Hill

Science Instruction with an African American Twist: A Demonstration to Highlight Cultural Values in Teaching

In the session, a videotape of two simulations will shown and discussed. The simulations illustrated the teaching of the water cycle from two cultural perspectives: the dominant cultural ethos in the U.S. and the African American cultural ethos.

S 4.3 **Ball Room A** **college** **panel (60 min.)**
Frank E. Crawley East Carolina University
Fanette Hines-Entzminger Tarboro High School
James Egerton Tarboro High School
Ragan Spain Tarboro High School
Reggie Cobb Southwest Edgecombe High School

A University-School Partnership Project to Reform Science Education

Presenters describe accomplishments of the Science Professional Improvement via Collaborative Education (SPICE) project, one university-school partnership project funded by the BellSouth-East Carolina University Partnership Program.

S 4.4 **Ball Room B** **college** **contributed paper (30 min.)**
Peter Veronesi SUNY Brockport

RBEST Rationale for Teaching Elementary Science: Impact on First-Year Teachers

This study asked first-year elementary teachers to reflect upon the current impact of their fall 1996 semester-long writing of their research-based elementary science teaching rationale (RBEST Rationale, Varonesi AETS, 1998).

S 4.4 **Ball Room B** **general** **contributed paper (30 min.)**
Jodi J. Haney Bowling Green State University
Charlene M. Czerniak The University of Toledo
Marcia Fetters The University of Toledo

Hands-On and Minds-On Professional Development: Integrating Active Thinking and Learning Strategies Through Reflective Journaling

We will share teacher journals completed during a two week NSF Institute. The journal activities followed a constructivist design enabling teachers to process workshop experiences.

S 4.5 **Bouquets** **college** **panel (60 min.)**
Meta Van Sickle College and University of Charleston
Margaret Bogan Jacksonville State University
Bill Baird Auburn University
Michael Kamen Auburn University
Carolyn Dickman Education

Use of Portfolios for Standards-based Performance in Teacher Education

We will describe how we use portfolios as evaluation tools to ensure that preservice teachers provide evidence of their potential to meet standards in thier teaching. Examples will illustrate some of the ways this approach has been useful to us. A dialogue with the audience will follow.

S 4.6 **Cellar**
Julie Thomas Texas Tech University
Project Directors
panel (60 min.)

Building Models, Bringing Change: Improving the Science Preparation of Elementary Teachers

Panel members will describe and discuss Models of Change, seven innovative programs funded by Texas Statewide Systemic Initiative (SSI) to support explorations in improved science teaching and learning for elementary children. This presentation will focus on lessons learned across the projects: 1) Developing a Collaborative Vision or "Filling out the Dance Cards " ; 2) Innovation as a Learning Process or "Now What?"; and, 3) Learning from our Hypotheses or "Dilemmas and Dreams." Participants will receive a CD-ROM defining the projects.

S 4.7 **Congress**
Maria M. Ferreira Wayne State University
middle/secondary **contributed paper (30 min.)**

Caring Teachers: Adolescents' Perspectives

This paper will present the results of a study that investigated urban and suburban adolescents' perceptions of the attributes of a caring teacher.

S 4.7 **Congress**
Dorothy L. Gabel Indiana University
Eric Worch Indiana University
college **contributed paper (30 min.)**

The QUEST Capstone Experience for Enhancing Middle School Science Teaching: A Collaborative Program Approach

An interdisciplinary course using energy as its theme and CBL inquiry activities was created with input from mentor teachers who model similar instruction in their classrooms.

S 4.8 **Executive**
Nancy Landes Biological Sciences Curriculum Study
Pamela Van Scotter Biological Sciences Curriculum Study
general **panel (60 min.)**

What Does "Aligned with Standards" Really Mean?

During this session we will explore with the participants the question of what it means for curricula to align with standards. We also will explore the Standards and Benchmarks as tools for developing new curricula and evaluating current curricula.

S 4.9 **Liberty**
Michael Padilla University of Georgia
Floyd E. Mattheis East Carolina University
Carol Kubota University of Washington, Bothell
Yasushi Ogura National Institute for Educational Research
Liz Doster East Carolina University
general **panel (60 min.)**

Staff Development Program for Science Teachers in Japan

A discussion of a recent study of staff development activities in japan and how they are different or similar to staff development programs in the U.S.

S 4.10 **Senate**
J. Randy McGinnis University of Maryland
Amy Roth-McDuffie University of Maryland
Carolyn Parker University of Maryland
college **contributed paper (30 min.)**

An Action Research Perspective of Making Connections Between Science and Mathematics in a Science Methods Course

This study documents and interprets efforts made by science methods professor to make connections between mathematics and science in an elementary/middle level science methods course.

S 4.10 **Senate** — general — **contributed paper (30 min.)**
Mary Stein   Wayne State University

Using Portfolios to Assess Teaching Competencies in Science Education
The gradual implementation of a large scale portfolio program will be described. Analysis of the portfolios revealed potential areas for program improvement.

Saturday, January 16, 3:50-4:50pm Session 5

Austin North
Texas Instruments

Texas Instruments
Corporate Sponsored Workshop

S 5.1 **Austin South** — **college** — **contributed paper (30 min.)**
Joan M. Whitworth   Morehead State University

Reaching Out to Teachers in Appalachia via Distance Learning
Description of a graduate level advanced science methods class delivered to elementary teachers via compressed video technology to remote sites in Appalachia.

S 5.1 **Austin South** — **middle** — **demonstration (30 min.)**
Judy Reinhartz   The University of Texas at Arlington
Linda Ramsey   Bebensee Elementary School
Sheryl Schickendanz   H.F. Stevens Middle School
Johnny Stephens   Palmer I.S.D.
Carma Whitney   South Euless Elementary

Empowering Middle School Teachers: The UT Arlington Story
The presenters will provide an overview of the ESTT program using interactive strategies along with demonstrations to engage participants.

S 5.2 **Ball Room A** — **college/supervision** — **panel (60 min.)**
Norman Lederman   Oregon State University
Michael Mix   Oregon State University
Lesley Blair   Oregon State University
Paul Kuerbis   The Colorado College
Keith Kester   The Colorado College

Aligning Undergraduate Science Courses with National Reforms
A panel consisting of science faculty and science educators will address several issues associated with national reforms and curricular innovation in university courses.

S 5.3 **Ball Room B** — **general** — **panel (60 min.)**
Andrew C. Kemp   The University of Georgia
Bill Baird   Auburn University
Erica M. Brownstein   Ohio Dominican College
Amy Cox   California State University
John A. Craven, III   Queens College/CUNY
Elizabeth Day   University of So. Carolina
Allen Emory   The University of Georgia

Graduate Student Forum: A Passport to Professionalism
We will share ideas and experiences to assist graduate students in their journey towards becoming professional science educators. Everyone is invited to come and participate.

S 5.4 **Bouquets** general hands-on workshop (60 min.)

Bonnie McCormick University of the Incarnate Word

Julia Barker University of the Incarnate Word

Exponential Growth Potential - Integrating Biology, Mathematics, and Technology

Participants will engage in a hands on activity that integrates bilogy, technology, mathematical principles, and population growth using a learning cycle instructional model.

S 5.5 **Cellar** general hands-on workshop (60 min.)

Stephen Marbel SEDL

Tom Gadsden Eisenhower Natl Clearinghouse, Ohio State

Access to National Resources and Information

Explore ways to link your teachers and students to on-line resources and information about science teaching and learning through the Eisenhower Natl. Clearinghouse and Eisenhower Regional Consortia.

S 5.6 **Congress** elementary/college contributed paper (30 min.)

Renee' S. Schwartz Oregon State University

Fouad Abd-El-Khalick American University of Beirut

Norman G. Lederman Oregon State University

An Exploratory Study of the "Effectiveness" of Elementary Science Spcialists

The study assessed differences between elementary teachers' and elementary science specialists' views of science teaching, instructional planning, and "effectiveness" toward student achievement of science literacy.

S 5.6 **Congress** college contributed paper (30 min.)

Laura Downey-Skochdopole Kansas State University

M. Jenice French Kansas State University

Teachers' Negotiations of Shifts in Power, Status and Authority in the Elementary School: Case Studies of Teacher Leadership and Empowerment in a Professional

Paper presentation of four case studies of elementary teachers' entries into leadership roles in a Professional Development School focusing on perceived changes effecting math and science.

S 5.7 **Liberty** general panel (60 min.)

April Dean Adams University of Houston

Eugene L. Chiappetta University of Houston

Robert Beck Clark Texas A&M University

Mary Long The University of Texas at Austin

Dawn Parker Texas A&M University

Robert James Texas A&M University

College of Education and College of Science Collaborative: A Dialogue

This panel discussion explores the benefits, the barriers, and the possibilities of teacher education collaborations between the colleges of education and science.

S 5.8 **Senate** elementary/college contributed paper (30 min.)

Tahsin Khalid Indiana University

College Students' Perceptions Regarding Three Ecological Issues

This study identifies and describes pre-conceptions held by pre-service elementary education majors regarding the three ecological issues -- Greenhouse Effect, Ozone Layer Depletion and Acid Rain.

S 5.8 **Senate** **college** **contributed paper (30 min.)**
Michael J. Wavering University of Arkansas
Carol Mueller University of Arkansas

Science Interns Beliefs About the Nature of Science

Masters level students in a year long internship were interviewed before, during and after the internship about thier beliefs about the nature of science.

S 5.9 **Executive** **general** **panel (60 min.)**
Judy Reinhartz The University of Texas at Arlington
Juanita Jo Matkins Virginia Commonwealth University

Inclusion: Teaching Individuals with Physical and Learning Challenges

The discussion will focus on best practices and research regarding students with physical and mild cognitive learning challenges. Chris McCallister, a graduate student who is physically challenged, will join the discussion to tell his personal story.

S 5.10 **Congress** **secondary** **panel (60 min.)**
Elaine J. Anderson Shippensburg University
Tracy Schoolcraft Shippensburg University
Gene Fiorini Shippensburg University
Greg Paulson Shippensburg University

Preservice Secondary Science Teachers as Science Partners and Mentors for Girls in Underserved Middle School and High School Districts in South-central

The panel of interdisciplinary faculty from a university in south-central Pennsylvania will discuss the rationale, the framework, the outcomes, and the future of the summer action science experience for preservice science teachers and girls in grades 7-11 attending the programs.

Saturday, January 16, 5:00-6:00pm Session 6

S 6.0 **Austin North** **general** **panel (60 min.)**
Kevin D. Finson Western Illinois University
Julie Thomas Texas Tech University
Jon E. Pedersen East Carolina University
Joanne Olson University of Southern California
Iris M. Riggs Cal-State Univ-San Bernadino
Joseph Jesunathadas Cal-State Univ-San Bernadino
Charles R. Barman

Redevelopment of the Draw-A-Science Teacher Test (DASTT-C) Checklist

This session will review the development of the DASTT-C, its revision, and some of its uses over the past two years in science methods courses across the country and in several other nations.

S 6.1 **Austin South** **middle** **contributed paper (30 min.)**
Rebecca L. Pringle Washington State University
Valarie L. Dickinson Washington State University

Classroom Learning Activities that Generate the Most Participation in Middle School Science

This session describes research results in an eighth grade middle school science classroom that determined which learning activities generated the most student participation.

S 6.1 **Austin South** — middle/secondary — contributed paper (30 min.)

Donna R. Sterling, George Mason University

Preservice Middle and Secondary School Teachers Misconceptions about Making Measurements using Laboratory Instruments

This three-year study investigated the measuring skills of preservice teachers and their misconceptions. The study has implications for K-12 teacher education.

S 6.3 **Ball Room B** — college — contributed paper (30 min.)

Sandra Finley, Southwest Educational Dev Lab (SEDL)
Glenda Clark, Southwest Educational Dev Lab (SEDL)

Teachers' Sense-Making of Science Standards, Curriculum, and Reform: A Focus on Structional Coherence

Vignettes from a study group of teachers serve as a focus to begin a dialogue around issues of coherence and ways for new teachers to reflect on their practice.

S 6.3 **Ball Room B** — general — contributed paper (30 min.)

Valerie K. Olness, Augustana College
Michelle Griffith, Sioux Falls School District
Robert Simonson, Sioux Falls School District

Moving a School District Towards Constructivism and the National Science Standards

How a school district is attempting to move towards "Teaching for Understanding" in alignment with the vision of the National Science Standards.

S 6.4 **Bouquets** — general — hands-on workshop (60 min.)

Robert B. McDonald, Texas A&M University - Corpus Christi
Jo Ann Montes McDonald, Texas A&M University - Corpus Christi

Building a Community of Learners Using Family Science Events

This workshop will provide participants with strategies and materials for implementing community/parent involvement programs with schools. Current research will be presented and discussed.

S 6.5 **Cellar** — college — hands-on workshop (60 min.)

Norman Thomson, University of Georgia

Monitoring Wound Healing in Plant Cells

Participants will investigate classroom techniques to monitor wound healing in plant cells constructed in an integrated exploratory problem solving environment. Potato tubers, lead sinkers, protractors, basic microscopy, cytochemistry, and mathematical sampling models are used. Corollary ultrastructural and biochemical research investigating wound healing will also be presented.

S 6.7 **Executive** — secondary — panel (60 min.)

Libby G. Cohen, University of Southern Maine
Ah-Kau Ng, University of Southern Maine
Dale Blanchard, University of Southern Maine
Elizabeth Fales, University of Southern Maine
Deb Dimmick, University of Southern Maine
Nancy Lightbody
Nancy Freese, Noble High School
Don Berthiaume, Biddeford High School
Dorene Johnson, Fdn for Blood Research

Biotechnology Works!

This session describes a summer institute, sponsored by the National Science Foundation, in immunology and genetics for high school students with disabilities and high school science teachers.

S 6.8 **Liberty** secondary panel (60 min.)
Susan Westbrook North Carolina State University
Jack Wheatley North Carolina State University
Laura Rogers University of North Carolina at Wilmington
Carol Maidon North Carolina State University

University-High School Partnerships for Science Education: Multiple Perspectives
Panel discussion to examine multiple models for developing and implementing high school-university partnerships designed to improve science teacher education.

S 6.9 **Senate** college contributed paper (30 min.)
Bill Baird Auburn University
Ralph Zee Auburn University

Team Projects: A Taste of Real Science in Our Methods/Content Course
Describes the use of team projects in a hybrid methods/content course for physical science teachers. These projects require teamwork, application of course content, and principles of teaching. Examples of final written and oral presentations will be shown and discussed.

S 6.9 **Senate** college contributed paper (30 min.)
Janet Carlson Powell University of Colorado

Are We Understanding the Power of Curriculum Materials?
The study of teachers who implemented a reform-oriented curriculum indicates that the use of a new materials had a greater impact on their practice than knowledge, staff development, or personal interest alone. The implication for teacher education is that we are missing opportunities to impact teaching practices if we do not stress the role of the newest generation of NSF-developed materials.

Sunday, January 17, 1999 8:00-9:00am Session 1

Su 1.1 **Austin North** middle hands-on workshop (60 min.)
Diana Mason The Univ of Texas at San Antonio
Kathy Mittag The Univ of Texas at San Antonio

Doing the TEKS! An Integrated Science and Mathematics Lab
This investigation integrates the physical science concepts of heat and temperature with mathematical and statistical concepts of scale, measures of central tendency, and regression.

Su 1.2 **Austin South** general panel (60 min.)
Nancy Finkelstein Harvard-Smithsonian Ctr for Astrophysics

I'm Teaching, But They're Not Learning!
Ever wonder why students don't always learn what we teach them? Check out MINDS OF OUR OWN, a new documentary on how children "learn" science.

Su 1.3 **Ball Room A** general hands-on workshop (60 min.)
Loretta Molitor Towson University
Sarah Duff Towson University

Transforming Preservice Science Teacher Education: A Workshop Based on a Project 2061 Case Study
Demonstration of the use of Project 2061 Materials in pre-student teaching field placements and method courses for upper elementary and middle schools – preservice and inservice teachers learning together.

Su 1.4 **Ball Room B** secondary demonstration (30 min.)
Mark J. Volkmann Purdue University

Issues-Based Inquiry: An Approach to Teaching Preservice Secondary Science
During this session participants will learn how my preservice secondary science students used issues-based inquiry as a field experience associated with learning to teach.

Su 1.5 **Congress** general contributed paper (30 min.)
Beth Shiner Klein St. Norbert College
Reid Riggle St. Norbert College
Mary Alyce Lach St. Norbert College
Mark Bockenhauer St. Norbert College

Ocean Voyagers Program: A Collaborative Program
This session will share the quantitative and qualitative evaluation results of the 1st year of this collaborative program joining government, colleges, and precollegiate schools.

Su 1.5 **Congress** college contributed paper (30 min.)
Leigh Ann Boardman Penn State University
Carla Zembal-Saul Penn State University
Maryann Frazier Penn State University
Heidi Appel Penn State University

Enhancing the *Science* in Elementary Science Methods: A Collaborative Effort Between Science Education and Entomology
A science methods field experience in which prospective elementary teachers engaged in subject-specific learning with Entomology faculty, graduate students and elementary children will be presented.

Su 1.7 **Senate** college panel (60 min.)
Harry L. Shipman University of Delaware
Robert Ketcham University of Delaware

Big Projects: Long-Term, Student-Designed Inquiry Investigations in Large College Courses
An interdisciplinary team implemented Big Projects in biology, chemistry and physical science courses (400-500 students). Participants will evaluate student work and hear how we did this.

Sunday, January 17, 1999 9:20-10:20am Session 1

Su 2.0 **Austin South** general panel (60 min.)
Nancy Finkelstein Harvard-Smithsonian Ctr for Astrophysics

CASE in Point!
See real teachers in action! Learn about CASE STUDIES IN SCIENCE EDUCATION, a new video series that takes education reform to a personal level.

Su 2.1 **Austin North** college contributed paper (30 min.)
David Allard Texarkana College
Delbert Dowdy Texarkana College

The Texarkana Preservice Science Improvement Project (TPSIP)
TPSIP is designed to improve undergraduate science courses taken by elementary education majors. It involves precollege science teachers, college science faculty, and undergraduate students.

Su 2.3 **Ball Room A** **general** **hands-on workshop (60 min.)**
Barbara A. Salyer Southwest Educational Dev Lab (SEDL)
Stephen Marble Southwest Educational Dev Lab (SEDL)

Preservice Teachers and Effective Instruction: What are Our Expectations for Instructional Behaviors in the Classroom?

Participants will share ideas about instructional behaviors expected from preservice teachers and compare expectations to instruction in videotaped lessons linked to differences in student achievement.

Su 2.4 **Ball Room B** **general** **hands-on workshop (60 min.)**
Dawn M. Pickard Oakland University
Marcia Fetters University of Toledo

Interactive Workshop Exploring Materials and Ideas to Prepare Learning Environments

An interactive workshop exploring materials and ideas that serve to prepare teachers who create inclusive learning environments.

Su 2.5 **Bouquets** **elementary/college** **contributed paper (30 min.)**
Angelicque Tucker Blackmon Emory University
Karen Falkenberg Emory University

Elementary Science Education Partners (ESEP) Science Education Contributing to College Students' Moral Development

This study was conducted to determine whether or not a unique course offered to undergraduate science majors contributes to the participants moral development.

Su 2.5 **Bouquets** **middle/secondary** **contributed paper (30 min.)**
Ellen Fowlkes Fulmore Middle School

Sex, Drugs, and TAAS

Presentation of a unique approach to the integration of the human reproduction unit within the framework of the 8th grade curriculum.

Su 2.6 **Congress** **general** **contributed paper (30 min.)**
Michael P. Clough The University of Iowa

Science for All Americans?

This session addresses the peculiar nature of scientific thinking, whether ALL students can and should learn science, and the implications for science teacher education.

Su 2.6 **Congress** **general** **contributed paper (30 min.)**
Chin-Tang Liu Southwest Missouri State Univ
Farella Shaka Southwest Missouri State Univ
Larry Banks Southwest Missouri State Univ
Becky Baker Southwest Missouri State Univ

The Science-related Profile of Faculty and Students with Respect to Classroom Environment and Science Beliefs

The findings about science beliefs and constructivist learning environment from teacher preparation programs for K-12 teachers of science are presented in this study.

Su 2.7 **Longhorn** general panel (60 min.)

Barbara S. Spector University of South Florida
Patricia Simpson St. Cloud State University
Marianne Barnes University of North Florida
Pat Dixon Florida State University

Help! I can't get control of my time! Sound familiar?

In this panel discussion women in the professorate will share criteria and strategies they are using to set priorities for thier careers and lives.

Su 2.8 **Rotunda** general poster presentation

Roy Hurst The University of Texas, Permian Basin

Assessing the Impact of an Enhancement Program...

Assesses the impact of an enhancement program for life science teachers in terms of its effect on the teachers' classroom environments and instructional methods.

Su 2.8 **Rotunda** middle/secondary poster presentation

Robert Cohen East Stroudsburg University

A 3-credit "stand alone" Methods Course

The poster will document the structure of the methods course I teach - its purpose is to promote discussion on the various techniques we use to achieve the common goal - better science teachers.

Su 2.8 **Rotunda** elementary/middle poster presentation

Glenda Love Bell The University of Texas at Austin

Elementary Science Teachers' Perceptions of a Life Scientist's Tool Kit: Implications for Teacher Education

The Mathematics and Science Education Cooperative (MSEC) model offers elementary science teachers increased confidence in teaching science and awareness of how personal perceptions impact teaching practices.

Su 2.8 **Rotunda** middle/general poster presentation

Meng-Jung Tsai The University of Texas at Austin
Lowell Bethel The University of Texas at Austin

Learning Strategies for More Computer Achievement, Better Computer Attitude, and Less Computer Anxiety

Correlation coefficients between learning strategies and computer achievement, attitude, and anxiety are anlyzed to find the best learning strategies for junior high computer learners.

Su 2.8 **Rotunda** elementary/middle/hig poster presentation

Hyewon Kim The University of Texas at Austin

Eighth Grade Students' Intuitive Concepts About "Water Cycle"

The purpose of investing students' intuitive ideas was to analyze their concepts of the states of water, evaporaiton, condensation, humidity, dew and frost.

Su 2.9 **Senate** college panel (60 min.)

Catherine G. Yeotis Wichita State University
Don Duggan-Haas Michigan State University
David R. Alexander Wichita State University
Dennis J. Kear Wichita State University
John J. Hutchinson Wichita State University

Collaboratives for the Improvement of Science and Mathematics Education

We report on the experiences of two universities in establishing collaboratives for the improvement of science and mathematics teacher preparation programs.

Sunday, January 17, 1999 10:40-11:40a Session 3

Su 3.1 Austin North college contributed paper (30 min.)

Charles Eick Auburn University
Bill Baird Auburn University

Assisting Interns through Networking and Field Support: Can We Improve Our Support of the Internship Experience?

Practicing interns receive support from our college throughout the internship experience. Some of these simple, but effective, methods of providing support will be described. Audience reaction and input will be encouraged.

Su 3.1 Austin North college contributed paper (30 min.)

Thomas Koballa The University of Georgia
Andrew Kemp The University of Georgia
Dava Coleman Cedar Shoals High School
Carolyn Keys The University of Georgia

Teacher Support Specialists in Science (TS3): Socializing Prospective Secondary Teachers into the Profession

Learn about the TS3 project's preparation and instructional phases and about issues and concerns associated with mentoring practicum students and student teachers that came to light during these phases of the project.

Su 3.2 Austin South general panel (60 min.)

Janet Bond Robinson University of Kansas
William Kubinec College and Univ of Charleston
John Craven Queen's College/CUNY
Meta Van Sickle College and Univ of Charleston

Impacting the Scope of the Preservice Experience: A Funded Collaborative

Four interactive sessions, one, an overview of the findings of 13 research studies, and three 15-minute sessions, each describing a specific study.

Su 3.3 Ball Room A general hands-on workshop (60 min.)

Marilyn V. Rands Lawrence Technological University

Using Technology in an Inquiry Classroom Environment -- Waves

Using simple materials and sound sensors interfaced with PCs, this workshop will explore in an inquiry mode, connections between material waves, sound waves and mathematics.

Su 3.4 Ball Room B secondary demonstration (30 min.)

James A. Rye West Virginia University
Nancy Priselac Garrett Community College
Jenny Bardwell West Virginia University

Connecting Science, Math, and Health: Applications of the Graphing Calculator in Teacher Professional Development and Student Academic Enrichment

The demonstration reveals how graphing calculators can be applied to nutrient composition of food to learn about statistics, experimental design, and other science/math concepts.

Su 3.4 **Ball Room B** **secondary** **demonstration (30 min.)**
Louisa Stark University of Colorado

Kitchen Electrophoresis: An Inexpensive and Colorful Introduction to a Fundamental Molecular Biology Technique

Engage students in learning the principles and uses of gel electrophoresis genetics, forensics, etc., for only 5cents/gel. Instructions for building Plexiglas gel boxes included.

Su 3.5 **Bouquets** **college** **contributed paper (30 min.)**
Christy MacKinnon University of the Incarnate Word
Judith Fowles Northside Ind School District

Multidisciplinary Sciences: A Graduate Program for Middle School Teachers

A Graduate program designed to enhance science content and technology knowledge will be presented. Issues involved in development and implementation will be discussed.

Su 3.6 **Bouquets** **college** **contributed paper (30 min.)**
Betsy Ann Balzano State Univ. of New York - Brockport
Linda Kramer Schlosser State Univ of New York -Brockport

Collaborative Internship Masters Program in Inquiry Teaching

This session presents a Masters program designed to address the professional development of beginning teachers by linking theory, practice, and research in an integrated Masters program, classroom internship, and graduate student research.

Su 3.7 **Longhorn** **general** **hands-on workshop (60 min.)**
Richard N. Vineyard Weber State University
Tammy V. Abernathy Weber State University

Asking Directions and Checking the Map, Where are We Now? Is this really a science class?

Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments." (National Science Education Standards, 1996).

Su 3.8 **Senate** **general** **panel (60 min.)**
Judith K. Sweeney Museum of Natural History and Planetarium
Norman G. Lederman Oregon State University
Mann-hsi Tso National Museum of Natural Sci
Huey-Por Chen Changua University, Taiwan

Integrating Informal Science Education Opportunities into Curriculum Reform: Models of Professional Development

This session will focus on the development and implementation of professional development programs that attempt to enhance K-12 teachers and teachers educators' use of informal science resources in the U.S. and Taiwan.

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1995 J. Preston Prather, University of Virginia
1996 Sandra Abell, Purdue University
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1998 Patricia Simpson, St. Cloud State University

Implication of Research for Educational Practice

1981 Wait-time and Learning in Science
by Ken Tobin of the Western Australian Institute of Technology and
William Capie of the University of Georgia
1983 Jane Kahle of Purdue University
1984 Training Science Teachers to Use Better Teaching Strategies
by Russell H. Yeany and Michael J. Padilla of the University of Georgia
1985 Using Research to Improve Science Teaching Practice
by Kenneth Tobin of Western Australian Institute of Technology,
1986 Active Teaching for Higher Cognitive Level Learning in Science
by Kenneth Tobin, William Capie, and
Antonio Bettencourt of the University of Georgia
1987 Training Teachers to Teach Effectively In The Laboratory
by Pinchas Tamir of The Hebrew University
1988 What Can Be Learned From Investigations of Exemplary Teaching Practice
by Kenneth Tobin of Florida State University and
Barry J. Fraser of Curtin University of Technology,
1989 Visual/Spatial Thinking: An Essential Element of Elementary Science
by Alan J. McCormack of San Diego State University
1990 Helping Students Learn How to Learn: A View from a Teacher-Researcher
by Joe Novak of Cornell University
1991 An Expanded View of the Learning Cycle: New Ideas About an Effective Teaching Strategy
by Charles R. Barman of Indiana University
1992 Teacher Development in Microcomputer Usage in K- 1 2 Science
by James D. Ellis of BSCS
1993 Understanding and Assessing Hands-on Science
by Larry Flick of Washington State University
1994 Teaching Evolution: Designing Successful Instruction
by Lawrence Scharmann of Kansas State University
1995 Using Visits to Interactive Science and Technology Centers, Museums, Aquaria, and Zoos to Promote Learning in Science
by Leonie Rennie and Terrence McClafferty
1996 General Biology: Creating a Positive Learning Environment for Elementary Education Majors
by Larry Scharman and Ann Stanheim-Smith of Kansas State University
1997 Empowering Science Teachers: A Model for Professional Development
by Ann Howe University of North Carolina at Raleigh and
Harriett Stubbs of North Carolina State University
1998 A Dynamical Systems Based Model of Conceptual Change
by Andrew Hurford, Haskell Indian Nations University

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1997 John Penick of The University of Iowa
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Dowling College

Marvin Druger
Syracuse University

Roger Olstad
University of Washington

Pincas Tamir
Hebrew University

Hans Anderson
Indiana University

Innovation in Teaching Science Teachers

1990 A Reflective Approach to Science Methods Courses for Preservice Elementary Teachers
by Dorothy Rosenthal of California State University, Long Beach

1991 Enhancing Science and Mathematics Teaching
by Kenneth Tobin, Nancy Davis, Kenneth Shaw, and
Elizabeth Jakubowski of Florida State University

1992 The Learning Cycle as a Model for the Design of Science Teacher Preservice and Inservice Education
by Peter Rubba of Pennsylvania State University

1993 Reconstructing Science Teacher Education Within Communities of Learners
by Deborah Tippins, University of Georgia,
Ken Tobin, Florida State University, and
Sherry Nichols, East Carolina State University

1995 Science for Early Adolescence Teachers (Science FEAT) A Program for Research and Learning
by Samuel Spiegel, Angelo Collins, and Penny Gilmer of Florida State University

1996 An Innovative Model for Collaborative Reform in Elementary School Science Teaching
by M. Gail Shroyer, Emmett Wright, and Linda Ramey-Gassert of Kansas State University

1997 Reconceptualizing the Elementary Science Methods Course Using a Reflective Orientation
by Sandra Abell and Lynn Bryan of Purdue University

1998 What the Science Education Standards Say: Implications for Teacher Education.
by Penny Hammrich, Temple University

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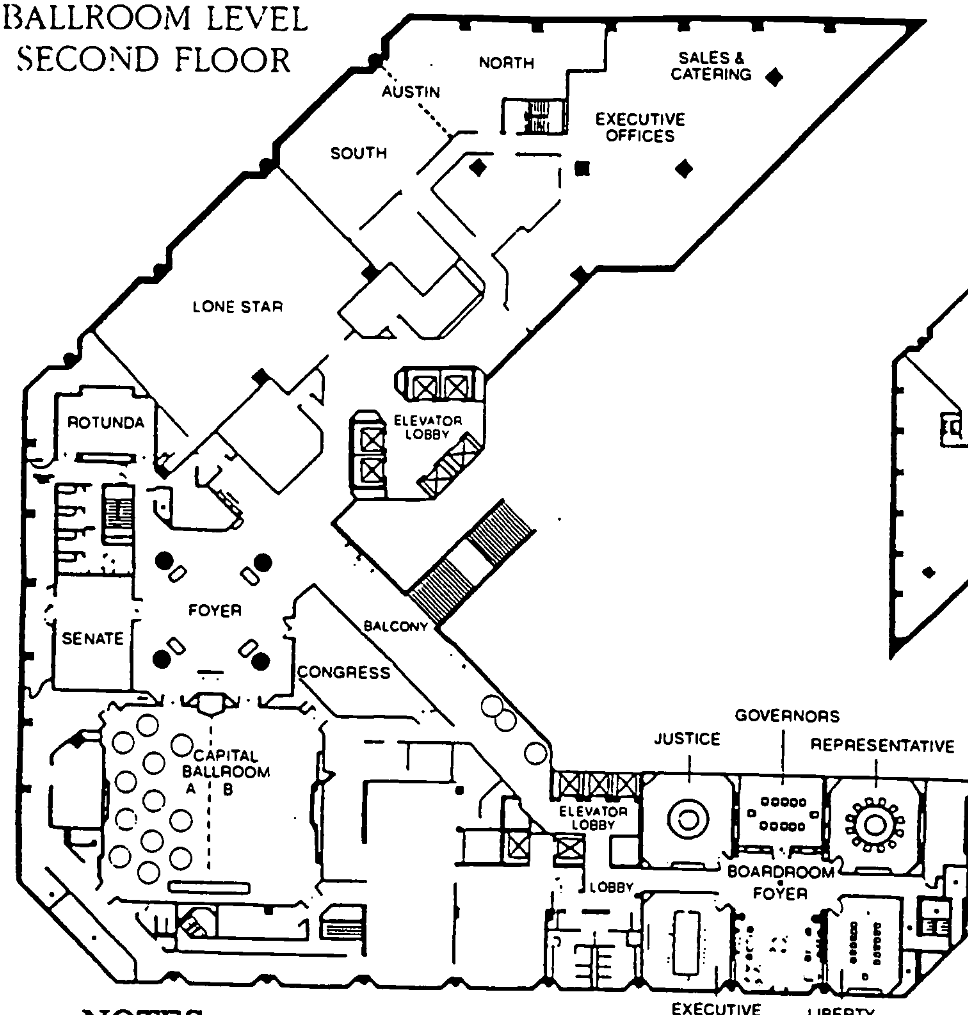
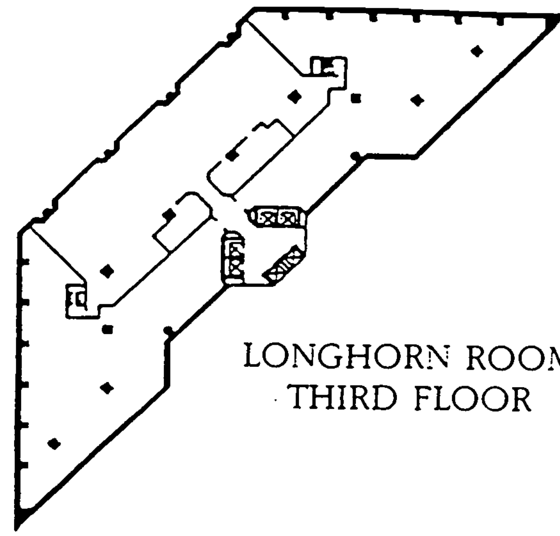
OMNI AUSTIN HOTEL
DOWNTOWN

BALLROOM LEVEL
SECOND FLOOR





LONGHORN ROOM
THIRD FLOOR

NOTES:

1999 AETS Conference Papers and Presentation Summaries

ISSUES IN SCIENCE ASSESSMENT IN A BILINGUAL/BILITERATE ELEMENTARY CLASSROOM

Jennifer A. Karpel, Purdue University
Sandra K. Abell, Purdue University

Until recently, assessment of student learning in science was perceived as a method to test what the student had learned at the end of a unit of study and to rank student performance (National Research Council, 1996). Assessments were not viewed as tools that informed elementary science teachers of their practice nor as tools that influenced elementary science teachers' curricula or methodological choices. The goal (American Association for the Advancement of Science [AAAS], 1989; National Research Council, 1996), is for science teachers to change and broaden their views of assessment in science. In the National Science Education Standards (NSES), assessments in science "can take many forms, including observations of student performance during instructional activities; interviews; formal performance tasks; written reports; and multiple choice, short-answer, and essay examinations" (National Research Council [NRC], 1996, p. 84). Science assessments should "probe the extent and organization of a student's knowledge. Rather than checking whether students have memorized certain items of information, assessments need to probe for students' understanding, reasoning, and the utilization of knowledge" (National Research Council, 1996, p. 82). Essentially, science educators have begun to view assessment as an instructional tool rather than merely an evaluative measure.

At the same time science teachers are expected to adopt this new perspective about assessment, they are being confronted with an increasing number of linguistically and ethnically diverse science students. Hispanic/Latino children are one of the fastest growing ethnic minority groups in the US (National Center for Educational Statistics, 1990). The assessment standards in the National Science Education Standards reflect knowledge of this growing diversity in US science classrooms:

> Assessment practices must be fair. Assessment practices must be appropriately modified to accommodate the needs of students with physical disabilities, learning disabilities, or limited English proficiency. Assessment tasks must be set in a variety of contexts, be engaging to students with different interests and experiences, and must not assume the perspective or experience of a particular gender, racial, or ethnic group. (NRC, 1996, p. 85).

The NRC has recognized that assessment practices must accommodate students, like the growing number of Hispanic/Latino students in the US, who do not speak English as their first language. Additionally, the NRC has recognized that assessment practices should be less Euro and Androcentric and more reflective of other groups. Currently, many culturally diverse students, such as native Spanish speakers, "are at the mercy of curriculum test developers who are not knowledgeable about these students' experiences in and out of class. Thus, the tests [end-of-chapter quizzes and standardized tests] do not enable many culturally diverse students to demonstrate their knowledge of science" (Luft, 1998, p. 114). This disadvantage for bilingual students and the NRC's shift away from Euro-Androcentric assessment practices coincides with Darling-Hammond's (1994) recommendation that assessments schould be locally developed by classroom teachers and used more as diagnostic tools rather than static, summative evaluations.

If elementary science teachers are going to help their Hispanic/Latino bilingual students become scientifically literate they need to be familiar with new parameters of assessment. They need to understand how to choose and develop assessments that will allow their bilingual students to demonstrate their knowledge and ways of knowing. Finally, elementary science teachers need to understand how they can use science assessments to a) gather information about the unique learning needs of their bilingual (Spanish/English) students, and b) to understand how this assessment information can help them modify their teaching strategies and curricula to meet the needs of their bilingual science students in their science classrooms.

Purpose and Relevant Background

The purpose of this study was to examine the types, uses, and roles of science assessment in a bilingual/biliterate (Spanish/English) elementary classroom in Honduras during one unit of science instruction. This study focused on how one teacher used assessment to a) inform her practice; b) evaluate student learning; and c) modify her curricula and teaching strategies to meet the needs of her bilingual students.

For the purposes of this study, a bilingual science classroom was defined as an environment where a) teachers made conscious curriculum and methodology choices to emphasize both biliteracy and science content knowledge development, and b) students were developing oral and written communication skills in two languages at the same time. The classroom in this study was bilingual and biliterate (Spanish/English) environment. Students were at various levels of language and literacy development in Spanish and English: their bilingualness and biliteracy was growing or emerging throughout the year. The teacher in this classroom was bilingual and biliterate (Spanish/English), and had intentionally developed curricular goals and teaching methodologies that were centered on bilingual and biliteracy development.

There are many different types of assessment: summative, formative, on-going, evaluative. This study, however, concentrated on the types, development, purpose and uses of on-going science assessments. This type of assessment is more diagnostic than summative. According to Darling-Hammond (1994) the diagnostic focus of on-going assessment makes it more equitable for minority or bilingual students. Through the use of on-going science assessments teachers are involved in gathering information about their students and using it to reflect on their teaching strategies and address certain problems in their curriculum.

Guiding Questions

Although research questions continued to evolve throughout the study, several guiding questions framed the study:

1. What kinds of assessment practices/tools does this bilingual teacher use during a science unit in her bilingual classrooms to gain understandings about her students' science learning?

2. What interpretations does this bilingual teacher lend to these assessments? (i.e.What do these assessments tell this teacher about her students' science learning? What do these assessments tell this teacher (if anything) about her students' second language (L2) development during science class?)

3. How does this teacher use the information gained from these assessments?

4. How does the information from these assessments affect the curriculum and teaching strategies in subsequent lessons within the science unit?

Methods

Theoretical Framework

Theoretical orientation and role of the researcher. This study was designed with a naturalistic (Lincoln & Guba, 1985) paradigm in mind. I (the 1st author) gathered data in an effort to understand the structure and essence of science assessment for one bilingual elementary teacher who taught in a bilingual/biliterate environment. This implied a phenomenological framework for data collection, data interpretation and data analysis. In using a phenomenological orientation I understood that "Interpretation is essential to an understanding of experience and the experience includes the interpretation" (Patton, 1990, p. 69). I recognized that each person's individual experiences influences his/her interpretation of the phenomena. I did not expect to find one, unanimous vision of how to effectively use assessment in a bilingual science classroom. Instead, I sought to focus mainly "on what people experience and how they interpret the world" (Patton, 1990, p. 70).

My role as a researcher, therefore, can best be described as "participant"; I actively took part in creating and influencing some aspects of the assessment experience that I researched. I experienced part of the phenomena under investigation because I helped the teacher become more aware of her science assessment practices and how to use them constructively to inform her science teaching practices. According to Wilcott (1990) I gathered my data "amongst my subjects rather than on my subjects" (p. 25).

Research Site

I have included a detailed description of the research site to clearly illustrate the classroom environment where the study was conducted. Furthermore, a thorough understanding of the research site will help delineate appropriate implications as well as limitations in this study.

The research site, the Anna Blanca Simon Bilingual School, is located in Zamorano, Honduras. At the time of the study the Anna Blanca Simon Bilingual School (ABSBS) served students in grades K-3 as well as nursery and pre-kindergarten students. By the year 2000 it will serve students through 6th grade. All of its classrooms are located within the college campus of a private, agricultural college (PAC). ABSBS was founded five years ago by parents who are employed by PAC in collaboration with teacher educators at a Research I university in the United States. ABSBS is a private school supported by parent fees, grants from PAC and private donations. All of the students have parents who are employed by the college in some manner. This does not mean, however, that all ABSBS students are Honduran. Many students have parents from countries in Central America, North America, Europe or South America. ABSBS students come from a wide range of economic backgrounds: some live in mud brick, one room houses with outdoor plumming and others live in neighborhoods with gardners. About half of the students live with parents one of whom is bilingual and biliterate (Spanish/English) and has an advanced degree (Masters or Ph.D.) in science. The other half of the students come from monolingual and monoliterate homes; Spanish is the first and only language that their parents speak and read. Some of the students from monolingual homes have parents with advanced degrees in science.

A bilingual learning environment at ABSBS is one "in which they [students] are encouraged to think, communicate, write, read, and learn in English and in Spanish...Bilingual children at ABSBS School become proficient and comfortable using both languages" (Anna Blanca Simon Bilingual School Planning Project, 1995, p. 4). The cultural context at ABSBS respects students' Latino heritage and their first language (Spanish). As a result, students are empowered to feel good about their emerging bilingualness as well as encouraged to become life-long science learners. These innovative perspectives create a unique environment at ABSBS--one that is not replicated in any other school in the region. ABSBS is considered to be a model of what bilingual elementary education in Honduras could become. Additionally, because its philosophy and teaching methodologies are based on current innovative practices used in many

US. elementary schools, it could also become a model of how to adapt mainstream teaching practices and curriculum to meet the needs of bilingual elementary students in the US.

Data Collection

I collected data in a multi-age grades 2/3 bilingual elementary classroom at the Anna Blanca Simon Bilingual School in Zamorano, Honduras. The study took place during one science unit on rocks and minerals that was approximately 4 weeks in length. It was part of an on-going curriculum development project between the Anna Blanca Simon Bilingual School and it US university partner.

Interviews. I conduced formal, tape recorded interviews using a semistructured and open ended format. For each formal interview I developed guiding questions based on field observations, my written reflections and previous interviews. Additional questions that were asked during each interview were derived from the teacher's responses. Informal, non-tape recorded conversations frequently occurred after school. These conversations/interviews were a natural part of reliving the most interesting or puzzling classroom moments of the day. Some of the ideas from these informal interviews were recorded in my reflection journal.

Observations. Every day, during classroom instruction as well as during field trips, I observed and recorded student actions, teacher actions and student-teacher interactions. My observations were guided by my research questions, but because of my commitment to grounded theory (Strauss, 1987) my observations remained open to themes and critical incidences outside these framing questions.

Journals. I kept a daily reflection journal as did the classroom teacher (my participant)[1]. The teacher and I agreed to write our reflections and questions in these journals after every lesson. However, the only entry that the teacher wrote directly after the introductory lesson was her first entry. All other entries were reconstructed during the last week of data collection. Although I believe that all the teacher's entries are valid reflections and recollections of the lessons, I feel the length of time between the lesson and the recorded reflection caused some ideas and reflections to be lost and blurred.

Participants

The teacher, Soñia[2], who participated in this study was selected based on her willingness to participate, her complete fluency in Spanish and English, her active involvement in the larger, on-going curriculum project with the US university partner and her status as primary (grades 1-3) elementary teacher. At the time of the study, Soñia was starting her fourth year of teaching at ABSBS. One week prior to the study, Soñia complete her masters degree in education through a U.S. affiliated and accredited university program[3].

Preliminary Data Analysis

Grounded theory and internal case analysis best describe the methods of analysis used during and after data collection. One theme that arose during data collection was the concept of purposeful assessment. In several different interviews, Soñia and I discussed the meaning of purposeful assessment. Soñia and I disscussed a critical classroom event during one after school debriefing session. The reflections that Soñia' shared with me that afternoon caused her to modify her teaching plans for the upcoming day. This event signaled the emergence of

[1] The participant is not the second author. The second author is the advisor to the 1st author.
[2] Psydonyms are used in place of all teacher and student names.
[3] It was not the same university connected with the ABSBS project.

another theme. In essence, a combination of grounded theory and ethnographic evaluations were used in data analysis. Additionally, data from interviews, field notes and reflection journals was triangulated to support the validity and reliability of the priliminary analysis.

Limitations

The uniqueness of the research site makes this study both interesting and limiting. I have not worked with or visited an elementary science classroom in the United States where close to 75% of the students live with parents who are practicing scientists with upper level science degrees. As with most case studies, the value in this one lies in the reader's ability to make her/his own connections and identify appropriate applications to their own research or teaching. Additionally, it may be difficult for many readers to relate to a bilingual classroom environment set against the backdrop of a developing country.

Secondly, for three consecutive months prior to this study I was involved in the daily routine of teaching in Soñia' classroom. We shared many ideas about science teaching before the study began. This sharing may have influenced Soñia actions as well as predisposed me to certain themes. Additionally, knowing some of Soñia' ideas before the study may have caused me to be unaware of the need for idea clarification and explanation. I tried to eliminate these blind spots by listening to Soñia' interviews during data collection and discussing any unclear ideas in the following interview.

Lastly, two problems with the data set limited the scope and detail of the data. First, the inconsistency of data gathering opportunities created one of the biggest challenges in this study. Although Soñia agreed to teach the rock and mineral unit at least four days a week, there were several times when she went up to eight days without teaching science[4]. Additionally, she was unavailable for interviews for over two weeks during the study. This severely hampered data collection opportunities. Second, all but one of Soñia journal reflection entries were written during the last week of the study; several weeks or days after the lessons occurred. Although all the journal entries are indeed her personal reflections, the time lapse between teaching and reflecting affected the detail and depth of the reflections. Additionally, I did not get to read Soñia' written reflections during the study because they did not exist. This hampered member checking and idea clarification. I tried to combat this by using the interviews for this purpose.

Discussion

During preliminary analysis many interesting findings about one teacher's science assessment practices with bilingual/biliterate (Spanish-English) students arose from the data. In regards to assessment tools, Soñia most frequently used informal, on-going assessments, such as anecdotal notes on individual students. In one of our beginning lessons, the goal of these anecdotal notes was to "see how detailed these observations were [the students' observations of rocks] and to see in which senses they relied to make their observations" (Soñia, 10/14/97-EJ)[5]. Accordingly, Soñia listed student names on index cards and recorded the descriptive vocabulary and the senses they used in observing and classifying their rocks. In note-taking format, Soñia recorded that "John-use hard, related to smell of a familiar place. Used a hearing test. Juan Carlos-Color, brightness, hard. No texture or shape. Chet-texture, smell, heavy, darker tone, shiny, temperature," (Soñia, 10/14/97-EJ). The last two note cards in this series were used to record general, whole-class assessments: "Students depend more on sight. They smell when

[4] The eight days without science reduced data collection opportunities by about 25%. Data was collected for a total of five weeks.
[5] 'EJ' signifies that the quote came from Soñia' personal reflection journal.

reminded to use other senses. None have use of hearing. Weight was not included in their observations," (Sońia, 10/14/97-EJ). It is interesting that these general assessments do not match some of the individual assessments that she made. One student used weight to describe his rocks and one student used a hearing test to describe the sound of his rock. When asked about this conflict between written data and her conclusions Soñia said that she also used her non-recorded observations to make conclusions. This was often the case in subsequent lessons. Soñia used non-recorded, oral information gathered by listening to students share and explain their ideas to make many of her whole class assessments. Interestingly, Soñia made conscious choices about when she wanted her students to share their ideas orally and when she wanted to have students record their ideas in a journal. Soñia did not, however, use students' written ideas to make her general assessments. She viewed assessment almost exclusively as data that was shared orally in class and that she recorded mentally or in her own writing, not written data recorded by students.

Although on-going assessments can be included as an integral part of a science lesson, Soñia did not include any of her on-going assessment strategies, time frames, or goals as part of her lesson plans; rather they were spontaneous assessments. When asked to define purposeful assessment (NRC, 1996) Soñia said that "purposeful assessment is assessment that is used by the teacher...to provide some type of information....If an assessment is given (to students), but not used by the teacher then it is not purposeful" (Soñia, 11/97-I)[6]. It was "the attention you give to the information you gather [that] is the important thing. It doesn't matter which many ways you can gather information. If it is there and you don't interpret it and use it for the benefit of your children it's just going to be information [i.e. not assessment]," (Soñia, 12/1/97-I). When asked if assessment had to be planned ahead of time to be purposeful Soñia replied "Assessment can be [created or conducted] on the spot or planned ahead of time but it all depends on how you use the data" (Soñia, 12/1/97-I). Soñia was firm in asserting that the purposefulness of a assessment in science was defined by how or if the teacher used it, rather than if it was formal or informal, planned or spontaneous, summative or on-going assessment. Purposefulness was tightly framed by the action of using the assessment data rather than the construction or intent of assessments.

Soñia' idea of purposeful assessment was closely connected to the ways she used the data from her assessments: "What you need to do is take whatever you can find and get from your students and then try to interpret and then make your instructional decisions for there to reteach, move forward, to stop, to do something else and that's what I feel is purposeful assessment" (Soñia, 12/1/97-I). One of Soñia' central uses of assessment was as a tool to inform her teaching strategies. After one class period focused on rock hardness testing and classification, Soñia reflected on some of the confusion she noticed during group work time. She had "a group that mixed step 2 and 3 of the process[7] and did not scratch all of the samples for the penny test. I also felt that some were confused between a scratch and a streak. I tried to use *rayon*[8] and *ralla*[9] to make this clear for them, and even if some of them got it I feel the goals of the activity were not completely reached," (Soñia, 11/25/97-EJ). It was apparent to her that most students did not understand the testing procedure that she had outlined for classifying rocks and minerals according to hardness. In response, Soñia committed to "try to reteach tomorrow using a more organized way of working to help them," (Soñia, 11/25/97-EJ). That evening she developed a graphic organizer that she used during her next lesson to help students organize their testing

[6] 'I' signifies that the quote came from an interview.
[7] A process for classifying the hardness of a controled set of rocks. Soñia wrote the hardness classifying process on the chalk board.
[8] Streak (in Spanish).
[9] Scratch or scrape (in Spanish).

procedure. Soñia drew this graphic organizer on large chart paper and placed in the front of the classroom so everyone could have access to it. Soñia felt that "this helped the students. They were able to go and check where they were supposed to be working [regarding their hardness testing procedures] and they kept coming to check it [the graphic organizer]," (Soñia, 11/26/97-EJ). Soñia used her informal, on-going assessment data to inform her teaching strategies. She modified her teaching plans to meet the needs of the students. Her focus on listening and observing students during work time and interpreting these actions lead to new, more effective teaching and learning strategies. In Soñia classroom, one of the most powerful uses of "purposeful assessment" is as a tool to indicate needed changes in teaching strategies and methods.

Implications and Conclusion

This study has the potential to inform science educators regarding the challenges of using informal, on-going assessment in bilingual and non-bilingual elementary science classrooms. Additionally, this study revealed some of the challenges of meeting the learning needs of bilingual/biliterate students in science. Identifying these challenges could help science educators modify their assessment practices and teaching strategies to more appropriately meet the needs of their bilingual/biliterate elementary students.

Yager and Penick (1983) have suggested that a variety of issues regarding teachers' limitations can contribute to a general lack of science literacy. Many teachers may have limited experience working with bilingual students and be unaware of their unique science assessment needs. Their limitations may cause bilingual students to feel excluded or misunderstood; trying to learn science with teachers and students who may not understand or accept their science ideas. Helping elementary teachers identify, plan, and use assessment practices that inform teachers when they need to modify their teaching strategies can contribute to science learning that is accessible and supportive to all students.

Science for all (AAAS, 1989) is a goal that all science educators are trying to achieve. More studies that a) address the science assessment needs of bilingual or multicultural students and b) reveal useful and inclusive science assessment practices for teachers with bilingual or multicultural students, need to be conducted before we can say that we have truly created a science learning environment for *all* students.

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PROJECT "GETTING UP TO SPE-ED": PRELIMINARY FINDINGS

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Project Overview

In the Spring of 1998, the project authors received a college of education research grant to assess preservice teachers' attitudes toward the placement of students with disabilities in inclusion classes. An attitude toward inclusion instrument was administered to participating students enrolled in teacher-education courses. A baseline of data regarding students' attitudes was obtained and analyzed. Then the authors facilitated a two day summer workshop for faculty involved in the training of the preservice teachers. The workshop focused on current information regarding special education policies and teaching/assessment strategies effective for students with disabilities included in the regular classroom. Special education resource persons, to include classroom teachers, a principal, and a parent, conducted the training. During the workshop, revisions to existing Core courses (beginning education courses) and (subject area) methods courses to reflect the workshop themes took place. These revisions were put in place in the fall, 1998 term. At the end of the fall term, 1998, students enrolled in teacher-education courses were given the attitude toward inclusion instrument. The authors want to determine any changes in students' attitudes overall following the faculty enhancement workshop and course revisions.

Goals

Project "Getting Up to Spe-ed" contains three main objectives. 1) To insure that undergraduate education students are well-versed in inclusionary practices, sensitive to the needs of students with disabilities, and endowed with skills necessary to make appropriate modifications for the diverse learners in K-12 classrooms. 2) To inform undergraduate faculty, particularly those who teach methods courses, of the latest rules/regulations and trends regarding students with disabilities and of teaching strategies appropriate for meeting the learning needs of these students within the regular classroom. 3) To revise undergraduate Core courses and courses in teaching methods to include techniques to modify instructional and assessment strategies for students with disabilities.

Rationale

Nearly 4.7 million school children with disabilities (approximately 10% of the total student population) during the 1993-1994 school year have been reported by the United States Department of Education (USDE, 1995). Many of these students receive instruction in a special education classroom, but for many the least restrictive environment is the general education classroom, a practice commonly called inclusion. Inclusion represents the belief that students with disabilities, whether or not they meet traditional curricular standards, should be integrated into the regular classroom (Friend & Bursuck, 1996).

With the current emphasis on inclusion, classroom teachers are expressing concerns about their lack of skills to meet the needs of a diverse student population. According to Goodlad and Field (1993), general education teachers view themselves as inadequately prepared to teach students with special needs. First year teachers felt their teacher preparation was ineffective to teach students with disabilities (Williams, 1990).

Thousand and Villa (1995) cite teachers' negative and faulty beliefs, teachers' misconceptions of learners, inappropriate school policies (e.g., tracking), poor administrative leadership, and resistance to change as deep barriers to successful inclusion programs. Most of these barriers could be addressed more fully in general education teacher preparation programs.

Two types of special education course work is often required for general education teachers. One course focuses on legislation and characteristics of special education students. The other emphasizes how modifications can be made to curriculum and instructional practice (Jones & Messenheimer-Young, 1989). A third type of course to include educational partnerships is advocated by Welch and Sheridan (1993). Strawderman and Lindsey's approach (1995) calls for an infusion of special education course work into existing courses; field experience with special populations, and cross-disciplinary training. The summer workshop/faculty enhancement opportunity addressed the first and second components.

Data Collection

Prior to the faculty workshop, in late April, 1998, students in sections of the targeted courses were given a test (Attitude Toward Inclusion Instrument) to ascertain the general attitudes of students toward the inclusion of special education children in regular education settings. The instrument consists of 30 questions which the respondents answer three times based on the following definitions:

1. Inclusion refers to the practice of attending the same schools as siblings and neighbors, being in general education classrooms with chronological age-appropriate classmates, having

individualized and relevant objectives, and being provided with the necessary support (e.g. special education and related services) to learn.

2. Mild/Moderate: This classification includes individuals with mild or moderate mental retardation, learning disabilities, orthopedic impairments, sensory impairments, or speech impairments.

3. Severe/Profound or Multiple Disabilities: Severe/profound includes all those students with severe mental retardation while multiple disabilities refers to a combination of impairments.

4. Emotionally Disturbed/Behavior Disordered: This category includes all those students with emotional disturbances or disorders which cause a student to exhibit behavior which may be problematic within the classroom.

The workshop, held in August, 1998, was attended by 14 faculty members. In December, 1998, students in sections of the targeted courses were given the same test as students took in the spring.

Data Analysis

Sum scores on each portion of the test given before and after course revisions will be compared to determine any change in faculties' and students' attitudes in general. Scores will be analyzed according to the age and/or gender of the respondents as well as by major, standing, and course title. Higher scores indicate a positive attitude toward including students with the identified category of disability in the regular classroom. At this time, only scores from Spring, 1998 have been studied.

Results of Analysis to Date

Females had significantly higher scores (more positive attitudes) on 'severe' than males.

$n = 205; r_{pb} = 0.138; p = .049$

There is a significant difference in relationship for all three categories and students enrolled in course, 5200:245 'Understanding Language Literacy' (mostly sophomores & juniors) and course, 5200:345 'Teaching language Literacy" (mostly juniors & seniors). The mean scores of these groups were significantly different. This difference suggests that the longer students are enrolled in the elementary education program, the more positive are their attitudes toward including special education students in regular classes.

The researchers were not surprised that there is a significant positive correlation between special education majors and categories of

'mild' n = 215; r = 0.166; p = .015 and 'severe' n = 215; r = 0.186; p = .006

'emotion' n = 215; r = 0.216; p = .002

The longer students are enrolled in the elementary education program, the more positive are their attitudes toward inclusion. There is a significant positive correlation between 'standing' (length of time in the program) and categories of 'mild' n = 170; r = 0.245; p = .001 and 'severe' n = 170; r = 0.208; p = .006 There is a significant positive correlation between 'seniors' and categories of 'mild' n = 215; r = 0.152; p = .026 and 'severe' n = 215; r = 0.151; p = .027

The researchers found one occurrence of negative attitudes toward inclusion. There is a significant negative correlation between secondary ed. majors and 'mild' n = 215; r = -0.138; p = .044

Evidence of Progress

The response of the participating faculty members to the workshop content and methods was extremely positive. Participants generated a list of recommendations to be shared with faculty in College of Education. These recommendations include: 1) an increase early-field experience in inclusion classrooms; 2) opportunities to simulate the team-teaching process; 3) class role play of interaction with parents; 4) requiring students to write lesson plans based on IEP's; 5) an increase in opportunities for faculty sharing and communication.

Some changes to course content was evidenced in faculty syllabi for Fall, 1998 courses. These modifications included: 1) the critique of an inclusion article in a language literacy class; 2) the writing of lesson plans aligned to an IEP teaching phonics and science methods classes; 3) discussion about modifying testing procedures in a math methods class.

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IMPROVING SCIENCE TEACHING SELF-EFFICACY OF ELEMENTARY PRESERVICE TEACHERS

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Introduction

Current reform in both teacher education and science education has focused on the need for improvement of preservice teacher training (APA, 1993; Blosser, 1989; Sivertsen, 1993). The National Science Education Standards (1996) includes a chapter titled "Standards for Professional Development for Teachers of Science" that emphasizes the need to prepare future science teachers who are capable of carrying out the extensive reform guidelines. In fact, "science education of preservice elementary school teachers is seen as a critical component in the systemic approach necessary to make real and lasting change a classroom reality" (Raizen, 1994, p. 7).

Recommendations for model preservice programs include: revised science courses designed for teachers that combine content and methods (National Research Council, 1996; Prestt, 1992; Yager & Penick, 1990), exposure to a variety of teaching experiences (Lunetta, 1975; Sunal, 1980) and an emphasis on improving preservice teacher attitudes regarding science teaching (Cox & Carpenter, 1989; Lucas & Dooley, 1982). One trend in preservice teacher education suggests an increase in site-based experiences in which authenticity and knowledge through action and reflection (praxis) are seen as central components. This paper will review pertinent literature and report findings associated with a study of the effects of these site-based preservice teacher experiences on science teaching self-efficacy beliefs.

Self-efficacy, a situation-specific construct, has been used in an array of studies to investigate factors that impact on preservice teachers' belief system and their sense of confidence as it relates to their ability to be successful teachers (Tschannen-Moran, Hoy, & Hoy, 1998). This study will examine the effects of a one semester site-based program where preservice teachers participated both in methods classes and in authentic classroom and school experiences. The site experiences included numerous teaching opportunities within the assigned classroom and during the methods classes. Preservice teachers received evaluations of these teaching experiences from the university cluster coordinator, methods instructor, site-based teacher and peers.

Perspectives of Site-based Teacher Education

Sykes (1997) offers a simple but important generalization: one studies education at the university and learns how to teach in a school. Accepting this claim, the need for a site-based teacher education approach is evident. Let's first contextualize the current basis of site-based teacher education within a larger frame. The dichotomy shown in Figure 1 is informative.

Figure 1. Models of Professional Education

The Traditional Approach	The Site-based Approach
* Preparation in University Settings	* Preparation Centered in Workplace
* Transmission of Knowledge Base	* Focus on Initial Teacher Competencies
* Application of Knowledge Base	* Competencies Developed through Experience and Reflection
* Supervised Practice in Selected settings	* Increased Responsibility for Districts, Schools, Teachers
* Control Vested in Faculties of Education	* Professional Development that is responsive to Teacher needs/ School needs

Site-based teacher education attempts to merge educational theory and practice through university-school partnerships. It occurs on-site and focuses on initial teacher competencies developed through experience and reflection. This also suggests that site-based administrators and faculty have an enlarged role. Berliner (1984) has suggested that professional teacher preparation programs should involve "live students to whom to teach concepts, where expert teachers can provide critiques of the lessons, and where the peers of the novice teachers and the children themselves can join in the analysis of the teaching activities that have just occurred." Freire (1982) calls for praxis, a process of action and reflection.

This paper expands the site-based premise with the following claim: the site-based approach can produce more effective beginning teachers, ones capable of identifying and solving problems through multiple effective and appropriate approaches. Let's first list and then discuss the reasons supporting this claim.

* **Authenticity:** Real settings provide a richer, more powerful context for linking theory to practice and practice to theory, developing preservice teachers'

personal repertoire of images, knowledge, and craft.

* **Educational Realism:** Real settings provide sharper, more grounded images and information about educational settings, teaching-learning transactions, and today's school children and their communities.

* **Mutual Impacts and Outcomes:** Real settings provide inductive opportunities for both universities and schools to mutually enrich each other.

* **Pedagogical Eclecticism:** Real settings provide an experiential vehicle for the examination of multiple educational theories, voices, and practices. This inclusiveness assumes multiple explanations, the whole-brain construction of understanding, and permits the selection of solutions reflectively. In this sense preservice teachers are theory builders, not theory users.

* **Multiculturalism:** Real settings provide for the expansion of teacher education into communities of children, parents, and their neighborhoods, providing the cultural and sociolinguistic dimensions that are impossible to improvise in a campus-based approach and that are critical for the understanding and remediation of school failure.

* **Collaboration:** Real settings foster networks of individuals and entities that function in many personal and programmatic (and often unforeseen) channels and dimensions.

Clearly, the advantages of a site based teacher education program are many. Benefits to the university and to the site are noted. In addition, the observation of increased self-efficacy of the preservice teachers throughout the semester is evident. This can be explained through an understanding of the theoretical framework of self-efficacy.

Theoretical Framework of The Self-Efficacy Construct

Self-efficacy, a component of social learning theory, is a psychological construct concerned with judgments about how well one can organize and execute courses of action required to deal with prospective situations (Bandura, 1977). Bandura claims that efficacy expectations are a major determinant of choice of activities, how much effort is expended, and how the effort is sustained in those activities. In Bandura's view self-efficacy is impacted by performance accomplishments, vicarious experience, verbal persuasion, and various physiological states. Unlike locus of control, the level and strength of self-efficacy seems to vary in specific situations. A complete discussion of self-efficacy is beyond the scope of this paper. The reader is directed to Tschannen-Moran et al. (1998) for a recent treatment of the literature.

Self-efficacy theory provides the educational researcher with perhaps the strongest indicators of subsequent classroom behaviors. This linkage is critical in the educational reform process in which theory is bridged to practice leading to improved educational quality and performance. Perceived self-efficacy theory has been researched in various domains from therapeutic conditions to educational settings. Results of experimental studies on therapeutic conditions have been consistent: The cognitive mechanism of perceived self-efficacy influences personal judgment about ability and competence in performing tasks. Moreover, these studies have indicated ways in which an individual's self-efficacy can be enhanced. In education, the construct of teachers' sense of efficacy has been correlated with various measures or teacher effectiveness, including classroom behaviors, attitudes, commitment and reactions to classroom problems (Ashton, Webb & Doda, 1983; Evans & Tribble, 1986).

A number of correlational studies on the efficacy of preservice teachers suggest that efficacy varies as teachers acquire skills and experience (Guyton, Fox & Sisk, 1991). However, the relation between preservice teachers and their performance has not been fully examined. Under experimental conditions of learning how to teach reading, the self-efficacy of preservice teachers has found to be influenced by the type of instruction and feedback received (Gorrell & Capron, 1990). These results offer critical evidence that the type of instruction provided in teacher education influences the preservice teachers sense of efficacy for teaching. Positive correlations have also been established between student teachers' sense of teaching efficacy and ratings by their supervisors.

Teachers' sense of efficacy refers to situation-specific expectations in which they can help students learn (Ashton, 1984). Teachers' efficacy influences not only choices of activities but also the amount of effort expended and the level of persistence in the face of obstacles. Thus, there is a clear linkage between a teachers' positive personal efficacy and student achievement. Finally, as an important component in science education reform, "science anxiety and efficacy and strategies that reduce anxiety and increase efficacy are worthy of attention in teacher education if we wish to improve the quality, quantity and success of science curriculum and instruction" (Czerniak & Chiarelott, 1990, p.55).

Methods

In an effort to assess the effectiveness of the site-based teacher education program, this descriptive study identified the factors in the site-based experiences that affected preservice elementary teachers' self-efficacy. As a situation specific construct, science teaching self-efficacy studies have been conducted to investigate factors that impact preservice teachers' beliefs and their sense of confidence as it relates to their ability to become successful science teachers. (Proctor, 1994; Tosun, 1994; Watters & Ginn, 1995).

The study used the Science Teaching Efficacy Belief Instrument (STEBI-B) to measure the preservice teachers' self-efficacy beliefs about science teaching (Enochs & Riggs, 1990). Two separate constructs were measured as defined by Bandura's theory. A science teaching outcome expectancy scale (STOE) and a personal science teaching efficacy scale (PSTE) made up the 23-item Likert-type survey. Levels of agreement with each statement varied from "strongly agree" to "strongly disagree" on a five-point scale. Acceptable validity and reliability criteria were established for the STEBI-B by the developers. (Cronbach's alpha coefficient of .90 was obtained for the PSTE scale and an alpha of .76 was obtained for the STOE scale). A follow-up questionnaire was administered to determine subjects' perceptions of the sources of efficacy and obtain open-ended comments about their field-based experiences. Finally, a sample of the population was interviewed as a cross-reference to the quantitative data.

Data Source

The study included the entire population ($n = 131$) of undergraduate elementary preservice teachers in the site-based teacher education program at the University of Houston during the fall of 1997. The 131 paired, pretests and posttests of the STEBI-B were analyzed for significance in mean score gains. The treatment consisted of a fifteen-week, four and a half day per week program in which six groups of preservice teachers undertook site-based experiences in twenty-two different elementary schools. Fifteen hours per week were given to university methods classes conducted on-site where, to varying degrees, school children, teachers, instructional materials, and classrooms were utilized by university faculty. During the remaining time (two days per week) preservice teachers were assigned to classroom teachers who served as mentors. The end of the semester culminated in teaching opportunities within the site-based classroom. Observations and evaluations of the preservice teacher were conducted by peers, the university coordinator, methods instructor and the site-based teacher.

Results/Conclusions

Results of the paired t tests yielded a t value of 11.52 which is significant at $p<.001$. The mean score gain between pretest scores and posttest scores was + 10.20. An analysis of covariance using the pretest as a covariate yielded an F value of 6.41 which was statistically significant at $p<.001$. Significant differences were found both in terms of science teaching outcome expectancy statements and in terms of personal science teaching efficacy statements. In fact, the efficacy mean gains were substantial among those reported in the science education literature (Tosun, 1994; Watters & Ginn, 1995). Results of the mean score gains in the STEBI-B by clusters are shown in Table 1. Results of mean score gains for each construct of PSTE and STOE are shown in Tables 2 and 3.

Table 1

Results Obtained from t test for Paired Samples for STEBI-B.

Cluster	N	pretest Mean	SD	posttest Mean	SD	*t*	*p*	Δ
1	17	83.82	10.85	95.82	6.91	4.78	<.001	1.11
2	22	81.59	7.48	96.41	6.47	7.08	<.001	1.98
3	27	84.63	9.25	93.89	8.74	5.02	<.001	1.00
4	23	85.08	11.33	98.78	10.05	9.20	<.001	1.21
5	22	79.36	7.84	87.14	9.31	4.31	<.001	.99
6	20	82.10	7.26	86.10	12.37	1.41	.175	.55
Total	131	82.89	9.22	93.09	10.18	11.52	<.001	1.11

Table 2

Results Obtained from t test for Paired Samples for PSTE.

Cluster	N	pretest Mean	SD	posttest Mean	SD	*t*	*p*	Δ
1	17	47.59	8.17	55.35	5.06	4.66	<.001	.95
2	22	45.27	6.11	55.95	5.14	7.62	<.001	1.75
3	27	48.81	6.70	54.67	5.99	4.05	<.001	.87
4	23	48.57	7.99	57.26	6.09	7.76	<.001	1.09
5	22	44.05	6.84	50.18	6.76	4.10	.001	.89
6	20	45.90	6.31	48.80	9.15	1.34	.196	.46
Total	131	46.77	7.12	53.78	7.06	10.67	<.001	.98

Table 3

Results Obtained from t test for Paired Samples for STOE.

Cluster	N	pretest Mean	SD	posttest Mean	SD	*t*	*p*	Δ
1	17	36.24	5.02	40.47	3.10	3.27	.005	.84
2	22	36.31	4.47	40.45	3.90	4.06	.001	.93
3	27	35.81	4.76	39.22	3.86	4.65	<.001	.72
4	23	36.52	4.50	41.52	5.27	6.70	<.001	1.11
5	22	35.32	4.03	36.95	4.73	2.08	.050	.40
6	20	36.20	4.51	37.30	5.52	1.15	.263	.24
Total	131	36.05	4.49	39.32	4.71	8.56	<.001	.73

These quantitative results were supported by interviews and written comments on questionnaires that determined the ratings for the extent of impact on self-efficacy from site-based experiences. The survey results from the questionnaire distributed at the final science class meeting were tabulated for the rating of variables by each cluster. Ten experiences were listed for the preservice teacher student to evaluate. The perceived impact on the increase in science teaching efficacy was rated from no extent (1) to great extent (5) for each experience. The results are presented in Table 4.

Table 4

Impact of Site-Based Experiences

EXPERIENCES by CLUSTER	1	2	3	4	5	6
1) Methods class assignments	4.59	4.48	4.48	4.26	3.18	2.95
2) Methods text	3.18	3.30	2.96	3.70	3.01	2.14
3) Methods class instruction	4.82	4.65	4.70	4.43	4.05	3.62
4) Methods class instructor	4.76	4.83	4.85	4.52	4.14	3.81
5) Observation of SBTE	3.76	4.39	3.78	4.04	2.77	2.29
6) Feedback from SBTE	4.06	4.30	3.63	4.26	2.91	2.05
7) Feedback from cluster coordinator	4.29	4.39	4.33	4.35	1.36	2.05
8) Teaching experience in methods class (cooperative group work, explanations,presentations, work with students)	4.81	4.70	4.41	4.30	2.95	3.43
9) Teaching experience in assigned classroom	4.76	4.78	4.11	4.70	3.50	2.52
10) Other experience this semester	4.65	4.56	4.05	4.23	2.80	2.12

Results indicated that the experiences of the site-based preservice program had a significant impact on the preservice teachers beliefs of self-efficacy. The study results show that the science teaching self-efficacy was positively impacted by the performance accomplishments of authentic teaching experiences. Additional factors that positively impact self-efficacy were also present in the site-based situation. Preservice teachers had the opportunity to observe teaching episodes of classroom teachers, the methods instructor, and peers. This observation provided the vicarious experience that Bandura credits with building self-efficacy. Finally, the feedback from the cluster coordinator and site-based teacher educator supplied the verbal persuasion and psychological states that also enhance self-efficacy. Feedback from the methods instructor, site-based teacher, peers and university cluster coordinator were mentioned as helpful and significant. The preservice teachers also noted that students reactions and enthusiasm in the science classroom encouraged them to continue to teach science in the future.

Implications

The implication for teacher educators is that this specific affective dimension can be significantly enhanced. The site-based program can provide the four factors Bandura identified as sources of information used to determine self-efficacy. The site-based experiences provide performance accomplishments through mastery teaching experiences, vicarious experiences through observation of peers and the site-based teachers, and social persuasion, enhanced physiological and emotional states from constructive feedback. The majority of these preservice teachers started the semester with a negative attitude toward teaching science, but they ended the semester with a positive view of themselves as effective science teachers in the future. In fact, when interviewed about their perceived ability to teach science in the future, one student replied, "Now I really can teach it! I've done it - I have proof that it does work - some of these techniques that we've been talking about and now I can walk in there - I know the exact steps - its incredible what this semester has done for me!"

The findings offer support for the growing trend to conduct preservice professional development education in a site-based context. This postmodern format implies that the shared power, control, and mission of university-school site-based collaborations can lead to important changes in preservice teacher education.

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DEVELOPING ACTION PLANS FOR AT-RISK OR MARGINALIZED STUDENTS

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Addressing the Needs of All Students

It is part of our task as teacher educators to make the invisible parts of teaching visible to our teacher education candidates. During class discussions and in written assignments pre-service teaches will often talk quite eloquently about meeting the needs of *all* students. This dedication to teaching *all* students appears to falter when confronted with activities that push the pre-service teachers to take ownership of situations and propose alternative actions, or when they are faced with teaching in diverse classrooms.

Education courses for general education teachers, including methods courses, often provide prospective teachers with some general characteristics of children with handicaps or students from different backgrounds. Special education courses often focus on student limitations rather than potential. This summary of characteristics without consideration for effective teaching strategies can intensify hidden stereotypes and prejudices (Kozal, 1991). Beyond experience with literature, or work with case studies that address issues faced in science classes by students with learning disabilities or physical limitations, prospective science teachers need field experiences with cooperating teachers who are known for their skill in helping each student reach their potential (American Association for the Advancement of Science, 1998). Minimal time in special education teacher education programs is devoted to science education, leaving special education teachers under prepared to teach science in resources rooms or to work with a science teacher (Lucas-Fusco, 1993). Science classes that are well structured and activity based are well suited to students with learning disabilities (Choate, 1994). Science methods textbooks often have short sections that describe various learning styles. Some authors prompt pre-service teachers to examine their expectations and how these expectations influence instructional behavior (Baker & Piburn, 1997). This is a great start, and raises the issues that teachers must address, but it often neglects to provide them with an adequate set of tools that they can use. Beginning science teachers need specific strategies and plans for meeting the needs of these students.

One of the major differences between a beginning teacher and a master teacher is that on a day when nothing seems to be going right the beginning teacher may get flustered and frustrated then start blaming the students for their inability to learn, or the district/state for having an unreasonable curriculum. Given the same set of conditions a Master teacher often switches to "Plan B" and sometimes, if circumstances dictate, to plans C, D, and E before getting frustrated or flustered. Having these backup plans and alternative approaches (both thought out and available) is one of the main differences between a novice teacher and an experienced or effective teacher. Novice teachers may be aware of the wide variety of resources available to them through their methods classes and through professional journals (Wielert & Sheldon, 1984), (Scruggs & Mastropieiri, 1994). Internet resources and articles are readily available and accessible. Awareness of options is not the biggest stumbling block that pre-service teachers face. The struggle comes in the personalization and implementation of strategies that make science accessible. Pushing preservice teachers to develop action plans for doing this is one strategy for helping preservice students make the transition from student to teacher.

The *National Science Education Standards* (National Research Council, 1996) describe six primary science-teaching standards. Three of these standards can be directly tied to the need to meet the needs of all students in a class and the need for a pro-active stance in addressing student needs. These standards are quoted below with annotations (*in italics*) of correlations to marginalized or at-risk students added by this author.

Teaching Standard A:

Teachers of science plan an inquiry-based science program for their students. In doing this, teachers

- Develop a framework of yearlong and short-term goals for students. *In special education terms these are called Individualized Program Plans (IEP's).*
- Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students. *Modifications and adaptations planned for students.*
- Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners. *Focus on what students can do, and their potential not their weaknesses.*
- Work together as colleagues within and across disciplines and grade levels. *As a science department and individual work with special education teachers and other support specialists.* (page 30)

Teaching Standard C:

Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers

- Use multiple methods and systematically gather data about student understanding and ability. *Working with special education teachers, consultants and parents to find out about students and best ways of supporting students.*
- Analyze assessment data to guide teaching. *Don't just get information, use it and modify or adapt instruction or locate support resources based on information.*
- Guide students in self-assessment. *Help students be proactive in requesting support.*

- Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makes, and the general public. *Focus on successes and benefits of inclusion, not just the dilemmas.* (page 38)

Teaching Standard D:

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- Structure the time available so that students are able to engage in extended investigations. *Arrange ample time for all students to engage in investigation.*
- Create a setting for student work that is flexible and supportive of science inquiry. *Work surfaces at multiple levels and accessible to all students.*
- Ensure a safe working environment. *Does not equal have some student excluded from lab activities, but making modifications and plans so that lab is a safe environment.*
- Make the available science tools, media, and technological resources accessible to students. *Identify and ask for support in obtaining adaptive technology (audible thermometers, Braille texts, voice-activated tools, etc.)*
- Identify and use resources outside the school. *Find out what is readily available in community for short or long term loan.*
- Engage students in designing the learning environment. *Seek student input on what they need and how the classroom can be modified to best meet their needs.* (page 43)

What is an "Action Plan"?

Action plans, as described in this paper, are these backup plans or alternative strategies written up and formalized by pre-service or novice teachers. Under the stress of the moment it is difficult for novice teachers to be able to brainstorm their options in a given situation. It is hard to keep in focus the needs of all students in a class. It becomes easy to blame students for their inability to understand and move forward. The goal of developing action plans is to help pre-service teachers move from being reactive to classroom events to proactive managers or facilitators in their classrooms. Students in this study developed action plans for addressing student needs in regards to: learning styles, gender, and cultural diversity. An action plan for classroom management is also assigned during field experiences and during student teaching/internship.

Developing action plans and presenting them to peers, cooperating teachers and faculty members can help refine these plans and develop ownership of these plans. As science educators we often ask preservice teachers to develop lesson plans and units. We do this and make it a course requirement because we know they can modify and use these plans and units in the future. Action plans represent a next step in supporting pre-service teachers prepare for their own classrooms, lesson plans and units help teachers think about issues of content and pedagogy. Action plans help them address what are often called the "invisible parts of teaching" those decisions that an experienced teacher makes on a minute by minute basis and that are woven into instruction but not always obvious to an observer or to their students. Action plans are a proactive step to address some of those issues that can place students at-risk of not being successful in science classes.

There are a few general characteristics that all action plans assigned by this author share. Specifics and framing will vary from assignment to assignment depending on the focus. The following can be used as a starting template for developing these types of assignments: a)Description of situation or rationale for need for action; b) Background information (if available); c) Identification of individuals involved.; d) Identification of available resources; e) Identification of 3-5 options.; f) Prioritization of options; g)Follow-up plans. As well as having students develop action plans that are assigned in the methods courses or during field experience it is hoped that students will take this strategy and continue to use it, possibly in less formal ways, through out their careers.

When the assignment is given and described to pre-service teachers a brief statement for the description of the situation or a sample rationale for the need for action is provided and has usually been part of the discussion for one or more class periods and students are expected to expand this to 2-3 paragraphs. A limited amount of information to get students started is provided about background information and available resources during course work and in readings. It is expected that students will talk with cooperating teachers and do some additional research prior to submitting their plans. For most action plans students are asked to bring 5 copies to class on the assigned day; one for the instructor; one for themselves and one for each of the members of their small working groups. On that day students spend a few minutes describing their plans to their peers in their group and are responsible for responding in writing to their peers plans one week later. Using this feedback and feedback from the instructor students then has one week to revise their plans. Directions given to the student for writing their action plans can be found in Appendix A. Sample action plans can be found in Appendix B. A sample rubric for grading an action plan can be found in Appendix C. These action plans, a teaching philosophy, resume, sample lessons and a unit they have developed become the beginning of their teaching portfolio which is evaluated at the conclusion of the student teaching/internship experience.

The Barriers to Developing Action Plans

In the beginning students resist doing these action plans. Time, patience and a great deal of discussion are required to help pre-service teachers clearly understand the purposes behind them, and see them as worthwhile and doable assignments. To set this up as a wonderful, exciting thing to have pre-service teachers work on would set anyone who tries this with their pre-service teachers up for frustration. The end products are worth the struggle, but classroom climate can become tense, especially during the development of the first action plan. There are some major barriers that make these types of assignments difficult for pre-service teachers. Most of these barriers are not ones that are easily or quickly addressed since they are issues of identity and role, and are often based in prior experiences or the lack of prior experience. It is one thing to say that your classroom is going to be a place where all students can and will succeed and learn, and quite another thing to make specific plans for making this goal a reality. Students will not always be able to articulate why this assignment is difficult. Providing examples or templates is helpful, brainstorming time in class and in small groups also can be helpful.

Reactive skills versus proactive skills

It is common to hear pre-service teacher start a discussion or their remarks with statements such as: "If teachers only..."; "Teacher should..."; "Teachers don't..."; "Why don't teachers just.". There seems to be little recognition in these statements that in a very short time they are about to become the teachers who they are making statements about or whom they are critiquing. In our education classes we often ask pre-service teachers to view classroom videotape or to do field experiences in schools where they analyze what is happening in the classes. The students analyze these situations in regards to topics such as: classroom management; issues around gender; multicultural perspectives; questioning patterns; assessment strategies; cooperative learning activities; content and pedagogy. So it is not surprising that as they enter methods classes they have skill in analyzing a classroom setting. Pre-service teachers often though become frustrated and feel threatened when asked or pushed to move past analysis of the situation and make recommendations for what could be done differently or subsequent to the episode observed. Preservice teachers are often quick to judge a situation as "good teaching" or "weak teaching"; they have less experience in thinking about what could or should be done differently.

Technician versus Professional

Pre-service teachers often get frustrated with education courses because they see them as hoops they must jump through, but they rarely see the relevance they have for the classroom. It is common for science methods students when asked what they hope to get from the course to write down things such as: setting up labs, making up chemical solutions, using equipment and discipline. They want to believe that there is a magic procedure out there for teaching that if they know the procedure and follow it they will be successful.

Lack of Experience

Most people enter teacher education courses feeling that they already know a great deal about teaching. After all they have been students for years. Handing students a yo-yo or other simple toy the first day of class and asking them to describe how and why it works the way it does can help student realize that familiarity with an object or process doesn't necessarily equal understanding or mastery. Most education programs try to provide pre-service teachers with a wide range of field experiences. These experiences are designed to help the student start to look at teaching from a teacher perspective instead of a student perspective. Depending on the placement, the assignment and their role during these field experiences though students may not gain the experiences needed to be able to brainstorm options and make plans.

Site Specific

The action plans shared at the end of this paper are ones that are geared toward learning styles, gender and diversity issues. Students are expected to develop two additional action plans during their methods course that are implemented and tested for effectiveness during student teaching or internship these action plans are: A classroom management plan and a professional development plan. A general plan can be developed in isolation of the school, but each school has a policy for inclusion or mainstreaming. Each school has a discipline code and set of procedures for disciplinary action and parent contact. Some students plan on returning to teach in rural settings and schools that are culturally very homogenous and are resistant to struggling with issues of diversity. Some pre-service teachers doubt the impact of socioeconomic status and are resistant to the need to address these issues. Through out our education programs we talk about the individuality of students, schools and communities and the need to take this into consideration when planning. Knowing this, novice teachers are hesitant to develop detailed plans without knowing the specifics of the setting. Pre-service teachers will often question the necessity of developing a plan prior to needing a plan and prior to getting to know their school. This concern disappears when they encounter situations where they can implement their plans.

<u>Ownership and empowerment: "The teacher emerges"</u>

Several years ago a pre-service teacher in a large metropolitan city in the southeast described to this author how he was moving from a student perspective to a teacher perspective. He was describing a tutoring experience where in the midst of working with the student he all of a sudden felt like a teacher. The young man he was working with was really struggling with understanding electricity. The diagrams in the book just didn't make sense and he felt lost in class, so he came to the after school tutoring sessions to get some help.

This experience was toward the end of his teacher education program and in the semester just prior to student teaching. He titled his journal entry "The teacher emerges." He was able to put into words what many of his peers were struggling to communicate in a variety of ways. Teaching and his role as teacher had become real to him, and he recognized that whether the student mastered the material or not rested primarily with him. How he structured and presented the material, the use of multiple-examples, and teaching strategies had a major impact on what kind of learning happened. Many pre-service teachers think that the successful completion of education courses will make them teachers. The successful completion of high school had made them college students. So it is natural that they might have the sense that if they complete their university courses they will become teachers. It is hard for students to understand that the completion of course work alone is not sufficient for becoming an effective teacher.

In most institutions specific content methods courses are taught just prior to student teaching. This provides an opportunity for students to think about and plan for what they will do when it is their class. Student teachers and interns make the transition from student to teacher but are still not anxious to take complete responsibility for the classroom or for student learning. When questioned about why they choose a certain content or way of organizing a lesson they will often defend their teaching choices or teaching style. They will say things such as: "If this were really my class I would… but I don't think my cooperating teacher would let me do that, and this is their class." Observations in first year teacher classrooms often show that the intents and goals they describe for their classrooms during pre-service education courses are not always translated into practice when they begin their teaching careers. Some authors make the claim that this happens because teachers lack the tools or skills needed to implement these changes. They know they want things to be different but they do not have a specific plan for how to do this.

Student Reactions and Feedback

As mentioned in the previous section, developing action plans rarely rates high on the fun or enjoyable list for pre-service teachers. Finding lessons or resources on the internet, teaching mini-lessons to their peers, field experiences and other course activities often rate much higher in preference. Across the year of methods and student teaching/internship, students' views about action plans usually undergo subtle changes. At the conclusion of student teaching they still may not like writing them, but most recognize their benefit. Some dynamics of students' reactions to action plans are presented below:

Confusion

When action plans are initially presented and described, students have a hard time understanding what an action plan is and why they would want to do one. They have worked in classrooms--they know that teachers don't write down action plans. They think that teachers make the decisions and structure the content intuitively. They are used to writing down or documenting what has happened in a classroom with an analysis of the situation. They have some recognition of the role of lesson plans and the need for them, but action plans often address contextual issues and they are not sure why they should write them or what they should include.

Resistance

Initial reaction is similar to the one they have when we talk about the importance of lesson plans. When they visit schools and talk to teachers about planning teachers often show them of book divided into 5 blocks and this makes up their lesson plans. When we ask students to identify rationale, objectives, materials, content outline, and assessment they and (sometimes) their cooperating teachers think they the university requires too much. In the crunch times of the semester this assignment is often viewed as an unnecessary burden.

Frustration

Once they start working on the assignment, frustration often sets in. In class they will often question: How can we do this if we don't know our classes or where our school is? The topics for action plans are ones that students have explored in multiple classes, but personalizing the information and shifting knowledge to actions is a frustrating and difficult process. Most students seek the advice of their cooperating teachers. When it comes time to share them and get feedback from peers, the list of strategies and possibilities expands and the assignment seems more manageable. It is usually the initial time they start trying to write down something that frustration is at it's highest.

Overwhelmed but optimistic

After the first action plan, most students feel like they could write one for most topics, given time to do the research. During either their methods field experience or during their student teaching/internship most pre-service teachers will try out some part of their action plan. This is when they find out if what they have proposed will work for them and with this group of students. Complete success is rare, but they usually find it fairly easy to modify and move forward. Often action plans will reflect their cooperating teachers or they represent and idealized view of schools and students. These action plans can be difficult for pre-service teachers to implement. A specific plan may not match their personality and they can't sustain it, or the complexity of the school setting is not addressed in the plan.

Even if students have limited success with their action plans by the end of student teaching/internship they see merit in having at least thought through the options. Some students take the activity to extremes and try to draft action plans for a wide variety of topics. Sometime toward the end of the methods semester or during student teaching/internship it usually starts to hit pre-service teachers about how much work and planning goes into teaching and they start to get overwhelmed. Action plans can help reduce this panic.

Instructional Issues/Concerns

Just as there are a set of concerns and range of emotions about this assignment from the students each semester, there are a series of concerns for the instructor. Most of the questions are around what topics to assign for action plans, balancing the number of action plans with other course expectations, and issues of framing the assignment and assessment. Each semester the assignment has been given slight modifications have been made in an attempt to better meet the needs of the future teachers.

Readiness issues

Pacing and timing when to assign these action plans is always problematic. Field experiences can vary greatly between students and between classes. Pre-service teachers must have started that transition from student to teacher for this assignment to make any sense. They also need a strong relationship with their cooperating teachers and/or peers to have the trust to ask for help and to take feedback as constructive and not critical.

Expectations

How detailed should these plans be is always a top question for students and a major concern for the instructor. Earlier versions of this assignment had the action plans as being a bulleted list of 8 to 10 strategies or resources that could be used and a sentence or two at the top identifying the topic. This was clear and most students found the task fairly easy. Most students started listing 8 to 10 web sites with related information. This makes a good resource list, but it was difficult for students to implement during their field experiences. There was little resistance to this assignment but also little ownership or personalization of the issue. As additional things were added to the action plan, initial resistance to the assignment has grown, but satisfaction and use of the action plans during student teaching/internship has also grown.

Evaluation

The focus on making action plans personal dictates that a rubric for assessment has to be structured to reward individuality. For an action plan to work for a teacher it must tap into the teacher's strengths and teaching styles. One plan will not work for all teachers. The plan also needs to be modified as experience is gained and with the changing student population. Some teachers will find something that works great most of the time and may not need multiple back-up plans. Some teachers are naturally aware of students who are struggling and make accommodations for them in what appears to be a seamless way. They often don't even realize that they are making these accommodations. Pointing these strategies out to them in the field can help them become more aware of what they are doing and encourages them to continue to support students. Other teachers will struggle with any student who does not share their own learning style, or can become frustrated with the student who may need additional time or the content structured in a multiple ways. For these teachers, having a plan in place to refer to can be very beneficial. Pre-service teachers will vary greatly along the continuum. Each semester, formalizing a rubric that is defensible is a challenge. A draft rubric is included in the appendix.

Another issue in assessment is the balance between evaluating the action plans individually and evaluating them as part of a teaching portfolio. The action plans are assigned individually but together with other resources becomes part of a teaching portfolio. It is the beginning of the type of documentation they will need to keep as entry year teachers, for continued certification and for national board certification. As part of a portfolio, there should be consistency between them. Since action plans are often written at different parts of the semester and year, what should be the expectation at the conclusion of student teaching/internship? Where should energy be devoted during those last weeks of teacher education program?

Future plans and goals

The use and potential of this type of assignment is something that this author continues to work on and struggle with. Feedback from pre-service teachers, cooperating teachers and administrators where these pre-service teachers take jobs has been positive. All agree that the topics of these action plans are issues that teachers need to wrestle with before they start teaching. Action plans represent one product of these reflections, even while the form for framing, explaining and having teachers formalize these action plans is under continual revision. It is unclear what other products might help foster this reflective, responsive and proactive stance toward at-risk students.

One option under consideration is student interviews. Another option is working with a special education teacher as they develop a student's Individualized Education Program (IEP).

The concern with adding additional assignments in this area is the resultant need to then drop or minimize other topics in the science methods course. It is the continued struggle of time and energy. If something gets added something else must come out to meet the constraints of time and resources.

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Appendix A. - Directions for Assignments

A complete example of the assignment is provided for learning styles. For all other actions plans the beginning prompt only is provided.

Action Plan -- Learning Styles

As science teachers we have a responsibility to teach all students. Each classroom will have students with a wide range of learning styles and abilities. How are you going to ensure that you are meeting the needs of your students? What resources are available to help you support students? "Learning Styles" is a huge category and can mean many different things to different people. To limit the focus of this action plan choose one of the following categories and address three areas in each of this categories.

A. Learning Disabilities (dyslexia, attention deficient disorder, etc.)
B. Physical Limitations (hearing, visually, or mobility impaired, etc.)
C. Gardner's 7 Intelligences
D. Your proposed category (Check with me about additional categories or interests that you have that might fall under learning styles.)

Use the following to guide your development of an action plan. This is not meant to be the way that you present your plan. Several of these items could be grouped together. How you develop your plan and present it is a personal decision, but these are the items that you will be evaluated on (see grading rubric).

- Description of situation or rationale for need for action. (Minimum of 2-3 paragraphs)
- Background information (Are there appropriate laws, regulations mandating support? Is the school or another agency providing support? Is there a school focus or school support for this area?)
- Identification of individuals involved. (Detail who is involved and what responsibility each individual has)
- Identification of available resources.
- Identification of 3-5 options for each area.
- Prioritization of options (which would you do first, second etc....).
- Follow-up plans (How are you going to that that what you have implemented is working or if you need to modify your plan?).

To get you started following here are some ideas that past students have used or thought about using:

- Write this up as a newsletter or news paper article telling the reader your plans,
- Use something PowerPoint and think of it as a presentation to a school and/or parents;
- Use a graphics program to show plan as a concept map or flow chart
- Use HyperStudio with links and buttons
- Take an existing lesson plan or unit and annotate it to demonstrate your plan

This is a time for you to integrate all the resources you have available, things such as: What you have learned about adolescent development; Learning styles; Your special education inclusion course; Course discussions; The film "How difficult can this be?"; Class materials/resources; Your cooperating teacher and other school resources.

Action Plan – Gender

It is easy to say that teachers should be fair to all students. It can be difficult to see small subtle things in classroom assignments; textbooks how we structure a lesson and even room arrangements that limit some students access to information. We have watched and discussed the film "Failing at Fairness." We have looked at textbooks and analyzed them for content and the graphics used. In previous classes you were asked to keep track of which students your cooperating teacher called on and what kinds of questions each student was asked. A very limited amount of time in previous coursework has been spent dealing with the dilemmas that homosexual adolescents face in a school environment. Each of these activities have helped build your background knowledge and helped you build skills for identifying subtle and not so subtle ways that women and men are treated in a classroom. Knowing all of this what things can you do in your lessons and as you plan your classroom to ensure that all students have access to the best type of learning environment for them?

Action Plan –Diversity

Similar to concerns that teachers have about issues of gender, issues of diversity are often subtle. Diversity can also take on a lot of different meanings depending on the context. Choose two categories from the following list or propose one or two of your own and develop an action plan that outlines how you are going to support students. For each category choose a minimum of two areas to address. This plan will be similar to the one developed for "Learning Styles."

- Culture (Middle East, Hispanic, Asian, Native American, etc.)
- Socioeconomic (lower income, homeless, urban, rural, migrant, etc....)
- Religious (Islamic, Judaism, Fundamental Christian, etc.)
- Other category or categories of your choosing (See me for approval)

Action Plan – Classroom Management

Regardless of how wonderful a teacher you may be or plan on being, or how busy or engaged you plan on having your students being, it is necessary to plan and establish some basic class rules and to have a plan in place for when a student breaks one or more of those rules. This action plan is your opportunity to think through how are you going to organize you class, arrange your classroom, and hold students accountable for their actions. This action plan differs slightly from some of the other action plans that you have developed for this course. For classroom management your action plans should include the following sections.

- Classroom map or diagram of your ideal classroom
- Class rules (including consequences if students break rules)
- Lab rules (including consequences if students break rules)
- Homework and make-up work policy
- List of individuals or categories of individuals you plan on es move from student to teacher.1colleagues, counselors, social workers, administrators, etc....) and what role you hope they will play.
- List of print or media resources that you can use additional support (i.e. Cantor, Slavin, Glasser, etc.)

Action Plan – Professional/ Life long learning

Once you leave the university and have full time teaching responsibilities it can be difficult to keep up on the changing and growing science disciplines and in the new education research. In class you have learned about the National Science Teachers Association, and other professional organizations, we have discussed and some of you have had a chance to attend some professional meetings. This action plan is designed to help you make a commitment to continued professional/life long learning. Using the following list as a starting point, identify 5 things that you plan on doing within the next year to support and build your understanding of science and teaching. Once you have identified these 5 areas also provide contact information for the organization or resource and establish a time frame for starting each activity.

- Teaching organization and related journals (you could list these as individual actions for example: Joining NSTA and joining the National Biology Teachers Association and receiving their journals could be two of your five activities.
- Science organizations and related journals (see above)
- WWW resources (spell out schedule for looking for resources and incorporating this into your classroom)
- Attendance at professional meetings (which meetings, how often)
- Presenting at professional meetings (which meetings, how often)
- Cooperative Learning
- Science Inquiry (topics, schedule, resources)
- Environmental Science
- Using technology to teach science
- Using community resources
- Write a grant to get additional resources for your classroom/school
- Graduate work

Appendix B: Sample Action Plans

Student Names have been changed.

Diversity – Kelly 1998
Learning Styles – Lee 1996
Gender – Angie 1997

*Note-- assignment and rubric has evolved so all aspects of revised assignments and rubrics may not be present in these examples.

Diversity Action Plan

Schools are a miniversion of the rest of society. Therefore, each school and each classroom will have students from a wide variety of cultural backgrounds. Teachers need to be sensitive to the diverse backgrounds that students come from, these differences need to be celebrated and used in teaching not ignored. Science is and has always been multicultural, driven by changing society and various religious beliefs. Science becomes more relevant for students when this is part of the a science classroom.

people resources: students, parents, other teachers, community members, cultural groups, museum folks, folklorists, university faculty

Media sources: PBS films and other films that show people doing science; NSTA publications and similar types of books that document science discoveries; WWW resources; museums;

Use extra material when teaching that show the contributions of other cultures and the role of society and religion on the history of science

Identify main topics in unit

Include this in class presentation -- supplimenting text

Identify cultures and religions represented in school and classroom

Research historical background -- looking speficially for contributions of multiple cultures

Ask students to do library or internet research for some topics -- doesn't have to always come from teacher

When choosing texts make sure that it doesn't just focus on white-european science

Show how science is part of everyday life and how people around the world add to science knowledge

LEARNING STYLES

Volume 1, Issue 1 November 1996

Learning Disabilities – We all have em!

Why we can't be elitists.....

L. R. Ning

4- Everyone...

Each of us learn and make sense of new information in different ways. The knowledge of this has to change the way that we think about teaching. Gone are the days that we think about teaching as filling a students head full of information. That image leaves people with the impression of teaching is that if you just give the students information they will learn it.

Some people learn really well from written word, others have to hear information, some need it in pictures, others need to do something with the information, and/or move around when then learn. Some of us need it completely silent when we are working others need background noise. There is no one way of learning that is "best" for everyone. Typical successful students can learn in multiple ways but may learn better or faster in their preferred mode.

Other students don't have that luxury. They have a hard time if material is presented in only one way. Therefore, as teachers we have to be aware of learning styles. Students that struggle or have a hard time learning material

continued on page 2

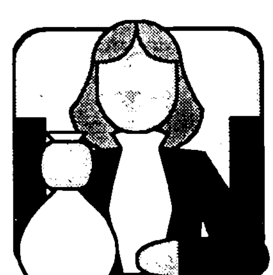
It is not courtesy – it is the law

Inclusion is here to stay

M. N. Stream

Public Act 124 mandates that all students be educated in the least restrictive environment possible. For most science teachers this means that special education students are now always going to be a part of our classes.
This law along with reforms that call for science for all means we have to rethink how we teach science. It is probably not good enough to teach science the way that most of us experienced it in high school or in college.
Most middle schools and high schools now have very active programs for mainstreaming students or have an inclusion policy. Sometimes the students are put into science classes and go to a resource room to take tests, etc.. sometimes a special education teacher works in the room with the science teacher.
It is our responsibility as science teachers to find out what our students need and work with other people to ensure we meet their needs.

INSIDE THIS ISSUE



Continued from page 1

the way it is usually taught in schools are often called "learning disabled."

There are tests that diagnose learning disabilities and help a teacher identify what some of the struggles that the student may have. In many ways those that are chosen to be tested are the lucky ones. They know what makes it hard for them to learn. The rest of us know that sometimes it is hard for us to learn but we don't know why.

As teachers it is our responsibility to structure our classes and our lessons so that all students can learn the material. We all have learning disabilities – some of us just need more help so they don't limit us.

So what can I do?

My promise to my students.....

When I find out that I have one or more special education students or students with learning disabilities in my science class I will do the following things:

- Talk to the student to see what kinds of accommodations they want.
- Consult with special education teacher to see what support is needed and what kind of support that they can provide.
- Arrange planning times with special education teacher so that they have a real role in classes they are co-teaching not just a supporting role.
- Call parents and open communication networks so that they will call me and will support the students.
- Plan lessons that use multiple skills and talents. Lessons that don't rely only on text or auditory skills.
- Use cooperative learning activities when possible.
- Have expanded class notes available for students who need them. This includes students with disabilities and students who may be ill and/or absent.

Resources – we have them, now lets use em!

Resources for working with students with learning disabilities. Resources include people, print and other sources.

People

There is a wide range of people who are available to help a science teacher meet the needs of students with learning disabilities.

Special Education Teachers can preview materials and suggest different ways of presenting curriculum.

Individual students know their strengths and limitations – they can tell you what kind of help they need and when they need it. As a teacher you just have to set the right relationship so that students feel comfortable talking to you. You also have to find times for one on one conversation so that students don't have to talk about their need for help in front of other students.

Parents know what resources and supplemental help students have had in the past and they can support students with homework and other class activities. They can also tell the teacher when a student is struggling if the student is hesitant to ask for help

Counselors can help teachers coordinate work between disciplines so that students don't get overwhelmed and facilitate communication between all parties involved

Materials

Textbooks are written at a variety of grade levels. Having print material available at multiple reading levels helps students.

Word processing software will tell the writer the readability level of materials. Use this when developing class materials.

Tape recorders allow students to tape class discussions for review at a later time.

Videotape classes for review of class discussion or procedures.

Activities

Cooperative learning groups allow students with different skills and abilities to work toether. It gives students time to ask questions and can highlight what they can do and not focus on their limitations.

Outlines of classnotes that students fill in during discussion allow students to keep up with notes.

Open-ended activities that have multiple solutions and ways of getting a solution.

he

Off to a wonderful learning experience for all students

Gender Action Plan 1997

Description of situation or rationale for need for action.

As a science teacher it is my responsibility to meet the needs of all of my students. This means that I also need to be aware of the hidden biases and attitudes that I may have about my students. As a female I originally read the gender materials and thought to myself there is no way that I would ever discriminate against girls in my science classes. Women don't do that to other women. I never thought I was discriminated against as a student – I wanted to provide that same kind of for my students. As a female science teacher I am a role model for girls in science.

During my teaching unit in my field experience and when watching my cooperating teacher (a woman) I realized that it isn't that simple. I thought these students have had a female teacher all year, and the woman's movement has had a huge impact on society that when I asked students to draw a scientists I wouldn't get the same results we read about in class. Boy was I wrong. They drew men or monsters! I also did a quick tally of my cooperating teacher and had her do one of me – keeping track of who answered questions and who was called on. Even though the class is evenly divided between boys and girls the boys had more of the class airtime.

So I'm convinced! I need a plan…

Background information
As far as I can tell there is no specific school or district focus in the schools that I have worked in dealing with gender. Mostly it is vague statements that all students need to be treated fairly and equitably. As a teacher I guess I have to figure out what this means.

Identification of individuals involved.
Me (The teacher!) – making this happens falls mainly on my shoulders. I have to keep track of how am doing at treating all students fairly and calling on equal numbers of males and females. I need to make sure that materials I use show a balance between gender and culture, etc… I have to make sure my class is a safe place for all students.

Students (especially the girls) – have to tell me when I am treating them unfairly or not giving them a chance. All students need to be able to tell the teacher what they need and when.

Other teachers – I need to share my goals with other teachers and seek their advice. Have teachers come into my class and see if I'm meeting my goals and give me suggestions.

Identification of available resources.
Print and multimedia materials
Articles in the Science Teacher, etc...
Books like "Failing at Fairness"

Identification of options for each area. + Prioritization of options
1. Develop a plan for calling on students (spinner, big dice, etc.) so calling on students is random and everyone gets called on.

2. Plan lots of cooperative learning group activities. Sometimes making these single sex groups and see if that makes a difference in how students work.

3. Posters and room displays that show women in science fields.

- Select supplemental material (including textbooks when I get the chance) that show the contributions of women in science.
-
- Each month locate and try one new strategy or use one new resource.

Follow-up plans
At the end of the year if I do all of these things my lesson plans should reflect this. I should have many different types of activities that I have tried. I should also have a collection of ideas that I could share with other teachers.

At the end of the school year I should be able to survey or have my students write about my class and all students would write about how much they learned and that science class was a good class where everyone learned a lot.

Appendix C: Sample Grading Rubric – Learning Styles

❒ Description of situation or rationale for need for action. (Minimum of 2-3 paragraphs)

- Description and rational moves beyond what was discussed in class and demonstrates integration of information from a variety of sources (including references) 10 pts.
- Description and rational based mostly on class discussions and resources but shows integration and personal reflection. 8 pts.
- Description and rational based on classroom discussion with some reflection. 6 pts.
- Description and rationale unclear or very broad. 4 pts.

Points Earned ______

❒ Background information (Are there appropriate laws, regulations mandating support? Is the school or another agency providing support? Is there a school focus or school support for this area?)

- Background information moves beyond what was discussed in class and demonstrates integration of information from a variety of sources (including references). 10 pts.
- Background information based mostly on class discussions and resources but shows integration and personal reflection. 8 pts.
- Background information based on classroom discussion with some reflection. 6 pts.
- Background information unclear or very broad. 4pts.

Points Earned ______

❒ Identification of individuals involved. (Detail who is involved and what responsibility each individual has)

- Description moves beyond what was discussed in class and demonstrates integration of information from a variety of sources (including references) 10 pts.
- Description based mostly on class discussions and resources but shows integration and personal reflection 8 pts.
- Description based on classroom discussion with some reflection 6 pts.
- Description unclear or very broad. 4 pts.

Points Earned ______

❒ Identification of available resources.

- Description moves beyond what was discussed in class and demonstrates integration of information from a variety of sources (including references) 10 pts.
- Description based mostly on class discussions and resources but shows integration and personal reflection 8 pts.
- Description based on classroom discussion with some reflection 6 pts.
- Description unclear or very broad 4 pts

Points Earned ______

❒ Identification of 3-5 options for each area.1 point per option (maximum of 15) 15 pts.

Points Earned ______

❒ Prioritization of options (which would you do first, second etc....).10 pts.

Points Earned ______

- ❒ Follow-up plans (How are you going to that that what you have implemented is working or if you need to modify your plan?).
  - Description moves beyond what was discussed in class and demonstrates integration of information from a variety of sources (including references) 10 pts.
  - Description based mostly on class discussions and resources but shows integration and personal reflection 8 pts.
  - Description based on classroom discussion with some reflection 6 pts.
  - Description unclear or very broad 4 pts.

Points Earned ______

- ❒ Presentation/organization of Action Plan 5 pts.

Points Earned ______

- ❒ Final plan reflects feedback from peers and instructor 5 pts.

Points Earned ______

- ❒ Feedback to peers for their action plans 15 pts.

Points Earned ______

Total Points Possible 100 Points Earned __________

THE RELATIONSHIP OF SCIENCE TEACHING SELF EFFICACY AND OUTCOME EXPECTANCY TO THE DRAW-A-SCIENCE-TEACHER-TEACHING CHECKLIST

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One concern of science educators is the beliefs of preservice science teachers toward science teaching. Consequently, the goal of developing positive beliefs in preservice teachers emerges frequently in science education courses and programs. Studies have indicated that, particularly at the elementary school level, low comfort levels toward science and/or science teaching tend to lead to the sporadic teaching of science, the teaching of science during inadequate blocks of time, or the omission of science instruction from the school day (Finson & Brewer, 1994; Riggs & Enochs, 1990; Wislon & Scharmann, 1994; Koballa & Crawley, 1985).

In science teaching contexts, self-efficacy is an individual's belief that one has the ability to effectively perform science teaching behaviors (called personal science teaching efficacy) as well as one's belief that his/her students can learn science given factors external to the teacher (called science teaching outcome expectancy) (Ramey-Gassert, Shroyer & Staver, 1996).

When teachers have low self-efficacy, their teaching tends to be characterized by authoritative, teacher-centered roles with a less clear understanding of the various developmental levels of their students. Rubeck and Enochs (1990) reported that teachers who were weak in content background tended to have significantly lower personal efficacy than did teachers with strong content backgrounds. In contrast, teachers with high self-efficacy tended to teach in way characterized by the use of inquiry approaches, more student-centered thought, beliefs that they can help any student overcome learning problems and succeed, and were more knowledgeable of their students' developmental levels. One logical conclusion is that the way preservice teachers view themselves and their roles in a science teaching context is at least partially derived from their self-efficacy.

The attitudes students possess with respect to science may also be related to the ways they perceive themselves in the role of being a scientist. Yager and Yager (1985), for example, found that if the work in which scientists engage is viewed as being unpleasant, then one's perception of a scientist (or the prospect of becoming a scientist) becomes more negative. Investigations into the perceptions of scientists have occurred for decades, with a notable early study being Mead and Metraux's work in 1957. Their work led later researchers to examine elements of students'

perceptions which could be classified as stereotypical (Chambers, 1983; Schibeci & Sorensen, 1993; Ward, 1977). The elements of one's perceptions about scientists are revealed through drawings one makes of a scientist. These stereotypical elements were refined by Chambers (1983) in his Draw-A-Scientist Test and later organized into a quantifiable checklist (the DAST-C) format by Finson, Beaver and Cramond (1995).

Thomas and Pederson (1998) reasoned that since students' drawings reveal much about their perceptions of scientists, drawings might also reveal students' perceptions about themselves as science teachers. In their work, Thomas and Pederson began with the DAST-C and revised it to include elements they judged to be characteristic of science classrooms and science teachers, calling the instrument the Draw a Science Teacher Teaching Checklist (DASTT-C). Through a collaborative effort with over a dozen science educators, the DASTT-C was further revised and refined.

This presentation will report the results of an investigation into the possible relationship between one's self-efficacy beliefs and perceptions of self as a science teacher.

Methodology

Sample

One hundred thirty-five preservice elementary teachers were utilized in this study. Students were enrolled within science methods courses at either a Midwestern or southern California university.

Instrumentation

During the first course period, students completed two instruments–the Science Teaching Efficacy Belief Instrument, STEBI-B (Enochs & Riggs, 1990) and the Draw-A-Science-Teacher-Teaching Checklist.

Within this study, reliability for the 13 item self-efficacy subscale of the STEBI-A was 0.89. This scale measures preservice teachers' beliefs in their ability to teach science. The alpha for the 10 item outcome expectancy scale was 0.78. This scale measures preservice elementary teachers' belief in that students can learn, given effective teaching. Both scales are based upon the social learning theory of Albert Bandura (1982) and the measurement work of Gibson and Dembo (1984).

The Draw-A-Science-Teacher-Teaching Checklist (DASTT-C) is a newly developed instrument. Its format and implementation is reported here. The DASTT-C utilized within this study is based upon the work of Thomas and Pederson (1998). This version consists of two-pages. The first page is for subjects to make their drawings and includes a square in which the drawing is to be made. Other information at the top of this page solicits demographic information, such as whether the subject is an elementary or secondary teacher, gender, and so forth. The second page is the checklist itself. The checklist is divided into four sections: teacher, students, environment, and relevant captions/non-prompted comments/other.

The teacher and student sections are subdivided into items dealing with "activity," "position," and "attitude/expression." The teacher activity subsection lists types of activities or actions the teacher might be typically performing in the science classroom (lecturing, using visual aids, etc.). The position subsection notes the teacher's location in the classroom and his/her posture. The attitude/expression subsection notes whether or not the teacher is happy or smiling. The student subsection on activity lists types of student activities typically present in the classroom, such as watching and listening and doing seat work. The student subsection on position notes whether or not students are arranged in rows, and the attitude subsection notes whether students appear to be smiling (happy). An additional part to the student section is for the gender of students to be noted.

The "environment" section of the checklist lists circumstances under which science instruction occurs, such as whether the instruction is indoors; how the teacher's and students' desks are arranged; the presence of laboratory materials/equipment on desks and tables; symbols of science, math, technology, etc.

The last section of the checklist allows the user to make note of any relevant captions which are present on drawings, including formulae, labels, explanations or descriptions subjects included with their drawings, and user comments.

Each of the first three subsections can be scored separately, and the subtotals are added to derive an overall DASTT-C score. The range of possible scores for the teacher subsection is 0-9, that for the students' subsection is 0-5, and that for the environment subsection is 0-9. The total range of possible scores for the checklist is thus 0-23.

A subgroup of ten student drawings, randomly selected, was used to determine inter-rater reliability for the DASTT-C in this study. The three authors separately scored the drawings and report the reliability to be $r = 0.733$.

Analysis

The following variables were selected from the DASTT-C and checked for individual correlation with the two subscales of the STEBI-B:

- Teacher demonstrating/handling/manipulating objects,
- Students conducting hands-on activity,
- Environment inside, and
- Environment includes symbols of science.

Additionally, a qualitative analysis of five to seven subjects' drawings was completed for each of high and low self-efficacy and outcome expectancy areas. Selections were made from those subjects who scored two or more standard deviations above or below the STEBI-B subscale means. The four subgroups' drawings were reviewed for patterns related to included or excluded variables.

Results

Table 1 reports the descriptive statistics for the two subscales of the STEBI-B. Table 2 depicts Pearson Correlations for each of the four selected dichotomous DASTT-C variables and the self-efficacy and outcome expectancy subscales. Self-efficacy was significantly and negatively correlated with an inside environment ($p = .027$). Outcome expectancy correlated with the three variables teacher demonstrating or handling objects, students conducting hands on activities, and an environment including symbols of science.

Table 1
Descriptive Statistics

	N	Min. Score	Max. Score	Mean	Std. Dev.	Reliability
Self Efficacy (13 Items)	148	13	65	47.95	7.31	.89
Outcome Expectancy (10 Items)	135	10	50	35.51	5.03	.78

Qualitative review of the high and low efficacy and outcome expectancy pictures revealed the following trends in the four categories:

High Self Efficacy

All five of the high efficacy teachers included captions within their drawings. Four out of the five included captions which specifically outlined teacher and student actions which portrayed experimentation and/or activity with objects.

Table 2
Correlations Table

	S. Conduct	Inside Env.	Sym. Of Science	Self Efficacy	Outcome Expectancy
T. Demonst.	0.084	-0.061	0.318	-0.004	0.152
S. Conduct.		-0.005	0.222	-0.008	0.201
Inside Env.			0.125	-0.166	0.058
Sym. Of Sci.				0.094	0.134
Self Efficacy					0.181

$N = 135$

Low Self-Efficacy

All low efficacy drawings but one included questioning looks and/or comments from the teacher and/or students. Only one of these drawings included a group arrangement. Four of the five depicted the teacher as the central figure with students either absent or watching.

High Outcome Expectancy

No obvious patterns were evident within the drawings of high outcome expectancy people.

Low Outcome Expectancy

Six out of the nine drawings of the lowest outcome efficacy subjects did not picture students.

Discussion

The relationship of self-efficacy to drawings which were not picturing an inside classroom seems appropriate. One might expect those who have higher self efficacy to be willing to use the outdoors as a setting for their students' science learning.

It was interesting to note that those highest in self-efficacy were very likely to include captions which explained the teacher and student behavior. This supports the theory's notion that

those with self-efficacy believe in their own ability to teach. While not prompted to include captions, these teachers were willing to add an explanation which focused on the steps of their pictured lessons. Contrarily, low efficacy teachers were more likely to include the expected questioning looks or comments from themselves or their students. Additionally, these teachers typically did not picture groups and they illustrated themselves as the central figure. This is consistent with past research which suggests that teachers low in self-efficacy are less likely to utilize groups.

Outcome expectancy's relationship to teachers' and students' use of materials supports the notion that those who believe that student learning is possible might also be more likely to utilize teaching strategies which allow students more variability in their classroom behavior. In other words, these teachers might be more apt to relinquish some of their own control of the classroom since they trust that students can learn.

When one considers the inclusion of symbols of science as also related to outcome expectancy, an additional proposition might be offered. Perhaps teachers highest in outcome expectancy are more likely to put great effort into their teaching which would result in drawings with more elaborate activity-based drawings with pictured symbols of science to support student learning. If a teacher believes that students are more likely to learn given effective teaching, they might be more likely to define teaching as going beyond a minimalist approach to teaching which might simply picture a teacher at the head of a class.

An interesting finding of the qualitative review of the drawings is that those low in outcome expectancy tended to not include students. This tendency supports the definition of outcome expectancy in that those who do not harbor this belief might dismiss the role that students play within the learning process. Teachers with such beliefs might perceive the science classroom as a teacher conducting a lesson with little recognition of the role that students play within the learning process.

Conclusions

While this study reveals a limited amount of support and explanation for the theory of self-efficacy and outcome expectancy, further development of the DASTT-C will better enable researchers to investigate the relationship of pictured classroom factors to science teaching self-efficacy and outcome expectancy. Additionally, this measure could prove to be a helpful assessment of preservice science teachers.

Specifically, the DASTT-C might better define its purpose and meaning. For example, should one utilize the DASTT-C as a pre/post assessment of the students' in a science methods course, what would the total of subscores indicate? Does a higher score truly indicate that there has been a change in students' perceptions over the course of the methods class?

Additionally, in utilization of the DASTT-C, these researchers found that some variables were difficult to score and not easily distinguishable from others. For example, almost all pictured teachers appeared to be leading and in charge. It was difficult to determine if teachers were lecturing, discussing, or giving directions except when the artists had included captions which noted what the teacher and/or students were saying and/or doing.

Investigation of preservice teachers' self-portraits is of value to, at the very least, science teacher educators and their students. With further refinement, the DASTT-C can increase its value to research in the field of science teacher education.

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AN ONLINE INQUIRY INSTRUCTIONAL SYSTEM FOR SCIENCE EDUCATION

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An instructional system may be defined as an arrangement of resources and procedures used to promote learning (Gagne, R., Briggs, L., & Wager, W., 1992). The Dick and Carey (1990) systems approach model for designing instruction is the most well-known systematic instructional design model. Traditional systems approach to instructional design by itself is not compatible with the concept of inquiry-based learning required in an online learning environment. The weakness of the systems approach for instructional design becomes apparent when learning is not linear. Furthermore, the systems approach is being challenged by constructivist theories and models which recognize that social context, roles and relationships are central to learning (Jones, Kirkup, & Kirkwood, 1993). Non-linear development models also recognize that learning is dynamic and unpredictable and that learners can and do make their own decisions about learning tasks (Thorpe, 1995).

Reform movements in science education

New reform efforts taking place in science education today are framed by the tenets of constructivism. Constructivist theorists regard learning as an active process in which a learner constructs knowledge and understanding in an active manner through personal experience or experiential activities. Constructivism has its roots in twentieth century psychology and philosophy and the developmental perspectives of Piaget (1954), Kant (1959), Bruner (1966), and Vygotsky (1978).

Another focus of the current reform movement in science education is to develop students' ability of inquiry as well as understandings of inquiry (NRC, 1996). The national standard on scientific inquiry defines scientific inquiry as "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work"

(NRC, 1996). Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Initial ideas for an online inquiry instructional system

In response to the demand of reform efforts and the lack of an appropriate design model approach, the Carolina Coastal Science project commenced with an idea to develop a Web site that was an organized, non-linear information resource in the context of an inquiry-based constructivist learning environment. Most of the content would be original, created specifically for the site,while other material would be available via links to other sites.

One of the main goals of this project was to create an online environment for primary and secondary students of varying abilities to engage in authentic scientific inquiry including: identifying questions that guide scientific investigation, using technology to improve investigations and communications, formulating scientific explanations using logic and evidence, recognizing and analyzing alternative explanations and models, and communicating and defending a scientific argument. This instructional system was created on the World Wide Web due to the fact that the nature of hypertext mark-up language (HTML) supports a user-centered learning environment through a non-linear information landscape. Also, a Web site is not a static entity. It can be a dynamic, changing entity in ways that are simply not possible with traditional printed material. Designing effective materials for science educators that provide instructional strategies based on constructivist approaches and various uses of technology was a challenge of this project.

Another important goal of the design and development process was to create a a user-friendly interface that would make it easy for novice teachers and students to navigate within the web site. Several modes of learning and teaching strategies were chosen to be available to the users, including a role-playing simulation-debate, open-ended inquiries, guided inquiries, independent research, and cooperative group learning.

Carolina Coastal Science

The resulting Web site, Carolina Coastal Science (available online at http://www.ncsu.edu/coast), contains 5 separate areas to engage students in different types of inquiry including:

1. An inquiry simulation in which students investigate the issues concerning the fate of the Shell Island Resort and then debate the future of this and other oceanfront structures threatened by coastal erosion;
2. An interactive photojournal that students can use to construct their own set of inquiry questions to explore;
3. A section of "Inquiry Images" which can be used as whole class guided inquiry activities;
4. A "Coastal Research Technology" section that students can use to identify the scientific instruments used by oceanographers and coastal geologists to collect data;
5. An educator's guide with a variety of teaching suggestions to assist teachers with incorporating the Web site into primary and secondary school classrooms.

The Educator's Guide

The Carolina Coastal Science educator's guide offers science educators a selection of teaching suggestions for implementing the instructional system into a classroom setting. These include:

- Using the "Shell Island Dilemma" as a JIGSAW II small group learning activity. Students work together in expert groups on an information seeking task. The groups are reorganized so that an exchange of ideas and information occurs by peer tutoring.
- Using the "Inquiry Images" as a whole class guided inquiry activity. This web site area can be used to generate discussion and debate on environmental issues.
- Using the "Carolina Coastal Photojournal" and "Coastal Research Technology" sections with students who wish to follow their own learning pathways.

The educator's guide also provides additional suggestions for implementing the instructional system into primary school (Figure 1) and secondary school settings (Figure 2).

Hypertext links occur throughout the educator's guide to facilitate navigation within the web site.

Figure 1: Primary School Suggestions .

- Use the Inquiry Images for entire class discussion.

- Use the Carolina Coastal Photojournal with students to discuss similarities and differences in the amount of sand, visible waves, and plant cover between the ocean side and marsh side of the same barrier island.

- Use the Carolina Coastal Photojournal with students to identify similarities and differences among the three regions of the Carolina Coast. Have the students note the presence and absence of barrier islands, inlets, coastal rivers, and sounds.

- Use the Carolina Coastal Photojournal for students to draw their own barrier island. Have students color in sand and plants.

- Use the quicktime videos and the aerial photographs depicting the migration of Mason's Inlet from October 1989 to November 1995 to enhance the ability of students to make predictions. Students can predict the direction and speed of Mason's Inlet, the fate of the Shell Island Resort and the eventual shape of Figure Eight 8 Island.

- Use the resources from the Coastal Research Technology section to have students brainstorm ideas on what a coastal oceanographer and/or a coastal geologist does. Ask students to think about what kind of tools these scientists might use.

Figure 2: Secondary School Suggestions

- Use the Shell Island Dilemma to engage students in an inquiry simulation debate. Your students' objective is to investigate the issues concerning the fate of the Shell Island Resort and then to debate the future of the Shell Island Resort. As your students engage in the investigation, they will identify the social, political and science issues with which different stakeholders must deal. Students should place themselves into the role of one of the stakeholders and complete a "Position Statement Handout" during their investigation. A "Student Record Sheet Assessment" is provided for each individual student to complete at the conclusion of the debate.

- Use the Carolina Coastal Photojournal to have students construct their own set of inquiry questions, such as, where should a development occur on the pictured barrier islands; what are the dangers of inlet side development; and, for what reasons should barrier islands be protected from development.

- Use the Shell Island Dilemma in order for students to create a multimedia presentation such as a HyperStudio stack in which they predict the fate of the Shell Island Resort.

- Use the Inquiry Images to generate entire class discussion.

- Use the Carolina Coastal Photojournal for students to predict the best location for an ocean outfall on the Carolina Coast for sewage disposal.

- Use the Internet to locate photographs of other coastal areas in the world and compare these to the Carolina coast. Focus on the presence and absence of barrier islands, coastal rivers and sounds. Where in the world do you find other extensive barrier island systems?

- Explore the Coastal Research Technology section to identify the scientific instruments used by oceanographers and coastal geologists to collect data. Have students use Internet search engines to locate actual coastal data sets acquired with the coastal research equipment.

- Use the ROV video clips with students to identify similarities and differences between natural and artificial reefs in the waters off the coast of Wilmington, North Carolina.

- Use the Cape Hatteras Lighthouse section to develop a debate on the issue of whether or not this lighthouse should be protected. A subsequent debate can conclude with a recommendation on protecting the structure.

- Use other oceanography web sites for students to explore their own coastal research topics.

The Shell Island Dilemma inquiry simulation

The Shell Island Dilemma is an inquiry simulation, in which students investigate the issues concerning the fate of the Shell Island Resort and then debate the future of this and other oceanfront structures threatened by coastal erosion. As students engage in the investigation, they identify the social, political and scientific issues with which different stakeholders must deal. Students place themselves into the role of one of the stakeholders. Questions are used throughout the instructional system to focus student's thoughts during their exploration:

> "As you explore the resources, remember that you are in the role of a stakeholder. Think about the current North Carolina policies regarding the placement of hard structures in public trust areas such as the beach. How does the current coastal policy affect your vested interests as a stakeholder?"

Students are presented with a brief description of their stakeholder role and are then presented with a recommended list of important resources to review. The resources include authentic documents and photographs, including aerial photographs illustrating the recent history of the migration of Mason's Inlet, current photographs of the Shell Island Resort, newspaper articles, statements from coastal engineers, permit applications to construct a hard structure, and meeting proceedings from the North Carolina Coastal Resources Commission. After students review the resources, they are to prepare a statement to decide what should be the next course of action regarding the Shell Island Resort. Students present their statement in a debate to decide the future of the Shell Island Resort. Each student also completes a "Position Statement Handout" (Figure 3).

Figure 3. Position Statement Handout.

1. Is your position for or against building a hard structure to protect the Shell Island Resort?

2. What arguments support your position?

3. What other individuals, interest groups or organizations do you think would agree with your position?

4. What other individuals, interest groups or organizations do you think would disagree with your position?

5. What are some arguments against your position?

6. How would you respond to these arguments?

After students have had enough time to review the resources and prepare their position statements, a class debate is held to decide the next course of action. When the debate is complete, students take a vote on the proposed solutions and conclude the debate when a consensus of 2/3 of the class agrees on a proposed solution. A "Student Record Sheet Assessment" (Figure 4) is completed by each individual student at the conclusion of the debate.

Figure 4. Student Record Sheet Assessment.

1. List all individuals, interest groups, or organizations that were in favor of building a hard structure to protect the Shell Island Resort.

2. List all individuals, interest groups, or organizations that were opposed to building a hard structure to protect the Shell Island Resort.

3. What environmental concerns were identified regarding the issue?

4. What economic concerns were identified regarding the issue?

5. What are the short-term costs and benefits of the proposal?

6. What are the long-term costs and benefits of the proposal?

7. List the 3 strongest arguments in favor of building a hard structure to protect the Shell Island Resort.

8. List the 3 strongest arguments against building a hard structure to protect the Shell Island Resort.

9. How would you personally vote on this issue? Justify your answer.

Applying the Dick and Carey model to the Shell Island Simulation

Although this instructional system was designed to be delivered in a nonlinear environment, each stage of the Dick and Carey model was applied to the design. The Dick and Carey model was then built on with constructivist components. The following explains how each component of the Dick and Carey model was implemented with regard to the instructional design of the Shell Island Simulation:

Determine Instructional Goal

The instructional goal arose out of a need for good environmental science teaching curricular resources that align with North Carolina Department of Public Instruction instructional objectives within the framework of the National Science Education Standards. There is currently a lack of inquiry-based simulations that North Carolina secondary school teachers can use in their classrooms which pertain to real-life problems in the state of North Carolina. The instructional goal of the system is for learners to identify the social, political and moral issues that different stakeholders must deal with in a current environmental science issue - the fate of the Shell Island Resort.

Analyze the Instructional Goal

When students are performing the goal, they investigate the issues concerning the fate of the Shell Island Resort. Students take a position for or against building a hard structure to protect the Shell Island Resort. Students develop a personal view of the issue. Students also identify environmental and economic concerns of various stakeholders regarding the issue.

Analyze Learners and Contexts

Learners use technology skills to explore an online Internet resource of information and use data to construct a reasonable explanation for an unresolved issue. Students must use critical thinking skills to explore an issue which is currently unresolved. Learners take a position in their role-playing which they may not necessarily agree with. Students understand and act on personal and social interests which facilitate development of decision-making skills while experiencing science in a form that engages them in active construction of ideas and explanations. They also communicate investigations and explanations.

Write Performance Objectives

- Students will identify environmental and economic concerns which may result from building a hard structure to protect the Shell Island Resort
- Students will list the 3 strongest arguments in favor of building a hard structure to protect the Shell Island Resort.

• Students will list the 3 strongest arguments against building a hard structure to protect the Shell Island Resort.

• Students will identify all individuals, interest groups, or organizations that are in favor of building a hard structure to protect the Shell Island Resort.

• Students will identify all individuals, interest groups, or organizations that are opposed to building a hard structure to protect the Shell Island Resort.

• Students will prepare a statement to decide what should be the next course of action regarding the Shell Island Resort.

Develop Assessment Instruments

Two different assessment instruments were designed to parallel and measure the learner's ability to perform the listed objectives.

1. After students review the resources, they prepare a statement to decide what should be the next course of action regarding the Shell Island Resort. Students present their statement in a class debate to decide the future of the Shell Island Resort. Each student completes a "Position Statement Handout" which is designed to assess the stated objectives before the class debate occurs.

2. A "Student Record Sheet Assessment" is to be completed by each individual student at the conclusion of the debate.

Develop Instructional Strategy

The strategy used in the instruction to achieve the terminal objectives was to design a role-playing activity. A current unresolved issue is selected - the fate of the Shell Island Resort, which is in danger of being destroyed by the migrating Mason's Inlet. Background information is collected. A real-life scenario is then developed. Stakeholder roles of real people are identified. Student roles are developed. An online research resource is created. A debate format is selected with set time limits . A time limit of two days (assuming 90 minute block periods) is given for student research and a period of 1-2 days is required for the actual debate.

Develop and Select Instruction

The instructional materials are developed in the context of a web site called "The Shell Island Dilemma" which is a section of the Carolina Coastal Science web site. An Educator's Guide is provided which recommends teaching strategies and assessments for implementing the instructional unit. A web site was chosen as the delivery mechanism of instruction because many resources students can explore such as newspaper articles are readily accessible in an online environment.

Design and Conduct Formative Evaluation of Instruction/Revise Instruction

Formative evaluation was conducted in a small group setting with a group of primary and secondary school educators enrolled in a graduate course on instructional design and evaluation of educational materials at North Carolina State University. This group made recommendations to modify the instructional program. These included creating a specific description of each stakeholder within the instructional system and developing a "Student Record Sheet Assessment". The Shell Island Dilemma debate simulation was field tested with a 10th grade environmental

science class. Additional recommendations after the field test resulted in the creation of a "Position Statement Handout" to be used by students during their investigation.

Conduct Summative Evaluation

Summative evaluation was conducted by a marine education specialist, a coastal geologist, a university professor with expertise in curriculum and instruction, and two secondary school environmental science teachers.

Constructivist Elements

The following elements were incorporated into the Dick and Carey model to create a constructivist environment within the instructional system:

• Learning occurs with the context of an authentic learning environment in which students use real information and make decisions in a learning environment.

- Learning occurs within the context of a social experience.
- Learners are provided an experience from multiple perspectives.
- Learners are provided with experience in a knowledge construction process.
- Learners are aware of their knowledge construction process.

Conclusion

The Carolina Coastal Science web site is an instructional system defined as an arrangement of resources and procedures used to promote learning. Although the Dick and Carey systems approach model for designing instruction was designed for linear instruction, this approach can still be used as part of the instructional design and developmental process in an inquiry-based online learning environment. Creating an instructional system in an online environment promotes the use constructivist theories in student learning due to the nature of their engagement within a hypermedia environment. Although the systems approach is currently being challenged by constructivist theories and models which recognize that social context, roles and relationships are central to learning, the Carolina Coastal Science Web site illustrates that the traditional systems model continues to provide a base for the design and development of instructional systems in an online constructivist environment for science education.

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"¡COMO QUE NO PUEDO!" STRATEGIES FOR THE RECRUITMENT AND RETENTION OF HISPANIC FEMALES INTO MATHEMATICS AND SCIENCE POST-SECONDARY PROGRAMS AND CAREERS.

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Early in this century, Mexican-Americans who attempted to enter the mainstream of economic and educational attainment faced a dilemma (Garza & Ockerman, 1979). Prior to the 1960's, discrimination, especially access to education, was common. Although discrimination is no longer a major factor toward attaining economic security and education, almost a decade later institutional and cultural barriers still stifle Mexican-American minority completion of pre-college preparatory programs. Eliminating these barriers, although difficult, must be attempted to develop a new generation of scientists, engineers, and mathematicians coming from minority and underrepresented groups who are willing and prepared to enter the science, engineering, mathematics, and technology (SMET) workforce. The economic growth of the nation is dependent on the inclusion of minority and underrepresented groups into SMET careers. This report especially addresses the barriers encountered by minority females preparing to enter scientific and technological fields.

The researchers conducted the study through literature searches that focused on female recruitment and retention in mathematics and science. It also included, in its search, topics such as science and mathematics anxiety, cultural barriers influencing SMET, minority and female learning modalities, teaching methods, and intervention programs. In addition, interviews of Mexican-American youth and their teachers was conducted to provide an insight for developing best practice models for female recruitment and retention in SMET. Finally, the researchers' personal experience with programs designed to recruit and retain minority and underrepresented groups, including females, into SMET and into the teaching fields has provided a basis for postulating recommendations to those involved in developing recruitment programs.

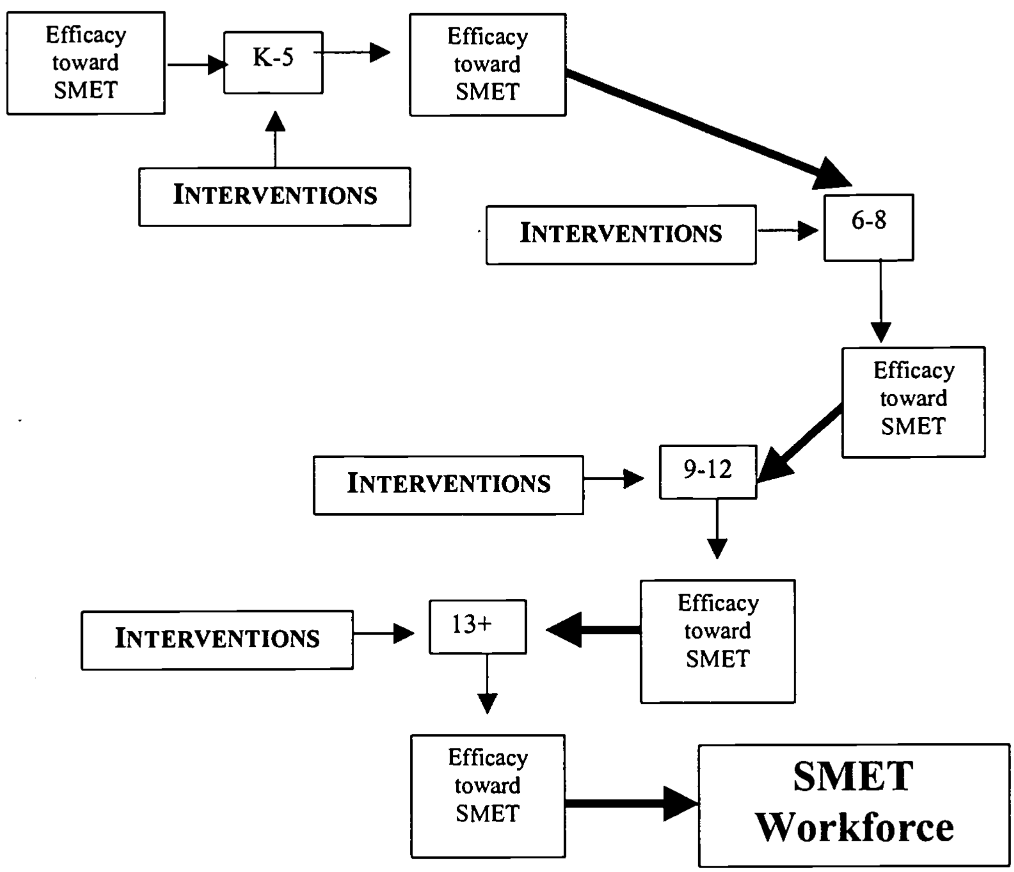
Hispanic Female SMET Career Support Systems Model

The researchers recognized that a support model for Hispanic females entering SMET programs at all levels needed development and exploration. The model presented here is still under revision and should not be viewed as our final representation of Latina recruitment and retention into SMET. The conceptual framework, at present, incorporates the attitudes and actions of Hispanic females as they first participate in recruitment interventions at the elementary school, middle school, high school, and finally the college level. Perception about future success in SMET is an underlying premise of our thoughts regarding recruitment and retention. Although academic preparation is considered a necessary attribute toward successful entry, the outcome of completing and entering the SMET workforce is a function of family and culture, science and mathematics anxiety, and support systems at the middle school, high school, and college levels. Perceptions about their ability to enter, compete in, and complete programs of study are directly tied to these factors.

The conceptual framework described in Figure 1 represents the resultant interactions of SMET interventions on academic preparation and career choice. At the national, level students, enter the pipeline as they receive support to boost or maintain their attitudes about mathematics and science (Sakai & Lane, 1996). Their belief in their ability to "do science and math" is affected by their experiences. The model represents the use of interventions that increase student self-efficacy or belief that they can be successful and able to enter the SMET workforce.

The intervention model indicates a continuum from elementary grades through to their university experience and eventually into their career choice. At every grade level

Figure 1. Conceptual Framework of SMET Intervention Model



students may receive interventions. As they receive interventions, their attitudes toward mathematics and science can be translated into a desire to enter SMET careers. In Grades K-5, children receive opportunities that increase their attitudes toward science through a variety of interventions. The Brownsville school district in south Texas provided funding between 1991 to 1994 for " Science and Mathematics Academies". The academies involved children alongside their parents or an adult learning partner in teacher-designed activities. The academies were implemented at every grade level up through high school. Students left the elementary grades with positive attitudes about science and mathematics. In the case of academies, an added benefit was the requirement of a learning partner, which resulted in the increase of active parental involvement. Interventions such as science and mathematics academies, summer programs, or weekday programs like Family Math or Family Science improved student self-concepts about their science and mathematics ability. Claire (1992) sited that these benefits can be extended to involving high school students with family members in an attempt to change attitudes about science and mathematics at home. The activities provide talented prospective SMET students with support systems that allow them to delay working immediately after high school to pursue post-secondary SMET programs.

A high number of Latina females enter middle school believing in their ability to do science and mathematics when involved in these interventions. Interventions at the elementary level, although few, increase their efficacy as they enter courses that are now offered in a middle school discipline format. If offered, students may take advantage of organizations or programs that specifically cater to them. Such programs like the Hispanic Mother Daughter Program, a program sponsored by the National Aeronautics and Space Administration, provide mathematics and science activities. During the summer, students may be involved in the Texas Pre-freshman Engineering program or TexPREP where they receive a curriculum that includes logic, algebraic structures, probability and statistics, and a variety of problem-based, hands-on activities (Berriozabal, 1993). This program is steadily becoming a national model for minority student interventions in engineering and mathematics.

During high school, organizations like the South Texas Engineering Mathematics and Science Program or STEMS, provide activities to interested students. The inclusion of females is not a focus, but Latina girls do participate. The activities include guest speakers, field trips, and enrichment activities. Guest speakers often involve Hispanic females as part of their activities. During the summer, the students participate in a program similar to TexPREP. The STEMS activities are broader in scope and include less mathematics preparation.

Schools as Barriers to Science, Mathematics, Engineering, and Technology (SMET) Career Selection

For many years educators have pondered the reasons why Mexican American students fail in school (Ockerman-Garza, 1982). New programs have been introduced in an effort to reduce the number of failures, yet this has not curbed the attrition of these students. Schools have not met their needs. Educators have failed to capitalize on the strengths of these students. Such educational attitudes have contributed to the long history of school failure by underrepresented groups.

Aside from all of the social factors faced by Mexican American students, the barriers imposed by schools may stifle Mexican American completion of pre-college preparatory programs. Some educators feel that the schools have unknowingly contributed to the pattern of failure observed in the nation's schools (Laosa & Henderson, 1993). Further, it is our belief that these barriers impede entry into post-secondary science, mathematics, and engineering programs. Thus, eliminating these barriers will develop a new generation of underrepresented scientists, engineers, and mathematicians willing and prepared to enter the science, engineering, mathematics, and technology (SMET) workforce.

The composition of schools places female students in situations where expectations are biased away from their femininity. They are often thought of by teachers and often themselves as inferior problem solvers. Further, their teachers have set lower expectations of performance in science and mathematics for this group. Research in middle school algebra has supported providing girls with environments which are less restrictive and more open to their needs (Stutler, 1997). Stutler considers that these classes should be less permeated with societal expectations of performance for these girls.

Different barriers affect the success and incorporation of students into schools. Sosa (1993) considers those barriers that impede entry into mathematics and science based on high expectations, student placement in upper level science and mathematics, increased staff development for teachers to address equity concerns, and taking an advocacy role in testing and grade retention. Of particular interest in Sosa's recommendations is the creation of an equity administrator to identify and work to remove barriers that thwart minority student success. The advocacy of minority and gender groups has suffered setbacks by anti-affirmative action legislation. However, the benefits to female students is documented by several local programs like the Hispanic Mother Daughter Program, South Texas Engineering, Mathematics, and Science Programs, and gender specific science and mathematics academies.

Bernstein (1992) focused on changes between gender in regard to mathematics anxiety as both males and females proceeded through the education system. It examined the feelings of math in students in single parent and nontraditional career preparation programs in relation to selected demographic characteristics. Survey instruments consisted of a brief math test and an attitude scale. At age 12, males felt slightly more math anxiety than females did. However, by age 14, females were more anxious about math than males and this continued up to the age of 19. Eventually both groups exhibited greater math anxiety. Males in the African-American, Hispanic, Asian, and Native American groups exhibited high levels of math anxiety, as did females in the African-American and Hispanic groups. Math anxiety was reduced by students participating in more rigorous coursework. In this study, the actions recommended for confronting math anxiety included asking math instructors to conduct a self-assessment of gender and ethnicity disparities in the classroom, starting a math club for females, and learning the visualization technique of anchoring.

Schools must present themselves as advocates for minorities and females. Learning activities and teaching methods that are more sensitive to these groups at all grade levels must be proposed as part of educational expectations. Career opportunities open to females in science and mathematics must be included in the curricular materials and discussions that occur in schools (Dobson & Hranitz, 1992).

Gender Differences in Learning Styles and Teaching Styles Appropriate for Hispanic Females in Science and Mathematics Courses

Research over the last decade has shown that males and females have different classroom experiences because they approach learning differently. Achievement expectations for females in some subjects are usually lower, as they are for members of certain racial and ethnic groups and for poor students. As girls progress through school, they are less likely to continue their math education, either taking more rudimentary courses or dropping the subject altogether (Pallas & Alexander, 1983).

Researchers continue to study the different perspectives from which males and females approach learning science and mathematics. Females prefer to use a conversational style in the classroom that fosters group consensus and builds ideas on top of each other (Ong, 1981). Males, on the other hand, learn through argument and individual activity. Most classroom discourse is organized to accommodate androcentric learning patterns. In addition, females are not likely to believe that math has utility in their lives; they see math as unconnected to a relationship model of thinking. Even if they persist in taking math courses, girls are apt to find that they don't like them, and liking the subject is key to success and possibly career selection.

Most classroom structures are supportive of white male, middle-class socialization models and are designed to foster independent non-collaborative thinking. It encourages sex-role stereotype forms of communication such as independence, dominance, and assumption of leadership, in which males have been trained to excel.

Teacher's attitudes must change in order to encourage mathematics achievement. They must understand and respect female learning styles which will help alter classroom discourse to accommodate female participation and provide a message to both males and females that no single learning behavior is greater than another.

Policy makers, science leaders, and science teachers have been searching for new ways of providing quality science learning experiences for female students (Didion, 1997). Our research supports and agrees with the following three reasons for action to address appropriate teaching methods to support Hispanic females in science and mathematics courses.

1. The demographics of K-12 science classrooms in this nation are changing. We must develop proactive models that support this change.
2. A more science literate populace is needed. Currently Hispanics in the U.S. comprise the fifth largest Hispanic population on Earth. Slightly over 30 million individuals live in the U.S. alone.
3. All students must have the opportunity to learn quality science and mathematics. Mathematics and science will be key to success in the future and every person must be able to contribute to society's improvement.

One way of providing a quality science and mathematics education for all K-12 students is through classrooms that recognize multicultural and gender concerns. The literature reveals five dimensions of multicultural education for K-12 classrooms that serve as organizers for science learning and teaching: knowledge construction, content integration, equity pedagogy, prejudice reduction, and empowering school culture (Atwater, Crockett, & Kilpatrick, 1996).

Multiculturalism is needed because of the changing demographics of this nation. In 1973, 20% of the population was a minority, whereas today, 40% of the population is considered a minority. One major problem minorities such as Mexican Americans face is the language barrier, many of them are learning English as a second language and are having a difficult time learning a new language. Science is a course that is often taught totally in English, which makes it very difficult for Spanish speaking students to learn.

This needs to change, ESL must be offered to these students so that they can have a chance to learn and participate in science activities.

Cultural differences in the classroom are becoming more apparent. One classroom can be filled with students from several cultural roots. Teachers need to be more diverse in their teaching styles, and try to explain terms and procedures to students in ways that they might understand and relate to the work or assignment.

Knowledge construction is important because knowledge in science would lead to understanding of natural phenomena acquired through a process in which students learn about scientific values, goals, assumptions, and preconceptions that have cultural meanings. Androcentric and Eurocentric pedagogies are not appropriate to Hispanic females.

Multiculturalists, feminists, and philosophers of science have challenged the traditional thinking about the nature of science. They believe that science has become problematic because its assumptions, preconceptions and limitations reflect the culture and politics of scientists who are mostly white males. The recognition of ethnic and gender contributions is not considered (Love, 1993; Shmurak & Ratliff, 1993).

Higher Education Institutions as Barriers to SMET Career Recruitment and Retention

Where the K-12 institutions may be considered as lacking, institutions of higher education fall way short of making any perceptible changes in their treatment and inclusion of Latina females. As an advocate for equal representation of all groups, Sheila Tobias writes that issues of gender equity have solutions. She believes that the barriers posed to women in the professions are preventable and curable and identifies discrimination at entry level, limited opportunities for advanced study, limited advancement, role conflict, and role socialization--lack of motivation to persist in the study of mathematics and mathematics-related subjects as barriers that have impacted female entry into SMET (Tobias, 1981). Earlier in this decade, institutions of higher education were considered to serve as a barrier into the professions for those females who have made a decision to pursue university training (McDonald, 1990). Even after considering the latest reports that note that females make up over half of the students enrolled in graduate programs and obtain the majority of masters degrees, problems with sexual harassment and future employment benefits exist (Department of Education Washington DC., 1997).

Outreach programs that support minority female recruitment are so limited in funding that many girls do not receive the benefit of recruitment and support efforts offered by institutions of higher education. In addition, the structure of universities and community colleges does not address the recruitment and retention needs of Latinas. Local initiatives that have supported females and minorities who have attained SEM proficiency will be identified and discussed later in this report. Recommendations will elaborate on initiatives that strengthen female and minority recruitment and retention [(Congress of the U.S. Washington D.C. House Committee on Science and Technology, 1982); (California State Post-secondary Education Commission Sacramento., 1988).

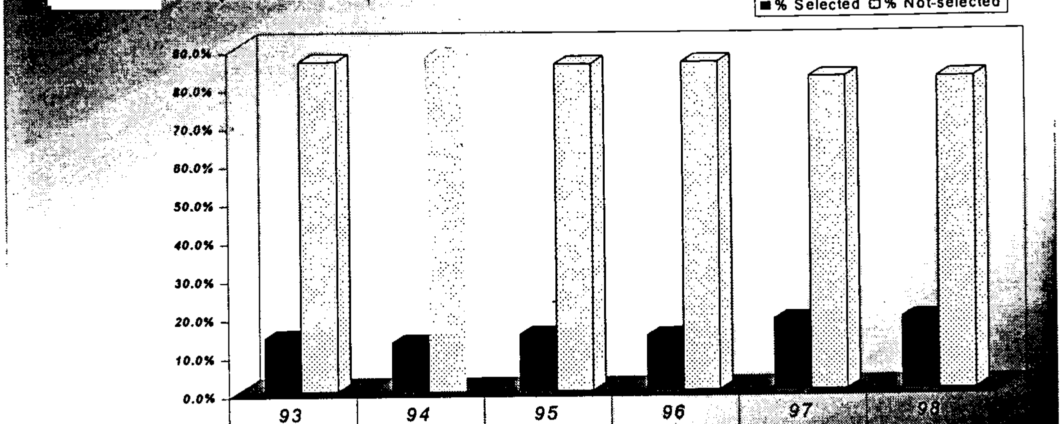
Local Results of Intervening Through Recruitment and Retention Projects. A large number of Hispanic boys and girls enrolled in public schools will unlikely pursue mathematics and science careers. Generally, the system is not established to foster SMET preparation. However, programs that approach recruitment and retention are part of initiatives in some south Texas schools and institutions of higher education. The interventions include outreach programs geared to address Hispanic females, programs to attract young, energetic, and knowledgeable students into the teaching profession, and mathematics, science, and engineering programs designed to increase access and opportunity for young Hispanics. The following are brief accounts of these programs followed by longitudinal studies of SEM proficiency and by what students and teachers claim support recruitment and retention of Hispanics into the SMET pipeline.

The Brownsville Independent School District received a $2.5 million grant from the National Science Foundation to improve science and mathematics achievement among its 40,000 K-12 student population, 97% of which is Hispanic. Teacher training, curriculum reform, policy analysis, and student activities were part of a comprehensive plan to prepare and recruit minority students into the SMET pipeline. Over the five years, school-year and summer programs provided students with activities intended to increase their participation and preparation (Ramirez, 1998). The outcomes of the study used various indicators. Of interest is the level of science and mathematics preparation of students. This outcome indicator was termed SEM proficiency. SEM proficiency was obtained when students had acquired a predetermined set of mathematics and science courses upon graduation. If a student had taken and completed a mathematics sequence that included pre-calculus and a science sequence that included chemistry or physics, then the student was labeled as being SEM proficient. Hypothetically, if a student had graduated SEM proficient then their likelihood of success in post-secondary science, mathematics, engineering or technology programs would increase.

Over the five-year period researchers noted that graduates were slowly gaining SEM proficiency. Table 1. Comparison of SEM Proficiency of BISD Graduates from

1993-1998 illustrates the increase in SEM proficiency over a five year period. In 1993, 13.9% of Brownsville ISD students were found to be proficient. By 1998, the SEM proficient had increased to 18.7%. The number is still far below the expected outcomes, but an interesting trend regarding the difference in female graduate proficiency emerged.

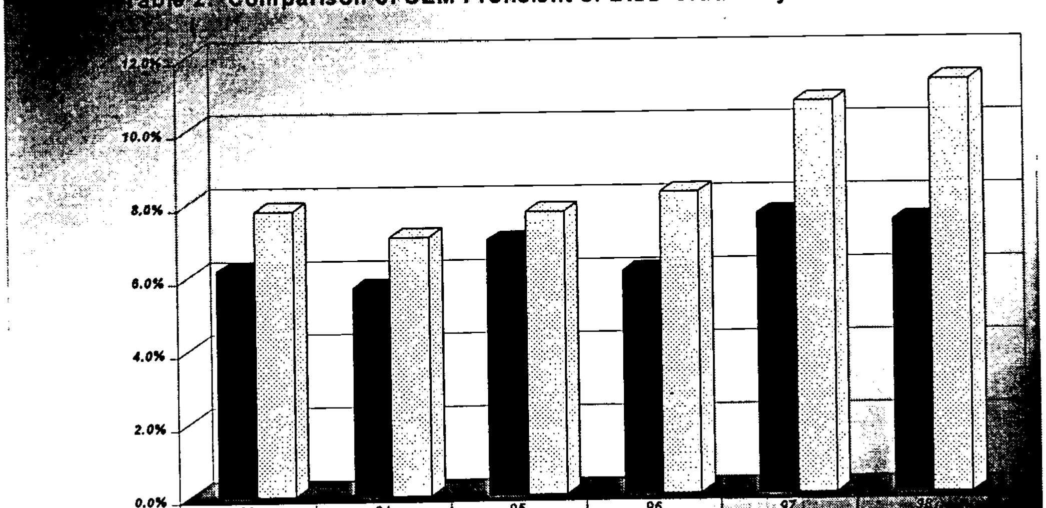
Table 1 Comparison of BISD Graduates from 1993-1998



	93	94	95	96	97	98
■ % Selected	13.9%	12.7%	14.7%	14.3%	18.3%	[illegible]
□ % Not-selected	86.1%	87.3%	85.3%	85.7%	81.7%	[illegible]

Table 2, below, compares gender differences in SEM proficiency of BISD graduates for the five year period. SEM proficiency for female graduates in 1993 were noted at 7.8%, whereas, male graduates were at 6.2%. By 1998, the SEM proficiency of

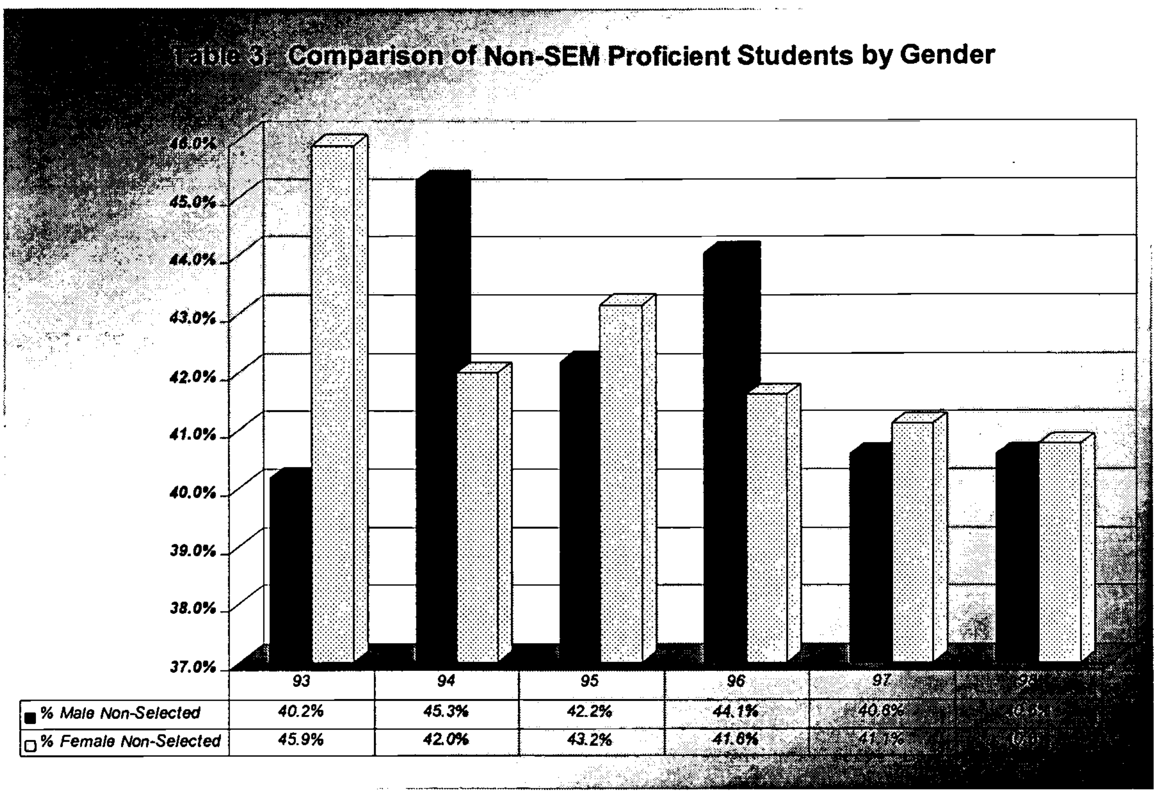
Table 2 Comparison of SEM Proficient of BISD Grades by Gender



	93	94	95	96	97	98
■ % Male Selected	6.2%	5.7%	7.0%	6.1%	[illegible]	[illegible]
□ % Female Selected	7.8%	7.0%	7.7%	8.2%	[illegible]	[illegible]

female graduates had risen to 11.3% while males had only made a 1.2% increase from the first year of the study.

From the onset SEM proficiency of female graduates was higher than their male counterparts. Table 3 below compares non-SEM proficient graduates for the five-year period by gender. In the first year of the study, the greatest disparity can be seen. As graduates participated in the NSF sponsored programs and other activities the disparity between male and females decreased.



A preliminary reason for the disparity in male and female SEM proficiency has eluded researchers. Although a causal relationship may never be discovered, the relationship between several programs that intervened during the time-period are suspected in the increased proficiency of minority females.

Some classrooms in schools may have become more female friendly. Recently, a male physics teacher provided an account of two situations that may become more commonplace in female friendly classrooms. In the first instance, he tells of two female students. The older was a senior and model Asian student who gained acceptance to the Massachusetts Institute of Technology (MIT). The teacher remembers the younger Hispanic female student explaining that if her friend could enter such a prestigious school that she would be able to enter also. The following year she joined her friend. Could it be that as female students see that they are just as likely to succeed as others before them, that they gain confidence and set goals that may be different from the norm? In another instance, the same teacher was assigned a physics class whose composition was entirely female. The students participated in laboratory activities and found that they had to rely on themselves to set up apparatus and calculate solutions to assignments. The teacher noted that in heterogeneously mixed classrooms these tasks were quickly taken by male students. Without males, the female students had to perform these tasks. The teacher insisted on not intervening when they were having difficulty. The teacher, after seeing the success of this arrangement, then structured his heterogeneously grouped classes to include homogenous, gender-based laboratory groups. Could more instances of homogenous grouping by gender have become more prevalent during the past five years? This philosophy may have been fostered later to other teachers since the teacher was assigned to coordinate and mentor school year and summer programs.

Over the past decade, many programs have influenced students, teachers, and the community. Their overall impact may be the key to changes in SEM proficiency. Further, in this case systemic factors may have been key to effect small, but significant, changes in teaching and learning which have resulted in more Hispanic females taking science and mathematics coursework.

Addressing the Need for Hispanic Teacher Recruitment in Science and Mathematics

Beginning in 1996, the University of Texas at Brownsville and the Brownsville Independent School District joined into a venture to support an intervention to attract high-ability graduates into teaching, especially teaching science and mathematics. The program was named the "Quality Student/Quality Teacher Recruitment Academy." Sixty students from all five Brownsville ISD high schools were invited into the program. The original group of students included all students from the top ten percent of the class who had declared an interest to pursue teaching.

The students were invited along with the parents to attend several workshops and information sessions together. Each session included both students and parents. The sessions included information to cope with university life both from the student and parent point-of-view, seeking and applying for financial assistance, and establishing communication between parents and students while in college. This included a session with using e-mail and chat sessions.

After the joint sessions, students and parents were separated to attend to their individual needs. The parent sessions were conducted by university experts in parental involvement and university assistance programs. The parental involvement sessions expanded financial aid, helping students cope with being away from home, and ways of supporting student independence. The sessions were received positively. Although, parental participation varied, usually one of the parents attended.

Students attended sessions provided by university personnel. The sessions included a variety of personal management and education topics. In addition, students were required to observe and take part in the instruction of younger children. The student observations were coordinated between the principals of the cooperating high school and elementary or middle school campuses. The students discussed a variety of education issues and topics during the weekly evening sessions.

The students and parents used the information from their experiences during an annual conference for teachers, community leaders, and students called the "Celebration in Teaching Conference." The students and parents were given opportunities to communicate their experiences and the value of the intervention as part of the conference. Invited guests from universities, state agencies, and local school districts were given an opportunity to actively participate as speakers and as participants in sessions given by the students.

Conclusions and Recommendations. Rosser (1997) suggested 20 teaching techniques based on research in women's studies, ethnic studies, and science education which were used as a basis for recommending interventions to address the learning styles, socio-cultural behaviors, and appropriate policy and educational arrangements which benefit and include Hispanic females in science and mathematics. She suggests that we expand the kinds of observations beyond those traditionally carried out in scientific research. Women students may see new data that could make a valuable contribution to scientific experiments. Second, she believes that the number and duration of the observational stage of the scientific method be extended. This is consistent with our thoughts regarding how hands-on experiences with various types of equipment in the laboratory may strengthen female students' confidence and understanding. We feel that female students would want to incorporate their personal experiences as part of class discussions or laboratory exercises. Teachers should key in on these experiences in both of these instances. Teachers should consider problems that have not been considered worthy of scientific investigation in the past. Although these problems may appear insignificant or trivial to male-centered thinking, women would want to explore these problems from their perspective. Further, formulating hypotheses focusing on gender as a crucial part of the question asked should be allowed exploration by females. Although difficult for traditional science teachers, there may be a need to undertake the investigation of problems from a more holistic, global scope than the more reduced and limited scale problems traditionally considered. Science teachers should also allow female students to use a combination of qualitative and quantitative methods in data gathering, along with allowing the use of methods from a variety of fields or interdisciplinary approaches to problem solving. Teachers could also use more interactive methods, thereby shortening the distance between the observer and object studied. The use of precise, gender-neutral language in describing data and presenting theories should be continually on the minds of teachers. They should also be open to critiques of conclusions and theories drawn from observations differing form those drawn by the traditional male scientists from the same observations. As was noted earlier by our observations, the use of less competitive models to practice science by structuring classroom assignments and arrangements should be practiced by teachers. Finally, teachers should place increased effort into strategies such as teaching and communicating with nonscientists to break down barriers between science and the lay person.

Science and mathematics may not appear different to males and females in others minds. However, the way we have approached teaching and learning, may gain acceptance in some circles. Teachers must consider the possibility that from an educational perspective, we must attempt all strategies that may yield success by all groups--especially Hispanic females.

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THE ROLE OF TEACHER-RESEARCHER COLLABORATION IN RESEARCH ON INQUIRY-BASED INSTRUCTION

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The purpose of this paper is to critically analyze collaborative work with teachers in the context of investigating inquiry-oriented instruction. The analysis is based on a review of empirical research and the personal experience of the author. I have engaged in extended collaborative work in four studies each of which lasted at least one year. The empirical component of this report is based on the research processes in these studies.

The objective of the analysis is to answer the question, What is the role of teacher-researcher collaboration in research on inquiry-based instruction? This question is motivated by a recent focus on inquiry-oriented instruction created by the National Science Education Standards (National Research Council, 1996).

Incorporating scientific inquiry into the curriculum and instruction is the defining characteristic of the National Science Education Standards (NRC, 1996). Implications of this position impact curriculum, instruction, and assessment. With respect to instruction, inquiry can be both a model of teaching for learning science content and content in its own right leading to specific cognitive, affective, and psychomotor outcomes. The complexity of inquiry teaching models and the sophistication of instructional objectives pose new challenges for assessment. Both teachers and science education researchers have a vested interest in understanding how to translate scientific inquiry for use in the classroom.

Background

Emphasizing inquiry as a part of reform in science education comes at a time when the focus of contemporary reform has shifted from student achievement to teachers and classroom practices. Education has been hit by repeated calls for reform over most of this century. Shulman (1989) has observed that the "first wave" of contemporary reform of schooling focused on improving achievement for all students. He described the drive for excellence, which for science education began in 1952 with the post-Sputnik era, as taking on a "classical" character by relying on standardized test scores as the major criterion variable. However, within these data were hints that the broad brush of standard scores as dependent measures missed the effectiveness of some teachers and schools and important behaviors of individual students. Thus the "second wave" of contemporary reform, which for science education began with the National Council of Teachers of Mathematics Curriculum and Evaluation Standards (NCTM, 1991), targeted teachers, classrooms, and the environment that supported the profession. Assumptions underlying more recent reform efforts, including the National Science Education Standards (NRC, 1996) and Project 2061 (American Association for the Advancement of Science, 1993), sharpen the focus on teachers by recognizing instruction as highly complex, requiring extended education and experience beyond basic licensure requirements. Extended professional education places highly skilled teachers not only in the role of student but also in the role of teacher educator and mentor (Shulman, 1989).

Researchers in teacher education and classroom teachers are following parallel courses through this second wave of reform. The complexity of classrooms and of new instructional models require a detailed look at classroom interactions. As a result, teachers have become directly involved in educational research on inquiry-oriented instruction, curriculum, and assessment thus conferring on research what Black and Wiliam (March 1998) called ecological validity. Ecological validity establishes the relevance of data collected in the classroom to the relationships among teachers, students and their physical and social environments. Tikunoff and Ward (1983) described the first wave of reform as "linear" where research, development, dissemination, and implementation proceeded with each step isolated from the next. Teachers rarely found results from this work relevant or understandable.

The paper examines in depth four studies conducted by the author. The first study (Flick, 1995) was done with a fourth grade teacher and the science learning of her students. The study specifically examined application of discussion and questioning skills, her effectiveness in integrating portions of her language arts curriculum, her use of community resources, and her integration of hands-on activities to guide learning in a science topic of which she had only rudimentary knowledge. The teacher contributed to the planning and implementation of observations. Her participation came out of her own time, there were no external funds supporting this project.

The second study (Flick, 1996) was a collaboration with all 24 elementary teachers and the principal in an elementary school in south central Washington state. The student population of the school was 77% minority, 49% had limited English proficiency, and 70% were low income based on eligibility for free or reduced lunch. The principal had charged the staff to consider ways to balance skill-oriented instruction with instruction that addressed higher level thinking. Within this context, teachers were asked to reflect on the nature of explicit instruction and examine the merits of an inquiry-based model for science teaching.

The third study (Flick & Dickinson, 1997) involved collaboration with four middle level teachers selected from a National Science Foundation program focusing specifically on inquiry-oriented instruction and the nature of science. The questions addressed by the study were rooted in the thoughts of teachers and students operating in real classrooms. Semi-structured interviews and classroom observations using high inference techniques were used to create four case studies.

In the fourth study (Flick, 1998) two experienced teachers were selected from a field of eight in a "critical case" sampling process. Teachers and their classrooms were selected not only because teachers exhibited the knowledge, skill, and intent to create an inquiry-oriented instructional environment, but also presented teaching strategies used to provide a continuous thread of inquiry across lessons.

Inquiry instruction for this analysis has been defined by statements in the National Science Education Standards (NRC, 1996) and in related criteria validated in a recent study of inquiry teaching (Flick, 1999) based on the work of Rowe (1973) (see Figure 1). Intersecting components of inquiry was a definition for instruction comprised of six components from an analysis by Anderson & Burns (1989) including (a) Instructional format, (b) Grouping arrangements, (c)

Time, pacing, and coverage, (d) Subject matter, (e) Student-teacher interactions, and (f) Task demands.

Figure 1

Criteria used to identify inquiry-oriented instruction based on Flick (1999).

Objectives for Teaching Inquiry

Problem identification - students actively examine a situation for problems to investigate or evaluate whether a given problem can be investigated in a given situation.

Information; facts; observations; data - students discuss, organize, or evaluate relevant previous knowledge (formal or informal) or observations and/or data made while investigating a situation.

Procedures; skills; design - Students describe, demonstrate, or evaluate the sequence of procedures or the design used during an investigation.

Inference; empirical relations - Students use evidence as the basis for stating relationships between variables or evaluate whether a stated relationship can be deduced from evidence.

Interpretation; explanation - Students link at least two ideas in sequence in order to explain how a system works or to compare two systems. Students evaluate an explanation based on the ideas used.

Application - Students interpret new experiences using concepts they already have or using concepts developed through instruction or students generate new examples for a concept or evaluate the application of a concept to a new situation.

Communicating - Students present results to others, share ideas or techniques.

Group Work - Students use social skills to engage in all elements of inquiry within a small group context.

Teaching practices that promote inquiry generally link segments of instruction together in order to provide opportunities for reflection, criticism, and analysis. Instructional formats must accommodate the cognitive and logistical demands created by these linkages. Teachers utilize a variety of formats from explicit instruction to open-ended discussion and investigation (Flick, 1998). The complex instructional formats have direct impact on time, pacing, and coverage. Typically more time is spend on less formal material. Pacing slows to allow for making inferences and interpretations and quickens to address specific facts and other background information. The teacher arranges the class in both small and whole group structures to afford appropriate interactions among students and between teacher and students. The task design and implementation are critical for they must foster developmentally appropriate higher level cognitive behaviors within students.

Analysis of Four Studies

Discussion of each study begins with the purpose and research questions. An analysis examines the role of the teacher-researcher collaboration.

The purpose of the first study (Flick, 1995) was to document the science instruction of a 4th grade teacher whose teacher education program of 20 years ago led to a major in teaching reading with no specific coursework in science or science education. The study focused on the planning and execution of a 31-day unit on the solar system with the teacher acting as a collaborator in the qualitative research design. The study had the following objectives:

1. Describe elementary science instruction planned and implemented by a skilled teacher whose academic training was in reading and language arts.
2. Describe teacher practice and teacher thinking as it compares to exemplary science teaching practice.
3. Identify implications for reform in elementary science education.

The collaboration involved 10 in-depth classroom observations of her, her students, and guest speakers. Discussions concerning the objectives of this study began near the start of the school year and continued through the follow-up interviews with her students and into the following school year. This study represents more than 17 months of intermittent to intense interaction around her classroom.

All six instructional components were directly determined by the teacher as part of her normal instructional sequence. The investigative work in the study involved pre and post-lesson discussions about planning and execution of lessons. The content of meetings included reflections on class observations, the conceptual focus of instruction, and the content of future lessons. Discussions addressed the following questions: (a) How does she achieve meaningful understanding of a complex topic: relationship of the earth, sun, and moon, (b) What is the role of reading, writing, and speaking in the science curriculum, and (c) How does her background influenced the preparation and delivery of the unit.

While the term "inquiry" was seldom used in teacher-researcher discourse, the investigation focused on how this teacher addressed major science education reform goals. As such, we discussed her strengths and weaknesses in subject matter and design of tasks. Of particular interest was the influence of her reading and language arts background on teaching science. Her reflections on her own abilities, plans, and execution of lessons formed major portions of the data used to interpret her instruction.

A brief example illustrate how her collaboration in the classroom research effort afforded important opportunities for understanding instruction. I suggested that students often harbor beliefs about a flat earth even when correctly expressing concepts about traveling around the earth or objects orbiting other objects. The teacher did some investigating of curriculum materials on her own and organized a debate that culminated this unit on the solar system. The demands of this task for the class were considerable and instructional formats and time had to be arranged to accommodate this activity. I interacted with the content of her instruction and her process of creating a new instructional context added significantly to the study.

The purpose of the second study was to document and interpret the thinking of elementary teachers concerning a generative learning model of instruction as they developed unit plans for teaching science (Flick, 1996). Observations focused on conflict and decision making as teachers were asked to specifically compare and contrast a particular generative learning model with an explicit teaching model prescribed by the principal. The student population included a high proportion of disadvantaged students where in many cases English was a second language. For the purpose of this report, GLM referred to generative learning models of instruction as a form of inquiry teaching suitable for elementary students. IPM referred to instructional process models of instruction representing explicit or mastery teaching. The questions for this study were:

1. What specific points of conflict do teachers perceive between GLM and IPM models of instruction?
2. In what ways do they see GLM as similar to their own teaching generally characterized as IPM?
3. What are implications for teacher education in science?

In terms of planning, all six instructional components figured into this collaborative, curriculum design process. However, in contrast to the previous study, the work of this collaboration took place almost entirely outside the classroom. The principal of the school supported the project which was made possible by a grant from the Department of Energy written by one of the second grade teachers. The grant provided release time for two, all-day, curriculum planning sessions for teachers at each of the grade levels K-5 to work together to design a unit in science. There were 12 sessions that formed the core of this study. I received a small stipend as an instructional consultant for the project.

The quality and productivity of the 12 sessions were critical for meeting the school's curriculum planning goals. Collaborative work was essential for obtaining worthwhile research data concerning teacher interpretation and use of generative and mastery learning models of instruction. Teachers needed to express themselves freely concerning their lack of knowledge, confidence, and/or skills with science content or technologies. In addition to these recordings, teachers turned in copies of their notes and drafts of unit plans. Visits were made to classrooms recommended by the principal to observe science lessons that presented a cross section of instructional approaches.

Collaboration also occurred at the level of staff-principal interactions. While not always in agreement with the principal's goals and requirements, the staff respected her guidelines recognizing her knowledge and skill as an instructional leader for disadvantaged students. I developed a collaborative relationship with the principal and consulted her frequently during the project concerning instructional format, student groupings, pacing and coverage, and task demands. The staff felt free to discuss issues of conflict and concern. I shared summaries of these discussions excluding teacher names with the principal three times during the project. Her collaboration was essential not only to the success of the curriculum design project but also central to the interpretive integrity of the research.

The purpose of the third study was to investigate how teachers initiate, conduct, and maintain a sense of inquiry as a part of instruction in science (Flick & Dickinson, 1997). Four middle level teachers collaborated in procedures for examining the alignment between instructional goals and observations of classroom teaching. The instructional goals were derived from an National Science Foundation (NSF) inservice project designed to improve teacher knowledge of science and inquiry-oriented teaching. With teacher input, we also examined what students perceived the goals to be.

Specific research questions were:

1. Are teacher intentions for instruction valid representations of recommended classroom practice presented in ISC workshops?

2. Do live and video tape observations of teaching practice align with teacher's verbalized intentions?
3. Are student interpretations of teaching practice aligned with teacher intentions?
4. Are student interpretations of teaching practice aligned with observed teaching behavior?

Semi-structured interviews and classroom observations using high inference techniques were used to create four case studies. The cases are described through the words of the teachers, the words of their students, and the reflections and synthesis of the authors.

The teachers were involved in the collaboration in multiple ways. They agreed to implement teaching that conformed to the inquiry-oriented principles presented in the NSF workshops. They also selected a topic for instruction based on curriculum presented in the NSF workshops. They offered reflections and insights into their planning and thinking through interviews before and after direct observations of instruction. Further, they participated in selecting a sample of students to be interviewed about the nature of instruction within their own classrooms. The teachers also collaborated in the design of the interview protocols used with the sample of students.

Critical elements of the collaboration involved establishing a rapport for discussing instructional formats and student-teacher interactions. This required a deep level of teacher involvement because the NSF workshops left the specifics of classroom implementation of inquiry principles up to the teacher. Through 10 to 15 years of experience, these teachers had developed a variety of teaching skills supporting sophisticated perspectives on teaching. These teachers had specific concerns about the reasonableness of implementing certain inquiry-oriented teaching principles relative to time, pacing, and coverage. These were practical concerns they faced daily and this collaboration offered a venue for expressing that thinking. The success of this study depended upon the candid reflections of experienced teachers with respect to the implementation of reforms in science teaching in the middle grades.

As with the elementary teachers in the previous study, this project also dealt with teacher knowledge in science. Inquiry takes a broader understanding of a subject area than a more didactic instructional format. Teachers had to feel comfortable enough to express concerns they had about their own developing knowledge in some cases. While the study was focused on teacher planning and teacher practice, the quality of the collaboration allowed the open exploration of other features critical to inquiry-oriented instruction such as the level of teacher understanding of science content.

The teachers needed to feel that the authors were there to make their particular classroom better for learning science and not simply for generating an evaluation study. The transcripts of teacher interviews revealed a distinct level of collegiality between researchers and teachers through the mutual expression of insights about teaching practice and discussion of personal strengths and weaknesses.

The purpose of the fourth study was to analyze the practices of two skilled and experienced middle level teachers with respect to research-based criteria for instructional scaffolding in support of inquiry-oriented teaching (Flick, 1997). The research questions were:

1. What do skilled, experienced teachers do when scaffolding inquiry-oriented instruction?
2. In what ways do they align with research-based criteria for scaffolding and inquiry-oriented instruction?

An initial observation period lasting eight weeks preceded the selection of two experienced teachers from a field of eight. These initial observations were critical to the collaboration for they afforded an opportunity not only for me to determine that I could find the type of teaching I was interested in studying, but also for the teacher to understand the nature of the study and to assess their commitment to the collaboration.

Classroom observations extended across ten weeks in one semester and an analysis of six observations with video tape support. The lack of external funding meant fewer observations and more careful planning and collaboration between myself and the teachers. An extended interview session with each teacher was audio taped to document information gained from several informal discussions that took place before, during, and after instruction.

An extended description of each teacher's practice was written to characterize instruction based on observations. Each characterization offered an analysis of instructional practices that scaffold the elements of inquiry teaching (see Figure 1). Each teacher reviewed his own description and provided input for reaching an agreement on the characterization.

The study was guided by discussions that took place around each observation. The teachers provided an ongoing narrative on what was happening, how plans were implemented or scrapped during the observed lesson, and what was planned for future lessons. These discussions were critical for understanding how the teachers guided complex instruction across time. The teachers described plans for grouping students, designing tasks, and promoting specific kinds of student-teacher interactions for scaffolding inquiry-oriented instruction.

By using insights gained directly from the teacher reflecting on his practice, I was able to develop an understanding of how constraints of time, pacing, and converge played a role in guiding the unique instructional formats of each teacher. Even though both teachers described similar structures for guiding the pace and content of the class (e.g. rapid questioning sequences with frequent student response), they each displayed significantly different types of student-teacher interactions. The meaning and purpose of these interactions were made clearer by timely observations and discussions afforded by the collaborative arrangements of this project.

Discussion and Implications

In the collaborative research described in this paper teachers did not have paid release time specifically for research purposes and I was not funded for research. I maintained my regular responsibilities at the university. The small grant in the second study (Flick, 1996) supported release time for teacher planning and my consultation but no time for research. Collaboration was important for carrying out these small-scale studies. Collaboration meant that all parties saw involvement as beneficial to their current work. Studies that speculate long-term or esoteric results may be of questionable value to full-time teachers especially if procedures take time away from teaching (Tikunoff & Ward, 1983). Conversely, the teachers had to understand and appreciate the need to invest time in discourse and other procedures designed more for the investigation of teaching than to further immediate instructional goals.

All of the studies focused on the problem of how to design and implement inquiry-oriented instruction. However, in the collaboration, the research design and final outcomes were influenced by the teachers. The study involving the fourth grade teacher (Flick, 1995) began as a study of the role of writing in learning science and evolved into a study of how a teacher primarily trained in the language arts guides classroom discourse in science. The collaboration with 24 elementary teachers (Flick, 1996) initially focused on instructional design but the teachers added objectives for teacher understanding of subject matter and the role of the principal as an instructional leader. In general, the problems were broadly defined by myself as the researcher but were influenced in each case by the needs, intellectual input, and backgrounds of the teachers. The input not only enriched the research effort and established its ecological validity, but also provided results directly usable by the teacher. For example, the fourth grade teacher (Flick, 1995) was using the flat-earth debate two years after the study was completed.

The atmosphere surrounding teacher-researcher interactions in each study was one of mutual respect. I, as the researcher, respected the teacher as a skilled professional whose knowledge in the area of study was indispensable for the conduct and outcomes of the project. The teacher(s) in turn, respected my teaching background of 12 years and viewed my knowledge in the area of inquiry-oriented instruction to be an asset to their professional development. This type of teacher-research collaborative relationship opens opportunities to explore subtle points about complex instruction. These opportunities are not purposefully created in larger studies that are dominated by externally structured research designs.

Highly structured, externally imposed research designs are important for investigating inquiry-oriented instruction. Larger studies often have more funding that buys more time and allows greater control over the study environment putting the researcher properly in a lead position for guiding the study. Such studies provide valuable information on broad, generalizable results. Externally structured studies are necessary, for example, for investigating the relationship among specific psychological constructs and their effects on learning science (Cavallo, & Schafer, 1994). Externally structured studies also generate insights for complex, longitudinal interactions among demographic variables and student achievement (Germann, 1994). As such, larger studies provide critical, albeit static, images of instruction. The aggregate data is reduced to an essence or essential model of instruction.

The role of teacher-researcher collaboration in research on inquiry-based instruction is to create a panorama or even moving picture of inquiry teaching. What the initial research question(s) miss, the teacher provides by way of commentary and criticism based on the actions of current instruction and on years of experience. The collaboration provides a venue for reflecting on teaching experience often missing in the normal working routines of teachers. A collaborative relationship also allows the researcher to comment and criticize the work of teachers in a format that not only adds to a research knowledge base but also adds to teacher knowledge and therefore to the quality of immediate teaching environment.

Guidelines for small scale collaborative research:

1. The research team minimally includes a teacher and science educator.
2. The research problem(s) may come from either member of the team, but its final expression is considered significant by both.
3. Decisions regarding specific research questions and methods start with the science educator but ultimately are a consensus.
4. From the beginning the team attends to concerns of both knowledge production and application of that knowledge to teaching.
5. The research effort is flexible enough to be sensitive to complexities of the classroom.

Strategies for implementing small scale collaborative research

1. Become familiar with the work of the teacher through several days of direct observation of the classroom over several weeks.
2. Engage in extended discussions concerning their work in order to establish areas of common interest and commitment to the project.

3. Meet regularly during the intervention or observation period to share observations and interpretations.
4. Share both theoretical and practical points of view.
5. Modify or add to the study while maintaining a common core of questions and investigative procedures.
6. Use discussions to plan ahead to the next term or next year to extend the investigation or implementation.

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A SNAPSHOT OF UPPER ELEMENTARY AND MIDDLE SCHOOL SCIENCE TEACHERS' SELF-EFFICACY AND OUTCOME EXPECTANCY

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In the last five years, many science education initiatives appear to newly emphasize (or continue emphasizing) two important issues- professional development sustained over time, and the need for summer institute attendees to share their knowledge with peers (e.g. Ohio's State Systemic Initiative, Purdue's Epicenter program, AAPT, PTRA program, Woodrow Wilson Fellowship Foundation).

During the last five years, the National Aquarium in Baltimore conducted an extensive data collection in an effort to (a) investigate the mechanism by which "master" science teachers instruct peers and (b) explore ways to optimize professional development for science teachers sustained over time. One component of the data collection involved evaluating "local" teachers who attended outreach provided by "master" teachers. The "local" teachers completed a survey during outreach and approximately 1 year later. Master teachers presented the outreach in districts throughout the United States. The "local" teachers provided data concerning self-efficacy, outcome expectancy and ethnicity as well as the approximation of their own students' economic status, geography, and ethnicity. Analysis of these data provides important guidance that educators can use to improve science summer institutes, and most importantly to better understand those science teachers who may commonly attend outreach provided by "master" science teachers, but who do not (for whatever reason) attend multiple week summer institutes. These data are very important for all those interacting with science teachers, but it is of particular importance for those involved in the planning and structuring of outreach with emphasizes "local" outreach using "master" teachers.

Data Collection

Prior to the start of each one-day outreach institute implemented by master teachers, every attending local teacher completed the self-efficacy scale of Riggs and Enochs (1990). This instrument has survey items that work together to define the two latent traits of outcome expectancy and self-efficacy. Numerous presenters at past AETS conferences reported data collected with this instrument. Local teachers supplied their names as well as their mailing address for the one-year follow-up survey. In the follow-up administration of the Riggs and Enochs (1990) survey, the local teachers supplied the following information: percentage of their students as a function of ethnicity (Asian, African-American, Hispanic, Pacific Islander, Native American, White); percentage of their students as a function of economic level (poverty, low income, middle income, upper income), percentage of students as a function of geography (rural, rural/suburban, suburban, urban). In total, 225 local teachers completed the follow-up survey (50% response rate).

Data Analysis

The authors computed two measures of self-efficacy as outlined by Riggs and Enochs (1990) for each local teacher who completed the follow-up survey. Using the Rasch measure, to take into consideration the non-linearity of the rating scale, the authors reported these two measures (outcome expectancy, self-efficacy) in Rasch log odds units (Wright & Masters, 1982). It is important to point out that investigation regarding "local" teachers in reality refer to teachers who are predominately White, but who do teach a range of students (ethnicity, SES, geographic).

The authors used two-way ANOVA tests to investigate the differences between the self-efficacy and outcome expectancy of local teachers dependent upon the levels of ethnicity, geography, and SES of their students.

The authors calculated each level of the variables (ethnicity, geography, and SES) using the following procedure. A local teacher that would classify (a) 50% of his/her students as Asian would be a teacher of Asian students, (b) 50% of his/her students as African-American would be a teacher of African-American students, and so forth. The authors used the same strategy to classify teachers as a function of students' geography and SES levels. Combination and stratification of the data helped the authors define the levels for each variable; ethnicity (white, minority); geography (suburban, urban); SES (poverty/low, middle/upper). Minority included a combination of the classification of Asian, African-American, Hispanic, Pacific Islander, and Native American.

Results

Outcome Expectancy

With an alpha level of .05, the analysis of local teachers' reporting of the percentage of students living at different economic levels, different geographic locations, and different SES regarding their score on outcome expectancy showed no significant difference. In other words, the authors found no significant differences in outcome expectancy (belief in what students can do) for different levels of their student's ethnicity, geography, and SES.

Self-Efficacy

The authors found similar results when investigating self-efficacy. The self-efficacy (confidence) of teachers is no different when analyzed regarding different levels of their student's ethnicity and geography. However, the authors found that there was a near significant difference between the levels of SES (poverty/low and middle/upper income), $F(1, 148) = 3.65$, $p = .05$. Teachers classifying their students as middle/upper income had a higher self-efficacy as compared with teachers classifying their students as poverty/low income.

Conclusion

One of the goals of this data collection and analysis was to better describe and understand the types of teachers attending the one-day outreach offered by master teachers. From the results, we concluded that the outcome expectancies of teachers were not dependent upon their students' economic level, geography, or ethnicity. Also, the teachers' self-efficacies were not dependent upon their students' geography or ethnicity. However, "local" teachers that classified their students as from a middle/upper income background had a higher self-efficacy as compared with "local" teachers who classified their students as poverty/low income.

The results indicated that the teachers' outcome expectancy was not dependent on the student's economic level; however, teachers' self-efficacy was significantly different between middle/upper income students and poverty/low income students. This discrepancy could be due to the instrument for measuring outcome expectancy and self-efficacy. Perhaps, the instrument was not measuring what we think it was measuring.

In addition, due to small and empty cell sizes within the ANOVA table, we combined and eliminated demographic variable levels. These combinations and elimination could have influenced the data analysis.

We believe that the results (as evaluated) indicate self-efficacy data could reveal underlying issues. For example, according to the outcome expectancy results, a teacher with poverty/low income students and middle/upper income students feel that there is no difference between these two groups based on what the students can do. However, if either group of students fall below the success level, the teacher would first fault themselves, thus, affecting their self-efficacy (confidence). For science educators involved in summer workshops and/or professional development focusing on outcome expectancy, we suggest the need to analyze self-efficacy preceding or in conjunction with outcome expectancy analysis.

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NATURE-OF-SCIENCE ASSESSMENT BASED ON *BENCHMARKS* AND *STANDARDS*

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One way to achieve a higher level of agreement on the nature of science (NOS) within the science education community is to embrace the two major reform documents, *Benchmarks for Science Literacy* (1993) and *National Science Education Standards* (1996). Both *Benchmarks* and *Standards* have many statements on NOS that can be used as the basis for research in this area of science literacy. This paper reports a study of the development and field test of a questionnaire based on NOS information in *Benchmarks* and *Standards*.

Problems with NOS Research

The nature of science is complex; as philosophers, historians, and sociologists of science have reminded us in recent decades. Long before Kuhn's *The Structure of Scientific Revolutions* appeared in 1962, there was vigorous discussion among academics about scientific knowledge and how it is achieved. However, *The Structure...* raised the intensity of the debate and caused many more persons to become involved, including many in the science education research community. This debate has become more vigorous in recent years.

In science education, NOS research has been done by individuals who have various ideas about the nature of scientific knowledge and how it is generated; however, until recently there has been little opportunity to achieve much agreement. Each researcher developed a questionnaire that reflected his or her own ideas about NOS, resulting in data sets that are difficult to compare. A recent historical study (Lederman et al., 1998) identifies 25 questionnaires developed since 1954 that purport to assess ideas and attitudes on science. An earlier, very comprehensive (480 pages) report by Munby (1983) gave detailed descriptions and critiques of 56 instruments designed to assess ideas and attitudes on science.

We want to focus on the importance of using consensus documents like *Benchmarks* (1993) and *Standards* (1996) as the first step to improving NOS research in the science education research community. Until *Benchmarks* (1993) and *Standards* (1996) appeared, there seemed to be little chance that any kind of consensus on NOS could be reached within the science education community. Now there is at least some chance that these documents will help science education researchers reach greater agreement on this complex construct and, perhaps, find more reliable and valid ways to measure achievement in this area of science literacy.

There are other problems in doing NOS research, such as relying too heavily on questionnaire data, but these will be treated only briefly in the last section of this paper. A recent (November 1998) special issue of Science & Education contains many ideas on the nature of science and science education that are well worth considering in order to avoid certain problems in NOS research. We want to focus here on the importance of using consensus documents like Benchmarks and Standards as the first step to improving NOS research in the science education research community. There is an important distinction that we want to make here between attitude toward and understanding of science, before we describe our own efforts to design and test the Ideas on Natural Science instrument. Many of the instruments described in Munby (1983) include both attitude and understanding items. We are interested primarily in assessing understanding about science not attitude toward it, even though that distinction is sometimes a bit fuzzy.

Development of Instrument

Developing NOS Items

Most of the 28 items in the questionnaire Ideas on Natural Science (Appendix A) used to collect data reported in this paper were drawn from the first chapter of Science for All Americans, (SFAA) (1990), the precursor of both *Benchmarks* and *Standards*. In some cases (e.g., items 1,3,4,5,6,7,10) items are the same or very nearly the same as they appear in SFAA and in other cases (e.g., items 2,8,9,11,12,13,14,16,17) the items follow closely from the content of SFAA, but the wording is changed. The remaining items (18-28) are consistent with the content of SFAA, *Benchmarks*, and *Standards*, but the wording of the items may differ quite a bit.

We are aware that the wording of a question or statement can have a big effect on how a respondent interprets the item, a problem faced by all researchers who rely on questionnaire data to answer research questions. The 'mechanics' of developing a good questionnaire are complex and we do not want to underestimate their importance. However, our main purpose in this paper is to focus attention on using the main reform documents to achieve greater agreement on the nature of science.

Grouping NOS Items

Many groupings are possible for the 28 items in this NOS questionnaire, and seven are suggested here:

1. About nature
2. How scientific knowledge grows
3. Validity and reliability of science knowledge
4. Scientific method
5. Science vs. technology
6. Scientists as people
7. Science and nonscience

Most of the items and the categories or groupings involve matters of epistemology. A few of the items (e.g., 1, 2 &3) and two categories (1&7) include aspects of the nature of reality. The boundaries of the groupings are not sharp; an item may seem to fall within two categories but we have 'forced' each item into one category only:

Group 1: Items 1, 2, 3, 5

Group 2: Items 4, 6, 13, 14, 19, 23

Group 3: Items 10, 21, 22, 28

Group 4: Items 8, 9, 11, 26

Group 5: Items 18, 27

Group 6: Items 15, 16, 17, 24, 25

Group 7: Items 7, 12, 20

For better or worse, we use these categories as a way to define 'nature of science'. If our main proposal (use *Benchmarks* and *Standards* to develop NOS research items) is accepted by the science education research community, we are confident that more groupings and many more items will be developed and used in future NOS research. Our efforts reported in this paper are only a modest beginning in that direction.

Field Testing The Instrument

The questionnaire was given to 5 classes covering 3 content preparations. Three of the preparations were in education, and two were in chemistry.

The Fall 1997 Study: Critical Issues Class

The 28-item INS questionnaire was developed early in the fall semester and administered to a "Critical Issues in Science" class of 15 preservice and inservice secondary science teachers (12 females and 3 males). This class is at the senior level and can be taken by both undergraduate and graduate students. It is a required course for the undergraduate certification program. For each item they circled 'agree' or 'disagree' and then explained why they believed their choice was correct. The class met once a week for 3 hours, and the week following the administration of the questionnaire about an hour of class time was devoted to discussing their choices and potential problems with the questionnaire. The results from the questionnaire are shown in Table 1.

Table 1. Student responses to the INS questionnaire.

Question	Correct Response	Percent Correct
1	A	92.8
2	A	53.3
3	A	53.3
4	A	78.6
5	A	100
6	A	85.7
7	A	50.0
8	A	93.3
9	A	61.5
10	A	64.3
11	A	69.2
12	A	26.7
13	A	93.3
14	A	93.3
15	D	100
16	D	100
17	A	84.6
18	D	80.0
19	A	100
20	A	50.0
21	D	50.0
22	D	86.7
23	D	64.3
24	D	100
25	D	73.3
26	D	85.7
27	D	26.7
28	D	61.5
	Average	74.2

On sixteen of the twenty-eight items at least 70% of the students selected what the authors considered to be the correct choice. Of the remaining thirteen items, students had low agreement (less than 55% correct) on items 2, 3, 7, 12, 20, 21 and 27 for a total of seven items. Items 2 and 3 involve assumptions about the universal nature of Nature, items 7, 12 and 20 are statements about the limits or domain of science, and item 21 taps the students' beliefs about the reliability of science knowledge. To the extent that a numerical score has meaning here, the average score was 20 out of 28. During discussion of the questionnaire, students who disagreed with the 'correct' response often did so for reasons involving the precise meaning of a word, such as 'confident', 'assume', 'usefully', and 'reliable'. The source of disagreement often seemed to be more about semantics than about fundamental (mis)understandings of the nature of science.

This does not mean that differences among the students did not exist; however, much of the disagreement seemed to originate in the interpretation of words in the questionnaire. Relying solely on a questionnaire to assess students' NOS ideas is a risky business.

The Summer and Fall 1998 Studies: Science Methods Classes

The questionnaire was given to two classes of "Reflective Teaching: Science," which is a methods course for the teaching of science. One of the classes was taught in the summer of 1998 and the other in the fall of 1998. The classes were taught by two different instructors, but the instructors met before the summer class to discuss content to be covered. The summer class met twice a week for 2 hours each session, and the fall class met once a week for 3 hours. Obviously the field component of the courses differs greatly due to the lack of regular, formal school settings in the summer. The classes were composed of both preservice and inservice secondary science teachers. This class is at the senior level and can be taken by both undergraduate and graduate students. It is a required course for the undergraduate certification program, the graduate certification program (Holmes Group), and the alternate certification program (students with degrees in other fields taking coursework to be certified). The Holmes Group students only take the class in the summer. Because of the many differences between the two classes, and the small sample sizes involved, in-depth analysis between the two groups will not be addressed in this paper. Demographic data taken for the students can be found in Table 2.

Table 2. Demographic data of Science Methods Classes

Characteristic		Summer 98	Fall 98
Sex			
	Female	8	9
	Male	3	3
Program			
	Traditional Program	3	5
	Holmes Program	3	0
	Alternative Certification	4	7
	Other	1	0

The questionnaire was given to the students on the first day of class and was to be returned on the second class meeting. For each item the students circled 'agree' or 'disagree' and then explained why they believed their choice was correct. The concepts in the questionnaire were stressed throughout the class as the *Standards* were a required text for the course. The results from the questionnaire are shown in Table 3.

Table 3. Responses of students to the survey.

Question	Correct Response	Percent Correct Summer 98	Fall 98
1	A	63.6	58.3
2	A	27.3	41.6
3	A	27.3	29.2
4	A	90.1	58.3
5	A	90.1	91.7
6	A	54.6	66.7
7	A	45.5	58.3
8	A	90.1	100
9	A	45.5	25.0
10	A	63.6	58.3
11	A	72.7	66.7
12	A	27.3	33.3
13	A	90.1	83.3
14	A	63.6	79.1
15	D	90.1	100
16	D	72.7	83.3
17	A	81.8	83.3
18	D	72.7	66.7
19	A	100	91.7
20	A	36.4	16.7
21	D	72.7	66.7
22	D	54.5	75.0

Question	Correct Response	Percent Correct Summer 98	Fall 98
23	D	81.8	83.3
24	D	72.7	91.7
25	D	63.6	83.3
26	D	63.6	83.3
27	D	18.2	8.3
28	D	68.2	37.5
	Average	59.1	65.0

For the summer 1998 course, on thirteen of the twenty-eight items, at least 70% of the students selected what the authors considered to be the correct choice, as compared to the "Critical Issues" class' sixteen. Of the remaining fifteen items, students had low agreement (less than 55% correct) on items 2, 3, 6, 7, 9, 12, 20, 22 and 27 for a total of nine items compared to the "Critical Issues" class' seven. For the fall 1998 course, on thirteen of the twenty-eight items, at least 70% of the students selected what the authors considered to be the correct choice, which also made the number of items thirteen as compared to the "Critical Issues" class' sixteen. However, the individual items in this set of items are not identical to the summer 1998 results. Of the remaining fifteen items, students had low agreement (less than 55% correct) on items 2, 3, 9, 12, 20, 27, and 28 for a total of seven items compared to the "Critical Issues" class' seven. Again however, the individual items in this set of items are not identical to the fall 1998 results. Across all three groups, it appears that items 5, 8, 13, 15, 16, 17, 19, 23, and 24 have the highest frequency of correct answers, while items 2, 3, 12, 20, and 27 have the highest frequency of incorrect answers.

The Fall 1998 Study: Chemistry Courses and some interpretation of what the instrument tells us

The survey was administered to 161 students in two different college-level chemistry courses. 97 students in the first semester of a general chemistry course and 64 students in a one-semester organic chemistry class participated.

The general chemistry course is designed for the science and engineering curricula, and is described in the university's general catalog as a study of "modern chemical theory and principles; quantitative approach and problem solving; descriptive chemistry of selected elements and compounds." Most of the students surveyed in this class were freshmen, with 51 males and 46 females participating. These students were primarily enrolled in the colleges of engineering, arts and sciences, and agriculture; however, a large number of students did not report choosing a college.

The one-semester organic chemistry course is described in the general catalog as covering "aliphatic and aromatic compounds; biological aspects of organic chemistry." 40 females and 24 males were surveyed, most of who were sophomores or juniors enrolled in the agriculture college. A synopsis of some characteristics of these students is given in Table 4.

Table 4. Characteristics of chemistry students surveyed.

Characteristic	General Chemistry	Organic Chemistry
Sex		
Female	46	40
Male	51	24
Grade Level		
Freshman	82	1
Sophomore	9	20
Junior	3	26
Senior	1	13
Graduate	3	1
Not Reporting	1	1
Age		
19 - 25	91	54
26 - 30	3	2
30 - 35	2	6
36 -	0	2
Not Reporting	1	2
College of Declared Major		
Agriculture	12	50
Arts and Sciences	17	1
Business Administration	2	0
Design	0	
Education	1	2

Characteristic	General Chemistry	Organic Chemistry
Engineering	23	1
General College	8	2
Mass Communication	0	0
Music	0	0
Not Reporting	34	8

A summary of student responses to the survey questions is given in Table 5. The mean score of the freshman chemistry class on the survey was 17.0 out of 28 questions (60.8%) with a standard deviation of 2.67 and reliability (KR-20) of 0.214. Two students received the highest score, 23 out of 28 (82.1%), and a single score of 9 correct (32.1%) represented the low score in this class. The mean score of the organic chemistry class on the survey was 17.5 out of 28 questions (62.4%) with a standard deviation of 2.70 and reliability (KR-20) of 0.276. Four students received the highest score, 22 out of 28 (78%), and a single score of 10 correct (35%) represented the low score in this class. Consistent with the low reliability is the fact that for two questions administered to the organic chemistry class, students scoring in the lower third overall received higher scores than students scoring in the upper third. This occurred with item 12 and item 15.

Table 5. Responses of students to the survey.

Question	Correct Response	Percent Correct Freshmen	Percent Correct Organic
1	A	84.5	85.7
2	A	55.7	48.4
3	A	36.1	35.9
4	A	81.4	82.8
5	A	84.5	96.9
6	A	59.8	70.3
7	A	62.9	62.5
8	A	72.2	70.3
9	A	18.6	18.8
10	A	76.3	68.8
11	A	60.8	75.0
12	A	43.3	45.3
13	A	69.1	73.4
14	A	83.5	87.5
15	D	89.7	89.1
16	D	59.8	60.9
17	A	69.1	75.0

Question	Correct Response	Percent Correct Freshmen	Organic
18	D	43.3	43.8
19	A	84.5	85.9
20	A	33.0	20.3
21	D	58.8	65.6
22	D	56.7	53.1
23	D	76.3	78.1
24	D	74.2	84.4
25	D	51.5	50.0
26	D	49.5	59.4
27	D	15.5	10.9
28	D	50.5	59.4
	Average	60.8	62.8

In reporting our final study, which has the largest sample size, we will also look at the groupings mentioned earlier and how the data might be analyzed according to these groupings. Related to our Group 1, which considers understandings of Nature, many students appear to disagree about the concept of universality. The statement "Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere" (item 3) generated agreement among only 63.9% of freshmen and 64.1% of organic students. Only an overall minority agreed that "Scientists are confident they can discover patterns in all of nature" (item 2) (44.3% of freshman and 51.6% of organic students).

The Group 2 items deal with how scientific knowledge grows, and overall the students did well in this grouping. 83.5% of freshman and 87.5% of organic students agreed that "Theories in science must be logically or mathematically sound and use a significant body of valid observations" (item 14). These students were also in agreement that "Change and conformity are persistent features of science" (item 19) (84.5% and 85.9%, respectively). The related statement that "Continuity and stability are as characteristic of science as change is, and confidence is as prevalent as tentativeness" (item 6) generated slightly less agreement (59.8% and 70.3%, respectively).

Items in Group 3 deal with validity and reliability in science. In spite of this substantial agreement as to how theories should be developed, almost half of the students in each group

(42.8% of freshmen and 46.9% of organic students) agreed that "The word 'theory' in science means a hunch or guess about how some part of the world works" (item 22).

Apparently, most of these students view science as a process with a set of directions. This refers to items in Group 4. It is likely that few of these students have been exposed to scientific research; rather, it is more likely that their views of science are largely based on exposure to science lectures in which they repeatedly are shown step-by-step procedures that lead to successful developments in science. Most participants (81.4% of freshmen and 81.2% of organic chemistry students disagreed with the statement "There is no fixed set of steps that scientists follow that leads them to scientific knowledge" (item 9). Also, while we disagree that science is only done by using controlled experiments (item 26), 50.5% of freshmen and 40.6% of organic students agreed with this statement.

When we look at the items in our Group 5, it appears that the distinction between science and technology to these students is unclear. A majority of students in both groups (56.7% of freshmen and 56.2% of organic students) agreed that "The purposes of science and technology are about the same" (item 18)". The single statement receiving the lowest score in both classes was item 27, which said that "most scientific discoveries are useful to people." Although we consider that the correct response to this statement is "no," 84.5% of freshman chemistry students and 89.9% of organic chemistry students agreed with this statement.

In relation to our Group 6, these students appear to hold scientists and their ability to judge and reason in high regard. Roughly half of the participants (48.5% of freshmen and 50.0% of organic chemists) agreed with the statement "A scientist is more willing to change her mind when new evidence appears than are other people" (item 25). Although the majority of subjects recognized that scientists could be biased in matters not pertaining to science, a substantial minority disagreed with the statement "Scientists are less likely to be biased in public matters that are other members of society" (item 16) (40.2% of freshman and 39.1% of organic students). And although most scientists were seen as behaving in an ethical manner within their profession, a notable minority (30.9% of freshmen and 25.0% of organic students) disagreed with the statement "The vast majority of scientists stay within the bounds of ethical professional behavior" (item 17).

Distinguishing between science and nonscience is our Group 7. Only 43.3% of the freshman chemistry students and 45.3% of the organic chemistry students, agreed with the statement "A hypothesis that cannot in principle be put to the test of evidence is not scientifically useful" (item 12). In light of this answer, it may not be surprising that few students (33.0% of freshman and 20.3% of the organic students) agreed that "Supernatural explanations of natural phenomena have no place in science" (item 20).

As a summary to this section on results of administering the INS to two chemistry classes, we compare the 7 groupings by ranking them in terms of "easiest" to "most difficult" for the students. Table 6 shows that grouping 2 (How scientific knowledge grows; items 4,6,13,14,19,23) are easiest for the students while grouping 7 (Science and nonscience; items7,12,20) is the most difficult.

Table 6. Relative difficulty of the 7 INS groupings (chemistry sample).

Grouping (name)	% Correct
2 (How scientific knowledge grows)	80.4
1 (About nature)	65.8
3 (Validity & reliability of science knowledge)	61.0
6 (Scientists as people)	56.4
4 (Scientific method)	52.5
5 (Science vs. technology)	48.4
7 (Science and nonscience)	42.9

Only for grouping 2 can it be said that students have a reasonably good grasp of that aspect of the nature of science. Groupings 5 & 7 are closely related in that both are asking for ideas about the domain of science. Analysis of subscales or groupings of similar items within a test provides information that can help a teacher decide where more emphasis is needed. For these data it is fairly clear that students do not differentiate between science and nonscience.

Conclusions

Nature-of-science research needs to have reasonable agreement among researchers regarding the nature of science; otherwise we will continue to use data collection instruments that are difficult to compare. Benchmarks for Science Literacy (1993) and National Science Education *Standards* (1996) are consensus documents that can be used as starting points for NOS research if science education researchers will agree to take them seriously. This is the main point of this paper. There may be other ways to achieve reasonable consensus on the nature of science, but these two reform documents are widely known and extensively used by the science education community. They offer a good opportunity for NOS researchers to achieve greater agreement among themselves regarding the complex nature of the natural sciences.

The development and field test of the 28-item 'Ideas on Natural Science' (INS) questionnaire reported in this paper are a step toward taking seriously *Benchmarks* and *Standards* as a foundation for NOS research. The low reliability of the INS instrument suggests that much work remains on developing an instrument that is both valid and reliable. Rather than sift back over the results of the INS field test, we want to conclude this paper with some observations and recommendations directed to NOS researchers and others interested in assessing students' ideas on the nature of the natural sciences.

1. Be careful not to confuse ideas on science with attitudes toward science. Lederman et al. (1998) make this point and we want to underline the importance of restricting NOS research to ideas on science.

2. Identify subscales or groupings within a NOS instrument that, together, define NOS literacy. The 7 categories we identified in our 28-item 'Ideas on Natural Science' questionnaire are not the only areas that might be needed to define NOS literacy. Reasonable agreement on both groupings and items is needed to be able to compare data sets among researchers.

3. Supplement paper-and pencil data with interview data. This recommendation is not new but it seems that few researchers follow it. Our experience has shown that students often interpret an item in ways that were not anticipated by the researcher.

4. Consider science content-specific NOS research as a way to improve, or perhaps enrich, current efforts. In This Is Biology (1997) Ernst Mayr observes that biology, and in particular evolutionary biology, differs fundamentally from the physical sciences. Rather than NOS perhaps we should consider nature of biology, nature of physics, and so on. Teaching about Evolution and the Nature of Science (1998) by the National Academy of Sciences raises questions that suggest NOS research should be tied closely to content-specific science.

Finally, we want to emphasize the importance of staying close to science content. Many of the disagreements among academics on the nature of science can be traced to misunderstandings of science content itself. The recent 'science wars', based on physicist Alan Sokal's parody "Transgressing the Boundaries: Toward a Transformational Hermeneutics of Quantum Gravity" published in the fashionable cultural studies journal Social Text, is basically a battle between those (natural scientists) who understand the content of science and others (social scientists) who have a much thinner grasp of science (see Sokal & Bricmont,1998, for more details). Benchmarks and Standards both take science content seriously as does Teaching about Evolution and the Nature of Science. Staying close to the content of science rather than the 'science-as- politics' viewpoint is, in our opinion, the preferable path for NOS researchers.

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Appendix A

Ideas on Natural Science

Do you agree or disagree with the following statements about the natural sciences? On the response sheet circle agree or disagree and explain why you believe your position is correct.

1. Natural science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study.

2. Scientists are confident they can discover patterns in all of nature.

3. Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere.

4. The modification of ideas, rather than their outright rejection, is the norm in the natural sciences.

5. Scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works.

6. Continuity and stability are as characteristic of science as change is, and confidence is as prevalent as tentativeness.

7. There are many matters that cannot usefully be examined in a scientific way.

8. Within a field of natural science (e.g., biology, chemistry, physics) there are common understandings about what constitutes an investigation that is scientifically valid.

9. There is no fixed set of steps that scientists follow that leads them to scientific knowledge.

10. Sooner or later, the validity of scientific claims is settled by referring to observations of phenomena.

11. Experimentation, where just one condition at a time is varied, is not possible in some areas of

the natural sciences.

12. A hypothesis that cannot in principle be put to the test of evidence is not scientifically useful.

13. Inventing ideas about how the world works is just as creative as writing poetry or composing music.

14. Theories in science must be logically or mathematically sound and use a significant body of valid observations.

15. Scientists usually work alone as they try to understand the natural world.

16. Scientists are less likely to be biased in public matters than are other members of society.

17. The vast majority of scientists stay within the bounds of ethical professional behavior.

18. The purposes of science and technology are about the same.

19. Change and continuity are persistent features of science.

20. Supernatural explanations of natural phenomena have no place in science.

21. Knowledge of nature generated by natural scientists is no more reliable than other knowledge.

22. The word "theory" in science means a hunch or a guess about how some part of the world works.

23. Laws in science are not subject to change.

24. Scientists have less interest in the fine arts than people in other professions.

25. A scientist is more willing to change her mind when new evidence appears than are other people.

26. Only by doing carefully controlled experiments can scientists learn about our world.

27. Most scientific discoveries are useful to people.

28. The validity of scientific knowledge depends heavily on the beliefs and customs of the country in which the scientists live.

THE USE OF THE *NATIONAL SCIENCE EDUCATION STANDARDS* AS A TOOL TO CRITIQUE THE TEXAS BIOLOGY I END-OF-COURSE EXAMINATION

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Summary of Presentation

This study analyzes the Texas Biology I End-of-Course Examination [Biology EOC], a state-mandated high school biology examination, by applying the criteria of the *National Science Education Standards* [NSES] (National Research Council, 1996) in assessment. The Biology EOC has been administered to all high school biology students in Texas since May 1994. The stated purpose of the Biology EOC is to "provide information about the effectiveness of a school's instructional program" (Texas Education Agency, 1993). After four years of experience with this examination, it is timely to evaluate its efficacy, particularly in the promotion and assessment of the scientific literacy of biology students.

The Biology EOC was evaluated as an instrument for promoting or assessing scientific literacy in biology, by comparing the questions and the design of the Spring 1997 Biology EOC with the NSES Assessment Standard B. The achievement component of Standard B, that specifies the most important science content for students to learn, was used to examine the science content of the Spring 1997 Biology EOC (Texas Education Agency, 1997).

The science content found in the 42 questions on the Spring 1997 Biology EOC was classified into five different categories. Two of those categories corresponded to the NSES Standard Assessment B science content categories that are considered by NSES as the most important for students to learn. The other three categories had content unrelated to criteria stated by the NSES. Of the 42 questions, 31% of the science content was classified under the NSES category *Knowing and understanding scientific facts, concepts, laws, and theories* and 21% of the science content was classified under the NSES category *The ability to reason scientifically.* The remaining 48% of the questions from the examination were classified under three categories unique to the Biology EOC. These categories included *The ability to interpret a chart or diagram*, *Manipulative laboratory skills*, and *The ability to answer common knowledge questions.*

When analyzed in the context of the NSES, the Biology EOC had deficiencies that are common to many state-wide science examinations (Gong, 1990). These deficiencies included: 1) few questions that concern biological or science concepts; 2) few questions that require a high level of thinking, i.e., synthesis; 3) no assessment in the NSES science content categories *The ability to inquire*, *The ability to use science to make personal decisions and to take positions on societal issues* and *The ability to communicate effectively about science*; 4) reliance on multiple-choice questions for assessment, in contrast with the NSES-recommended assessment format of open-ended questions.

The significance of the study is two-fold. First, it uniquely documents an analysis of an actual state-mandated science assessment in Texas. There have not been any published question-item analysis of any of the released science assessment examinations. The lack of any analysis of the Biology EOC in Texas is also typical of most states. A literature search using ERIC did not reveal specific critiques of actual state-wide science examinations in any state. Thus, there is a need for science educators to evaluate these examinations as a means of science education reform, and to inform the science education community and the public as to their adequacy in complying with measures recommended for reform of assessment in science education. Secondly, the study is significant in that it may serve as a model for those interested in evaluating the conformity of other state-wide science examinations to the NSES.

The results of this critique should be considered as states create or revise their state-wide science tests. Examinations should be developed that reflect the NSES assessment guidelines, in order to promote greater scientific literacy in our students. Examinations should 1) contain questions that assess the science content that is most important for students to learn, 2) contain open-ended questions, and 3) be used as only one component of a total science program evaluation.

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THE USE OF THE CASE NETWORK STANDARDS IN PRESERVICE LEVEL PORTFOLIO DEVELOPMENT

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The CASE (Certification and Accreditation in Science Education) project is a joint NSTA/AETS undertaking to develop standards for science teacher education that are:

1 consistent with the national science education standards and other standards projects

2 applicable to multiple levels of preparation

3 based on research and best practice

4 performance-based

5 flexible enough to allow for program variation and experimentation (Gilbert, 1997, p.6)

During the four years since the project's inception, science teacher educators have grappled with their own conceptions of the CASE Network standards and how they will help guide best practice in science teacher education. This paper presents preliminary work on the implementation of the standards using a generative conception of portfolio development.

Like many other NCATE accredited programs, Hofstra University's secondary science teacher education program requires only one science teaching methods course. The number of concepts to be understood that related directly to science teaching was extensive and students were wearied by the sheer load of coursework. Well over 50 percent of the class meetings had written or hands-on assignments attached to them and it was proving increasingly difficult to broaden the scope of the course without increasing the number of performance pieces that students had to complete.

Reorganizing the Science Methods Course

After reading the standards, joining the CASE Network, and learning that if the standards were adopted by both NSTA and AETS, NCATE was expected to use them during reaccreditation, it seemed even more expedient to reorganize the science methods course around the standards. Prior to the first meeting of the science methods course, its syllabus was revised by eliminating all assignments associated with the concepts scheduled to be presented. The content of each class remained essentially unchanged. Each concept was evaluated by comparing it to the indicators at the preservice level of the standards. Once it was determined that each of the standards would be addressed within the concepts presented in the course, the generative phase of the project began.

Students were given a copy of the standards as a part of their syllabus and were asked to generate a list of projects that would demonstrate that they had achieved the standard (see Appendix A). As additional support, students were asked to work in groups and consult the CASE Network website (now at: http://www.aets.unr.edu/AETS/draftstand.html) for further clarification of standards, indicators, rationales, and recommendations.

The Cooperative and Collaborative Nature of Student-Generated Portfolio Evidence

While the course followed the syllabus, the students generated what they considered best evidence for achieving the standards. It was decided that the evidence that students would generate would be best housed in a portfolio. Much debate surrounded the discussions of how the portfolio was organized. It was decided that the portfolio would open with a letter to the reader that described the students' philosophy of teaching and how the inclusions in the portfolio were arranged around the standards. A table of contents followed. The next section included the actual evidence that the standards were attained and a description of why the students' believed the inclusions evidenced their attaining the standards. The final piece was a professional resume.

Quite a bit of mediation was also required. The students fell into at least one of three groups: (a) Those who wanted to do the minimum required; (b) Those who wanted to further interpret the standards to suit their needs; and, (c) Those who argued that most of what was suggested did not fit the standards exactly. In the final analysis, the students came to consensus around the wishes of the second group (see Appendix B). Once what constituted best evidence was accepted, they set out to choose submission dates. It was decided that instead of structuring 10 separate projects to address all ten standards, five projects that addressed two standards each would be more efficient and would allow for adequate preparation within the submission dates. Finally, the project placement on the calendar was determined by how much time each would take to complete.

Countering the Drawbacks

Some drawbacks are apparent when using cooperation and collaboration in developing student-generated portfolio evidence. There are ways to reduce the drawbacks. One drawback is the time it takes for students to work toward consensus. A strong facilitator is needed to decrease the amount of time spent rambling and arguing. Teaching students how to disagree agreeably may also be necessary to move the process along. Once this process has been completed by current students, the professor may opt to only allow future students to modify the existing projects.

Another drawback can occur when the evidence students choose is not what their professor would consider best evidence. This can be approached in a number of ways. If the professor chooses the concepts to be studied throughout the course and provides structure that reflects the standards as part of the syllabus, students will still have the opportunity to learn what the professor views as most important while generating a portfolio with inclusions that they feel are important. Another approach would allow the professor final veto on all projects. An opposite approach would be to value what the students view as important and let their conceptions direct the development of the evidence. By doing so, the reader of the portfolio can gain additional insight into how students actually approach their work when left to their own devices.

The final drawback discussed here would be not knowing what to expect from one administration of the course to another. Sometimes students rise beyond expectation and sometimes they fall below expectation. The professor must be flexible with regard to the needs of each class. Some classes will require more hands on contact from the professor to help students become successful using this method. The professor will be able to decide if this approach to using the standards is working for a particular group of students and if it is not, the professor has the option to suspend or terminate the approach.

Conclusion

When employing this approach to implementing the standards, the professor must impress on students how critical it is to make decisions as quickly and efficiently as possible. Otherwise, they will not have time to complete the projects within the scope of the class. It is also helpful if the professor is willing to give up some measure of control and allow students to take the development of projects where they believe it should go. This provides students with leadership opportunities and requires them to make sense of what they have been taught in a more personal way.

After a bit of initial grumbling, students were quite happy with what they developed and talked often about how both the process and the product helped prepared them to teach. They were able to discuss the standards and their interpretation of them with ease by the end of the course. This helped instill confidence about how much they actually knew about preparing to teach science. Since the students chose what they considered best evidence and designed projects, the complaints about workload decreased significantly. This method of using the standards generated many positive outcomes in our estimation and we will begin to move beyond baseline data when the standards are finalized.

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Appendix A

(Excerpt from the secondary science methods syllabus for bachelors and masters degree candidates)

This course is designed to help you attain the National Science Teachers Association (NSTA)/The Association for the Education of Teachers in Science (AETS) *Standards for the Preparation of Teachers of Science* as set forth in the 1/21/97 draft version of the Certification and Accreditation in Science Education (CASE) Project. They are as follows:

1.0 Content

Teachers of science should possess an understanding of science concepts sufficient in breadth and depth, to support student learning as defined by state or national standards developed by the science education community.

2.0 The Nature of Science

Teachers of science should engage students in activities defining the values, beliefs and assumptions inherent to the creation of scientific knowledge within the scientific community.

3.0 Inquiry

Teachers of science should engage students regularly and effectively in science-related exploration and inquiry.

4.0 The Context of Science

Teachers of science should relate knowledge constructed through science to the life and interests of students and to the needs, values, issues and interests of the community.

5.0 Pedagogy

Teachers of science should create effective learning opportunities for a diverse community of students, helping them to derive meaning from science instruction and creating a disposition for further inquiry and learning.

6.0 The Science Curriculum

Teachers of science should engage students in a science curriculum that is consistent with state and national goals for education and appropriate for the students' needs, abilities, and interests.

7.0 The Social Context

Teachers of science can effectively employ peer, family, and community resources to facilitate the education of students in science.

8.0 Professional Practice

Science teachers are part of a professional community that improves practice through personal education and development; community outreach; mentoring new colleagues; working with preservice teacher, participation in research ; and collaboration with colleagues to improve current practices.

9.0 Learning Environments

Teachers of science should design and manage safe, secure and stimulating learning environments that meet the needs of all students.

10.0 Assessment

Teachers of science should use a variety of assessment strategies that are aligned with goals and methods of instruction, appropriate to the level of the students, and conducive to continuous learning through science.

Appendix B

(Student-generated projects using the CASE standards)

Project 1: *Standards 1.0 (Content) and 6.0 (The Science Curriculum)*

- Work with your group to design a concept map demonstrating the interrelatedness of the concepts taught in a first year science class using the state standards in your discipline. The product should be your own but discussed and shared with your group members for further input. Please include a copy of the New York State (or Regents) standards for your teaching discipline.
- Compare and contrast the national and state goals for science education in your discipline. How do they compare with your own goals for science education in your classroom?

Project 2: *Standards 7.0 (The Social Context) and 9.0 (Learning Environments)*

- Develop a list of community resources for science teachers. This list should include places to visit locally for field trips, local organizations that provide guest speakers, and places that provide resource materials for science teachers. Report the name, address and phone number of the community resource and the name of a contact person (if applicable).
- Develop a set of science activities that involve families for a family science night. What could you include that would make science seem fun and attainable for all members of a family?

- Design your ideal science classroom including the materials that you will need, the company from whom you can purchase them and their prices. In addition, diagram the set up of the room itself. Remember to consider the needs of diverse learners.

Project 3: *Standards 2.0 (The Nature of Science) and 4.0 (The Context of Science)*

- Answer the following questions: Why is the number of American-born scientists decreasing and why are fewer students choosing to pursue scientific careers? How do you think that science teaching practice has influenced this trend? What will you do in your classroom to help reverse the trend? This paper should be researched and use APA style in its construction, citations, and references.
- Using a topical issue, develop a 'real world' lesson plan. Include a lesson plan and describe how and why your lesson is both topical and important from a real world perspective.

Project 4: *Standards 5.0 (Pedagogy) and 8.0 (Professional Practice)*

- Write a 5 page paper on the meaning and precepts of multicultural science education. This paper should be researched and use APA style in its construction, citations, and references. Describe how you will make your class meaningful for a diverse group of students by using the cultural capital they bring to the classroom.
- Join a professional teachers organization; one preferably in your teaching discipline but a general teacher's organization will do. Supply a copy of your ID card or canceled check.

- Write a discussion of what concerns you most about the act of student teaching or being observed in your own classroom next semester.

Project 5: *Standards 3.0 (Inquiry) and 10.0 (Assessment)*

- Prepare to teach an inquiry based lesson or laboratory in your discipline. Include a lesson plan and describe how and why your lesson promotes inquiry among students. Include a discussion of what factors should be considered in order to maximize the amount of learning stimulated by the lesson.
- Develop three alternate forms of assessment for the same material.

A POST-FINAL ASSIGNMENT FOR THE METHODS COURSE: PROVIDING AN INCENTIVE TO PROFESSIONAL GROWTH FOR FUTURE TEACHERS

Michael L. Bentley, Virginia Tech

Novel Strategies for the Methods Class

One important function for AETS as an organization of teacher educators is to foster communication about effective teaching strategies for science teacher preparation courses. Two new strategies/methods I have recently adapted to my own classes at Virginia Tech are the "post-final assignment" (Rosengren, 1993-1994) and the "truth signs" activity (Harmin, 1994). The strength of the post-final assignment is that it is a strategy for extending student learning past the end of the course, and even beyond the initial teaching license. It is a course component that can foster further professional development among beginning teachers, and it supports the ideal of life-long learning. The Truth Signs activity has different potential outcomes. The main value to me of this activity is that it helps future teachers reflect on their core educational values, and exposes them to an activity adaptable to their own science classrooms at any level.

The Post-Final Assignment

Biologist John H. Rosengren. (1993-1994) regularly presents his students with a "Post-Final Assignment." The assignment, which is really optional and voluntary, is intended to "show students that college courses are just the beginning of acquiring knowledge." Rosengren wants to enable students to broaden their knowledge through the "discovery of new books to read and places to see." (p. 181) He provides his students with an annotated book list and requires them to read three or more books. His post-final assignment also includes a "Places to Go" list. After students have read a book or visited a site on the list, Rosengren asks them to send him a post card with their comments and reaction. While not revealing the numbers in his pool of former students, Rosengren claims to receive about ten post cards per year. Those students who complete the assignment receive a "Citation Certificate" and a book.

I have adapted Rosengren's idea to my science methods course and curriculum courses. Appended are recent versions of post-final assignments for two of my courses, *Methods for Teaching Secondary Science* (Appendix A) and *Secondary School Curriculum* (Appendix B). The secondary methods course at Virginia Tech is in the licensure sequence for students who have majored in biology, chemistry, physics or one of the earth-space sciences, and who are preparing themselves to be middle school or high school science teachers. Students taking the secondary curriculum course are also in a licensure program, but the class includes many non-science majors who are specializing in other secondary subject areas.

The post-final assignment is presented to each student individually during an exit interview on the last day of class. Students are not given a time limit for completing the assignment; they have the rest of their lives to do it (but, as I tell them, only the rest of *my* life to receive their certificates). I believe that whatever work my former students put into this assignment it will be a rewarding experience and lead to learning and professional growth.

An example of a reading for the future secondary teachers is Jay Lemke's *Talking Science* (1990). This book explains his research in secondary science classrooms using methods of linguistic analysis that cast light on the hidden curriculum and on teachers' epistemological assumptions. Books on both lists include Aldo Leopold's *A Sand County*

Almanac (1968) and Daniel Quinn's *Ishmael* (1993). These texts may enable the future teachers to think more deeply about the historic and ethical dimensions of their work in the classroom. Both works also may further these teachers' environmental education.

Examples of post-final assignment field sites for the new teachers to visit include the American Museum of Natural History in New York City and Chicago's Field Museum. New elementary teachers in my Elementary Curriculum course are sent off to Indianapolis' Children's Museum and Chicago's Museum of Science and Industry.

In post-final assignments for all classes, the new teachers are urged to share their lesson plan ideas and experiences with their peers, for example, by participating in an education-oriented listserv or by contributing an article for a teachers' publication, such as *Science and Children*, *Science Scope*, *The Science Teacher*, or *Science Activities*. New teachers also are urged to collaborate with their teaching colleagues in action research related to an area of interest. They are encouraged to attend an annual state or national convention, such as those sponsored by the National Science Teachers Association or the National Council for the Social Studies and their state affiliates, and to submit a proposal to contribute a presentation at such meetings.

While some activities recommended in the post-final assignment are individual and others collaborative in nature, all promote professional development and life-long learning. I only began using this strategy in 1997 and still look forward to getting my first post card.

The "Truth Signs" Activity

In Merrill Harmin's (1994) ASCD-sponsored handbook of teaching methods, the "Truth Signs" activity is classified in the category of "Strategies for Expanding Student Confidence." It is a strategy he adopted from Pilon (1991), who prefers to call the activity "philosophy signs." Harmin claims that teachers have reported that the strategy works well at all grade levels and describes the strategy succinctly as "Posted signs that remind students of important truths about learning and living." (p. 49) He clarifies by adding that truth signs are not rules and are not directions on what to do (e.g. "raise your hand to speak"), but are reminders of important and relevant guiding ideals. Harmin provides a script for a model lesson that use the following five truth signs that he has posted in his own college classroom:

- "Everyone needs time to think and learn.
- We each learn in our own ways, by our own time clocks.
- It's okay to make mistakes. That's the way we learn.
- It's intelligent to ask for help. No one need do it all alone.
- We can do more and learn more when we're willing to risk." (p. 54)

In his model lesson, Harmin has the teacher displaying a single message to the class on a card, reading it aloud and having the class responsively read it together, and then initiating a discussion by asking the class if it is a "true saying." Following the discussion, after a consensus is reached about the truth of the saying, the card is posted on the classroom wall for continuous referral throughout the course. Harmin sites research by Hart (1983), Caine and Caine (1991), and Marzano (1992) and argues that it is "often heartening, reassuring, and strengthening" for students to be reminded of these posted verities. Harmin recommends using no more than six or seven signs in the classroom at a time so as not to dilute the power of the signs.

Here are two sample truth or philosophy signs I offered my own students in my science teaching methods course:

- "Practice is never a simple application of general rules to concrete situations, and theory is never the simple abstraction-generalization from practical situations to general schemes. Practice and theory, like knowledge and experience, stand in a relation of mutual adaptation, of mutual questioning, and of mutual illumination." (Bettencourt, 1993, p. 47)

- "The art of thus giving shape to human powers and adapting them to social service is the supreme art; one calling into its service the best of artists; that no insight, sympathy, tact, executive power, is too great for such service." (Dewey, 1954, p. 638)

After working with these signs in a manner similar to Harmin's method, I invite my students – who are concurrently carrying out internship hours in local schools - to find and post truth signs in their own classes. My students enjoy this activity and eagerly research their own truth signs. Here is a sampler of the Truth Signs suggested by my Fall 1998 secondary science methods students:

- Never let yesterday's disappointments overshadow tomorrow's dreams.
- A mind is like a parachute...it works best when OPEN.
- Know your limits, then break them.
- "Progress always involves risk. You can't steal second base and keep your foot on first."
- "The whole point of getting things done is knowing what to leave undone." Stella, Lady Reading
- "Justice cannot be for one side alone, but must be for both." Eleanor Roosevelt
- "Quarrels would not last long if the fault were only on one side." Francois de La Rochefoucauld
- "Teamwork is the fuel that allows common people to produce uncommon results." - Anon.
- "What happens to a man (sic) is less significant than what happens within him." - Anon.
- "If we are to achieve a richer culture, rich in contrasting values, we must recognize the whole gamut of human potentialities, and so weave a less arbitrary social fabric, one in which each diverse gift will find a fitting place." Margaret Mead

Conclusion

In this paper I discussed two novel teaching strategies suitable for use in teacher preparation courses. Rosengren's "post-final assignment" is a strategy which enables students to see past the end of the course and into their lives as professional teachers. It is a course component that can lead to professional growth and it supports the ideal of life-long learning. Harmin's "Truth Signs" activity has the potential to help future teachers reflect on their core educational values. It is an activity that beginning teachers can immediately adapt to their own science classrooms at any level.

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Appendix A

SAMPLE POST-FINAL ASSIGNMENT FOR A SCIENCE TEACHING METHODS COURSE

EDCI 5784 GRAD. SEM. IN ED.: Tchg in Secdy Sch I: Science FALL, 1998

A Post-Final Assignment: Continuing Education beyond the Classroom

You have now completed the University's requirements for the course EDCI 5784. However, in the instructor's view, you have just commenced your study of science education. The purpose of a post-final assignment is to "show students that college courses are just the beginning of acquiring knowledge." (Rosengren, 1993-94, p. 181) If and when you complete the assignment you will receive a "Citation Certificate" and a book.

Your assignment, if you should choose to accept the challenge, is to complete any *three* readings in the first group (books), any *three* items in the second group (field trips, museums, etc.), and any *one* item in the third group (taking action). When you have completed the assignment, send a post card to me, c/o the Department of Teaching and Learning, Mail Stop 0313, VT, Blacksburg, VA 24061.

On the post card, include a few sentences representing your response to the experience. Your response will be recorded and my grade book will show you received the Citation Certificate. Note that there is no time limit for completing this assignment - you have the rest of your life to do it (but only the rest of *my* life to receive your certificate)! Your work on this assignment will be rewarding as you continue to grow professionally and learn.

Category One: Books
Read any*three* of the following:

Bentley, M. L. (1998). Constructivism as a referent for science education. In M. Larochelle, N. Bednarz, & J. Garrison, (Eds.), Constructivism and Education. New York: Cambridge University Press, pp. 233-249. The text is available from the Bentley webpage http://www.chre.vt.edu/bentley Also see: http://www.cup.cam.ac.uk/scripts/webbook.asp3.Isbn=0521621356 . This is a chapter in a book on constructivism in education and is listed in the syllabus. The article represents this instructor's position regarding the current education reform movement.

Cole, M. and Griffin, P. (Eds.). (1987). Contextual factors in education: Improving science and mathematics education for minorities and women. Madison, WI: Wisconsin Center for Educational Research, University of Wisconsin.

Freire, P. and Macedo, D. (1987). Literacy: Reading the word and the world. South Hadley, MA: Bergin & Garvey Publishers, Inc.

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Quinn, D. (1993). Ishmael. New York: A Bantam/Turner Book.

Sagan, C. (1997). The demon-haunted world: Science as a candle in the dark. New York: Random House.

Category Two: In the Field

- Visit a world-class museum and study it as a curriculum resource. Take notes about the museum's contents and its potential contribution to your middle/ high school class. The Smithsonian Institute museums are all world-class (e.g. Air and Space Museum, Natural History Museum, National Zoological Park). Other examples include the Field Museum, Chicago (Lake Shore Dr., 60605), the Museum of Science & Industry, Chicago (57th & Lake Shore Dr., 60637), and the Museum of Natural History (79th Street and Central Park West, New York).

- Visit a regional science/natural history museum – for example, the Science Museum of Virginia, Richmond, the North Carolina State Museum of Natural Sciences, Raleigh, NC 27626 (http://museums.mdmi.com/naturalsciences/), and the Virginia Museum of Natural History, Martinsville, VA (http://minerva.acc.virginia.edu/~vnmh-uva/)/

- Attend a state convention of a professional science teachers' organization – a state affiliate of NSTA or a teachers' organization in your field. For example, in Virginia, the Virginia Association of Science Teachers meets annually in the fall. Another example is the American Association of Biology Teachers (AABT), which represents life science teachers.

- Attend a regional or national convention of a professional science teachers' organization. For example, the National Science Teachers Association hosts several regional meetings each fall, and a national meeting in the spring. The North American Association for Environmental Education meets in the fall. Info on meetings can be found on the organizations web page (see links from the Science Education Program homepage).

- Participate in a summer professional development institute program. Institutes are sponsored by federal agencies as NASA, NSF, and the Department of Energy, and organizations like the Association for Supervision and Curriculum Development (ASCD), NSTA, museums, and state education departments. Recent summer instituteds include NEWMAST, NEWEST, NEW, the Keystone Science Institute, and Project Atmosphere. For programs in your area, check out the state department of education, the VAST home page (or your state science teachers' organization), or NSTA's home page. An alternative experience in this category would be to participate in an Earthwatch expedition. For information about Earthwatch expeditions, contact Earthwatch, 680 Mount Auburn St., PO Box 1904, Watertown, MA 02272.

Category Three: Taking Action

- Share your teaching ideas and experience with your peers. Write an article for a local, regional, state, national, or international science education journal or magazine - such as *Science and Children*, *Science Scope*, *The Science Teacher*, or *Science Activities*, or submit to a general teachers magazine, such as the *Middle School Teacher*. Alternatively, submit a proposal to do a presentation before your peers at a state, regional, national or international science (or biology, chemistry, earth science, physics...) teachers' convention.

- Collaborate with one or more teaching colleagues in action research related to some area of mutual interest in your teaching. For example, you might decide to change some aspect of your teaching, such as, for instance, implementing a portfolio assessment system, or using a new technology or method.

- Attend *at least* three (they need not be consecutive, but note the date and sequence) meetings of your local school board - either where you teach or where you live. Reflect on the meaning for the local secondary school curriculum of the deliberations and decisions you witness there.

- Volunteer for and participate as a member of the Science Committee or Curriculum Committee of the school or district in which you teach. Document the activities of the Committee and evaluate the school's or district's success in reaching its goals.

- Spend a summer as a paid or volunteer naturalist/interpreter at a state or national park. The National Park Service maintains a web page at http://www.nps.gov, which includes information on individual parks as well as job and volunteer information. You may also write to Seasonal Employment Program, Human Resources Office, National Park Service, PO Box 37127, Mail Stop 2225, Washington, DC 20013.

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Rosengren, J. H. (1993, Dec.-1994, Jan.). A post-final assignment: Continuing education beyond the classroom. Journal of College Science Teaching, 23(3), 181-182.

Appendix B

SAMPLE POST-FINAL ASSIGNMENT FOR A CURRICULUM COURSE

EDCI5694 Secondary School Curriculum SAVE FOR FUTURE REFERENCE

A Post-Final Assignment for Curriculum: Continuing Education beyond the Classroom

The purpose of a post-final assignment is to "show students that college courses are just the beginning of acquiring knowledge." (Rosengren, 1993-94, p. 181) If and when you complete the assignment you will receive a "Citation Certificate" and the first three to complete the assignment also will receive a book.

You have now completed the University's requirements for the course EDCI 5694, Secondary School Curriculum. However, in the instructor's view, you have just *commenced* your study of curriculum and instruction. Consequently, the assignment, if you should choose to accept the challenge, is to investigate curriculum in your field in greater depth by selecting activities from the choices below.

When you have completed the assignment, send a post card to me, Michael L. Bentley, c/o the Department of Teaching and Learning, Mail Stop 0313, Virginia Tech, Blacksburg, VA 24061. On the post card, include a few sentences representing your response to the activities and what you learned. Your card will be recorded in my grade book and you will receive a "Citation Certificate" and a book.

Note that there is *no time limit* for completing this assignment - you have the rest of your life to do it (but only the rest of *my* life to receive your Certificate!). I believe that your work on this assignment will be rewarding as you continue to grow professionally and experience the use of various resources in teaching your subject to secondary students.

Post-Final Assignment for EDCI 5694

Category One: *Read at least one of the following:*

Bowers, C. A., & Flinders, D. J. (1990). Responsive teaching: An ecological approach to classroom patterns of language, culture, and thought. New York: Teachers College Press.

Larochelle, M, Bednarz, N., & Garrison, J. (Eds.). Constructivism and Education. New York: Cambridge University Press.

McCutcheon, G. (1995). Developing the curriculum: Solo and group deliberation. New York: Longman Publishers USA.

Orr, D. (1992). Education and the transition to a postmodern world. Ithica, NY: State University of New York Press.

Posner, G. J. (1995). Analyzing the curriculum. 2nd. ed. New York: McGraw-Hill, Inc.

Ross, E. W., Cornett, J. W. & McCutcheon, G. (Eds). (1992). Teachers' personal theorizing: Connecting curriculum practice. Albany, NY: SUNY Press.

Sarason, S. (1996). Revisiting the culture of the school and the problem of change. New York: Teachers College Press.

Sizer, T. R. (1992, 1985, 1984) Horace's compromise: The dilemma of the American high school. Boston: Houghton Mifflin Company.

Slattery, P. (1995). Curriculum development in the postmodern era. New York: Garland Publishing, Inc.

Category Two: Sites to See, Places to Go. *Do one of the following:*

- Visit a first-class, world-class museum and study it from a teacher perspective, as a curriculum resource. Take notes about the museum's contents and the learning potential there for high school students in your subject.

  (The Smithsonian Institute museums are all first-class. An example of a world class museum in the science area is the Museum of Natural History, 79th Street and Central Park West, New York.)

- Attend a state convention of the professional state teachers' organization in your field. For example, in Virginia, the Virginia Association of Science Teachers meets annually in the fall.

- Attend a meeting of the professional national teachers' organization in your field. For example, in science, the National Science Teachers Association hosts several regional meetings each fall, and a national meeting in the spring.

- Participate in a summer professional development institute program in your field. Various institutes are sponsored by the Association for Supervision and Curriculum Development (ASCD), subject-area organizations, museums, organizations like the John Dewey Society and the Bertran Russell Society, state education departments using Eisenhower grants, and federal agencies like NASA and the Department of Energy. For programs in your area, check with your state's department of education, your state teachers' organization in your subject area, or the national organization. An alternative experience in this category would be to participate in an Earthwatch expedition. For information about Earthwatch expeditions, contact Earthwatch, 680 Mount Auburn St., PO Box 1904, Watertown, MA 02272.

Category Three: Taking Action. *Do one of the following:*

- Share your teaching ideas and experience with your peers. Write an article for a local, regional, state, national, or international teachers' publication in your field, or a piece for a general teachers magazine, such as *Middle School Teacher*. Alternatively, submit a proposal to do a presentation before your peers at a state, regional, national or international teachers' convention.

- Collaborate with one or more teaching colleagues in action research related to some area of mutual interest in your teaching. For example, you might decide to change some aspect of your teaching, such as, for instance, implementing a portfolio assessment system, or using a new technology or method.

- Attend *at least* three (they need not be consecutive, but note the date and sequence) meetings of the local school board either where you teach or where you live. Reflect on the meaning for the local secondary school curriculum of the deliberations and decisions you witness there.

- Complete Activity 7-2, which involves interviewing teachers about curriculum change, (Doll, 1996, p. 335). Reflect on your findings and what they mean for curriculum renewal in this school system.

- Volunteer for and participate as a member of the Curriculum Committee of the school in which you teach. Document the activities of the Committee and evaluate the school's success in reaching its curriculum goals and objectives.

References

Doll, R. C. (1996). Curriculum improvement: Decision-making and process. 9th ed. Boston: Allyn and Bacon.

Rosengren, J. H. (1993, Dec.-1994, Jan.). A post-final assignment: Continuing education beyond the classroom. Journal of College Science Teaching, 23(3), 181-182.

HAVE JOURNAL WILL TRAVEL: USING TRAVELING JOURNALS IN SCIENCE METHODS CLASS

Warren J. DiBiase, The University of North Carolina at Charlotte

Keeping a reflective journal is a major requirement of the middle-secondary science methods class at UNC-Charlotte. Each student is asked to keep a journal of their thoughts and reflections as well as any questions for which they are seeking answers. In addition, the students share what meaningful learning, major concepts, and/or insights they are developing. The students' reflections generally focus on assigned and outside readings, field experiences, class activities, and class discussions. However, the students often use the reflective journal to share their concerns and vent their frustrations. Issues of concern and frustration for the students include but are not limited to discipline, the ability to modify instruction to meet the needs of all learners, accountability (where the teacher is held responsible for student performance on state mandated testing), feelings of inadequacy and low self-confidence, and techniques to motivate students to learn.

The journal writing process is normally a two-way communication between the instructor and the student. In this class, however, sets of traveling journals are used. The journals not only travel between the students and the instructor but among the students in the class. The traveling journal process is explained to the students during the first class meeting.

Students write one journal entry during the period between subsequent class sessions. Journal entries travel in pocket folders supplied by the students. Each journal entry is written on a separate sheet of paper. Entries are marked with the number that corresponds to the week in the semester during which the entry was written. Entries can be either handwritten or typed. The students either place their names on an entry or mark the paper in such a way that they will be able to identify them at later date. The students deposit the folders in a designated place upon entering the classroom. After class, each student leaves with another student's folder. The students place their next journal entry into this "new" folder. In addition, the students are required to read and comment on all the other entries traveling in the folder. The students write their comments to a journal entry on a separate sheet of paper, on a “sticky” note, or directly on the entry itself. As such, the methods students have an opportunity to read and comment on each other's thoughts, concerns, questions, ideas, and insights. The students repeat this process, in similar fashion, all semester long.

The instructor collects and reviews journal entries three times: one-third into the semester, two-thirds through the semester, and again at the end of the semester. The folders circulate through the class prior to collection of the journal entries. At this time, the students retrieve and collate their journal entries, clip them together, and place their name on each entry. The instructor returns the entries during the next class session. The students remove the reviewed entries from the folders and place the latest, uncirculated entries into their folders and exchange them with another student. The traveling process begins anew. This whole procedure is repeated one additional time during the semester.

In the traditional two-way journal, the only feedback the students receive is from the instructor. Yet, all classes are composed of diverse individuals, each having their own expectations, perceptions, and experiences. As such, we all have much to offer and learn from each other. The traveling journal provides an opportunity for the students to both receive and provide feedback. In this way, the students are exposed to views, beliefs, and insights from a number of diverse and unique perspectives. As a result, the students are given the opportunity to critically assess their own beliefs, views, and perceptions.

A four-point rubric is used to assess journal entries. The scoring rubric is shown below.

4
- Entry provides an overview and reaction to assigned reading(s)
- Entry provides evidence of reaction to and assessment of class activities and discussions
- Entry provides evidence of "deep" reflection

3
- Entry provides only an overview of assigned reading(s) but no evidence of reaction to and assessment of class activities and discussions OR
- Entry provides an overview and reaction to assigned reading(s) but little or no reaction to and assessment of class activities and discussions
- Entry provides evidence of "moderate" reflection

2
- Entry provides little or no assessment/reaction to assigned reading(s) and/or class activities and discussions
- Entry provides no evidence of reflection

1
- Entry off topic

0
- No entry

The students have a bit of a problem understanding the logistics of how the journals travel at first. However, they fully grasp the process after two classes. Initially, the students are reluctant to comment on other student's journal entries. As the semester progresses however, they become more comfortable reading and commenting on other student's entries.

Traveling journals have been a requirement of the middle-secondary science methods class for the past three semesters. During this time, the process has been refined and fine-tuned. Methods students are asked to share their opinions of this process at the end of the semester. What follows are the general themes, which emerged from the students' comments.

Advantages	Disadvantages
• nonthreatening, anonymous, eliminates the fear factor, less stressful	• hard to keep track of, some students forget to return or loose entries
• get to view other's opinions	• some students do not comment, too little feedback
• realization that "I am not the only one thinking this!"	• a lot of work
• opportunity to vent and share with others	• hard to read other's handwriting
• encourages text reading	• others do not take you seriously
• got some helpful hints and nifty quotes	• need time for the take-up and hand out of folders
• forces you to think	• not enough practical advice given

Reflective journals are a requirement of many science methods classes. The process of writing these journals is normally a two-way communication between the instructor and the student. Traveling journals however, provide an opportunity to create an on-going discourse and community of sharing among the students. Although the process has some disadvantages, they are overshadowed by the benefits of using traveling journals.

PARTNERSHIPS TO PROMOTE PROFESSIONAL DEVELOPMENT AND INQUIRY LEARNING IN THE HEALTH SCIENCES

Genevieve Bardwell, West Virginia University
James Rye, West Virginia University
John Lewis, Greenbrier West High School
Cathy Morton McSwain, Webster Springs Junior High School
G. Jill Hyde, Marshall University Resource Collaborative
Priscah Simoyi, West Virginia University

Science teachers, who give providential thought to expanding their role as an educator, can reap benefits through programs such as the Health Sciences and Technology Academy (HSTA). Through HSTA, teachers partner with faculty at West Virginia University (WVU), high school students, and local communities across the state of West Virginia. The mission of this campus-community partnership is to increase the college-going rate of underrepresented students, and the number of health care providers in the medically under-served rural communities of West Virginia. HSTA provides academic enrichment (science, math, and technology) and leadership development for these high school students through on-campus summer institutes and extracurricular "after school" science clubs. The students gain from the informal science education opportunities and "the power of informal learning experiences" (NSTA, 1998, p. 154), as advocated by the National Science Teachers Association. The secondary science and math teachers who facilitate this informal science learning are enriched by their associations with faculty in higher education, and participate in on-going professional development offered through HSTA (Bock, 1996, Rye, 1998, Rye & Chester, in press). These opportunities enable teachers to become aligned with the "Changing Emphases" as set forth in the National Science Education Standards (National Research Council, 1996), e.g., "teacher as source and facilitator of change" (p. 72).

Program Participation and Scope

HSTA was initiated in two West Virginia counties in 1994, and has expanded to 20 counties. Over 400 secondary students (24% African American, 37% low income) and 50 teachers currently participate. Most of the teachers are certified in science; a small number are certified in other areas (e.g., mathematics and health occupations). At a summer campus institute, teachers complete professional development activities offered by post-secondary faculty (e.g., in education and the health and natural sciences) on the use of technology and inquiry-based instructional models that embed scientific ways of thinking and experimental design. In the following weeks at the institute, teachers work alongside faculty to practice these strategies by engaging students in analogous learning activities. These activities place a principal emphasis on relating science to human health through problem-solving, enabling teachers and students to gain exposure to science research skills, as well as university settings and personnel.

The community-based component of HSTA utilizes after-school science clubs as a vehicle for students and teachers to collaborate with faculty at West Virginia University on projects of student choice. According to the National Science Standards, "Teachers [should] select science content and adapt and design curricula to meet the particular interests, knowledge, skills, and experiences of students" (National Research Council, 1996). Following a problem-based approach, students conceive their project, investigate the problem, and present their findings at the annual HSTA Community Symposium. HSTA teachers, HSTA curriculum coordinators, post-secondary faculty, community health professionals, and local experts, work with the students to help them relate their project to health problems, and to set forth experimental designs. Accordingly, many of the projects that emerge through HSTA programming address contemporary health-related issues in the students' community.

Professional Development Leading to Classroom Reform

HSTA teachers are the most important learning resource for participating students (Rye, 1998). Rye portrays a model of teaching articulated through HSTA professional development, which emphasizes a paradigm shift from teacher-centered to student-centered instruction. One of the problem areas is ensuring student choice, which is vital to engaging student interest and maintaining it over the long haul. This concept is especially difficult for those teachers who are hesitant to apply science education reform strategies, so on going workshops and modeling is crucial. In their club environments, HSTA teachers are encouraged to use several inquiry-based approaches, one of which is the "three P's of science" (Peterson & Jungck, 1988, Rusbolt, 1994): problem posing, problem probing or solving, and peer persuasion. Collaborations among faculty in the health and natural sciences enable teachers to learn a variety of scientific techniques, such as DNA manipulations, histology preparations, and more broadly, experimental design, which enhance their understandings of the nature of science, and how to pose and solve problems.

Collaborations with faculty in education and HSTA curriculum coordinators provide HSTA teachers with various workshops and graduate courses to further integrate health science content, theory, and practice. The workshops acquaint teachers with computer techniques, new software, and other advanced technological practices they can take back to the classroom and clubs. For example, at the 1998 Fall workshop, teachers completed a “colony transformation experience” as part of an introduction to a molecular biotechnology curriculum (Hildebrandt & Brown, 1998) that is designed for high school students. A recent thrust has been directed to increase use of students' projects in teachers' classrooms: Teachers are invited to design integrated science modules that embed project themes, field-test the modules in their classes, and amend the modules to insure successful future application. An example of such is the ongoing module development project entitled "Ultraviolet Rays and Global Changes" (http://nt-hsta.hsc.wvu.edu/health/uvproje/nebulae.htm). HSTA students across the state have gathered data daily on the UV-B high. With this database, students can examine how various variables (e.g., latitude and season) affect ground-level UV intensity, and then relate these results back to health in their community. HSTA Teachers and a curriculum coordinator are preparing a UV module complete with related investigations, which is to be field-tested this spring. The framework being used in the modules is an outgrowth of a NSF statewide teacher enhancement program, the Coordinated and Thematic Science (CATS) project. Since it incorporates the state's instructional goals and objectives, this module framework is "teacher friendly." HSTA curriculum coordinators guide teachers to incorporate pedagogical techniques such as the learning cycle and concept mapping into the design of these modules, to insure an atmosphere of meaningful learning for the students (Odom & Kelly, 1998). HSTA teachers are positioned to observe how these strategies increase their students' reasoning abilities and achievement in future high school science courses. Other model programs, across the country, which espouse to successful reform-based science education use similar tactics and guidelines (Dickinson, 1997; Johnson & Lawson, 1998; Radford, 1998).

Additional incentives for teachers that are an integral part of the professional development include the opportunity to earn tuition-waived graduate credit and then a master's degree in secondary education (Rye, 1998). To date, eight teachers have completed their degree and approximately 12 others are pursuing such. Of those who have earned their degree, most have elected to stay with HSTA. Program evaluation data from questionnaires administered by the project evaluator--the West Virginia University Office of Health Services Research--suggest that teachers are transferring inquiry-based techniques to the classroom: On a scale of 1 (not at all) to 5 (a great deal), over 70% of teachers (n=30) responded "4" or "5" in respect to using the 3P's and concept mapping in their regular teaching.

Extended Investigations Facilitated by Teachers

The number of community-based science projects facilitated by HSTA teachers has grown concomitantly with expansion of the HSTA program, from approximately 35 projects during the 1995-96 programming year to 100 during 1997-98. An inductive analysis (Patton, 1990) of all projects (n = 100) carried out during the 1995-96 and 1996-97 programming years revealed that the majority were health-related, and yielded 47 different themes (Chester & Rye, 1997). Themes that accounted for at least seven projects, along with example titles, were (a) bacteria ("The effect of cooking temperature on the growth of bacteria in hamburger"), (b) dietary intake ("Comparisons of dietary excesses and deficiencies via two analysis programs"), (c) drinking water quality ("Lead? pH? A water analysis of 3 [area] schools"), (d) fat content of foods ("How much fat is in french fries"), (e) senses ("Do you remember smells better in the morning or the evening?"), (f) stream water quality ("The effects of [industrial] production on the water quality of Salt Lick Creek"), and (g) teen health ("Noise induced hearing loss: How does music that teenagers listen to affect their hearing?). Collapsing of themes through a logical analysis (Patton, 1990) revealed that they could be accounted for by four broad categories: human nutrition (33 projects), risk factors for disease (27 projects), environmental quality (24 projects), and physiological processes (10 projects). Most of the projects carried out during 1997-98 also could be accounted for by one of these four categories, however, there was a greater diversity of projects--including investigations into microwave leakage and the portrayal of smoking in movies--and several in the area of plant growth, e.g., "The effect of UV [light] on the germination and growth of marigolds."

These extended investigations represent a major thrust of HSTA community-based programming, and accordingly, teachers' evaluation of HSTA programming reflects the utility of this component. For the 1997-98 year, the mean ratings (1= nothing/not at all to 5 = a lot/very) of teachers as to what they have learned from being involved in HSTA community programming, and the overall effectiveness of that programming, were $\underline{M} = 4.285$ ($\underline{n} = 35$) and 4.107 ($\underline{n} = 28$), respectively. Mean ratings of teachers on these parameters for previous years, as reported by Rye (1998) and Rye & Chester (in press), are approximately as high or higher, and provide evidence that these extended investigations are meaningful program components. In justifying the rating of what was learned from participating in HSTA, one teacher simply put it this way: "I always learn along with the kids." Another was more explicit: "Until HSTA, I, a veteran teacher of 24 years, never really understood experimental design. Now, after using *Students and Research* [Cothron, Giese, & Rezba, 1993], I finally understand and am able to act. Students truly know what significant research is."

Teachers' Stories

Herein we provide in-depth perspectives of three exemplary community-based student projects, authored by the teachers who facilitated the student research, during 1996-98. In these stories, teachers have discussed (a) how the project was conceived (problem posing), (b) how the problem relates to human health and/or community issues, (c) project implementation (problem probing or solving), and (d) presentation of the findings to others (persuasion). The stories also provide the teachers' perceptions of what students gained from the experience and how facilitating the project contributed to their own professional development. These stories convey how programs such as HSTA can result in positive changes in teacher practice and improvements in student attitude and achievement.

Bacterial Counts in Undercooked Hamburger

Science projects at the middle school and early high school levels are a learning experience for both teacher and pupil. This is because the classroom science investigations at and below this level generally consist of a series of steps which the students can follow mindlessly--a sort of "cookbook approach" to science where the student follows a step-by-step procedure, records data, and answers a few questions related to the investigation. The young science student has had very little experience with problem posing, problem solving, or persuasion--the 3P's of the scientific method (Peterson and Jungck, 1988). The teacher quickly learns that many aspects of the scientific method are simply beyond the scope of most young students.

In order to prepare a science project, a student must be able to solve a problem scientifically. The first step in the problem solving process is to pose a problem. Although the young science student may not be visually impaired, he probably does not question what he sees. Unfortunately, observation without question can not become science. In order for the student to begin an investigation, he must be able to ask questions about what he sees and, more importantly, formulate hypotheses to guide his research. Therefore, we began the 1996 school year by presenting the students in our HSTA club with a few simple experiments designed to help them make observations, ask a few questions, and draw some important conclusions.

During the first few months of the year, our HSTA club performed quite a few interesting investigations. One of the experiments was "Hamburger Sizzler" (Campbell & Myers, 1997), an investigation which was designed to compare bacterial growth in raw hamburger to that in undercooked and well-done meat. The actual experimental procedure for "Hamburger Sizzler" did not allow the researcher to differentiate among different strains of bacteria and only provided data on the number of bacterial colonies which could be cultured from samples of raw, undercooked, and well-done hamburger.

Our initial research indicated that bacteria could be found on both raw and undercooked hamburger. This supported the student's initial hypothesis that the longer the meat was cooked, the fewer bacteria would be found. A few of the students were interested in determining if any of the bacteria could be *E. coli* 0157:H7, a deadly strain of bacteria mentioned in some of the background information provided in the "Hamburger Sizzler" investigation. The students had begun a scientific investigation in which they merely followed a step-by-step, cookbook procedure and were about to expand that procedure to consider an important community problem: to determine if the hamburger they were consuming contained dangerous bacterial contamination. Solving this project (the second of the 3P's) would require a great deal more work.

Implementing a project to determine if *E. coli* were present in hamburger required some special considerations. First, the students were going to have to learn sterile techniques in order to culture bacteria. Any bacteria found in the hamburger samples would have to be treated as if they were potentially pathogenic species. Second, special nutrient media would have to be used to culture the *E. coli*. Although the instructor was aware of several selective media useful in identifying the presence of *E. coli,* at this point no one knew whether or not any of the special media could differentiate between harmless strains of *E. coli* and the deadly *E. coli* 0157:H7. Therefore, special safety precautions, and expertise from a medical clinic, would be necessary in the culturing and examination of bacteria.

Research about *E. coli* on the Internet and assistance from the Rainelle Medical Center, our local clinic, provided the students with background knowledge about the rare strain of *E. coli* known as 0157:H7 which had been responsible for several deaths in the Western states. A member of the staff of the Rainelle Medical Center suggested a selective agar, which would not only grow *E. coli*, but would also allow an expert to determine if any of the colonies were the deadly 0157:H7. This agar, called MacConkey II agar, was purchased and used along with the assistance of the local medical center to complete the experiment.

The HSTA students modified their hamburger experiment to determine if there were *E. coli* bacteria on raw hamburger. Finding that there were *E. coli* on the raw hamburger samples, they set out to determine if cooking the hamburger killed the *E. coli* bacteria. They also incorporated procedures to determine if any of the samples of hamburger would contain the dangerous *E. coli* 0157:H7.

Our results using plain nutrient agar indicated that there were live bacteria in raw, undercooked, and even well done hamburger. Only one sample of well-done hamburger showed bacterial contamination, but the selective agar test indicated that those bacteria were not *E. coli*. The students compiled the data in tables and analyzed it using graphs. After gathering their data and recording it, the students wrote a report in which they attempted to persuade others that their hypothesis had been supported--the third of the 3P's.

After completing the investigations, the students were obviously aware that eating undercooked hamburger was dangerous. Their hypothesis (raw hamburger will contain *E. coli* but proper cooking will kill that organism) was supported. They also learned that it is important to carefully clean dishes, utensils, and surfaces that have been used in handling raw hamburger. More importantly, the students learned that they could gather information about a community problem using the proper scientific method. Simply cooking hamburgers at different temperatures became a means to gain invaluable experience in making observations, forming hypotheses, designing experimental procedures, gathering data, drawing conclusions, and persuading others--all aspects of the scientific method.

Facilitating the *E. coli*/food poisoning HSTA student project has contributed to my own professional development. The first major challenge I had to overcome was to motivate the students to devote an hour and a half a week of their own time to do research. The discovery of the "Hamburger Sizzler" lesson provided our club with an investigation that held the students' interest and sparked their imagination for several weeks. Perhaps the most important lesson I learned was that students will work on anything in which they are interested. Illuminating a young scientist's mind merely requires a spark of interest. Once the students were actively involved and eagerly questioning each and every result obtained, the job of teaching scientific procedure was made easy.

Young science students are weak in problem posing, problem solving, and persuasion--three important areas of the scientific method. Facilitating the young science students in becoming stronger in these areas requires experiments that are interesting and meaningful to the budding scientist. Providing our young students with such research opportunities is one of the main challenges facing science teachers who wish to improve students' research skills.

Hike for a Healthy Heart

The Hike for a Healthy Heart project was a result of the HSTA student's experience at the HSTA summer institute. During the institute, the students were exposed to a gross anatomy lab. It was during these sessions that they noticed the diseased hearts of so many of the cadavers and learned that West Virginia led the nation in heart disease. Upon returning to their clubs the following fall, the students were concerned about the rate of heart disease they had discovered and were curious as to whether the state trends were also true in their own county. It was during this time that the club came up with the research question "What is the leading cause of death in Webster County?"

The students believed that pulmonary disease would be the leading cause of death in Webster County because of the high percentage of persons employed in the mining industry as well as those who smoked. They found however, after researching the death certificates at the courthouse and the demographic study done for the county hospital, that heart disease is by far, the leading cause of death.

This information spurred the club to use this research in posing a problem. They believed that heart disease was preventable. The problem posed - what could they do about it? Thus preventing heart disease became the target of the students' community-based project and the beginning of the problem-solving phase.

The next several months our club continued to research the causes of heart disease while trying to design a walking track that would be easy, safe, simple, and convenient to use. The students felt that if the track did not meet these specific needs it would be more convenient not to exercise. It was also important to the students that persons with heart disease could walk without becoming isolated and overexerted by climbing hills. Their planning resulted in a track that is on sidewalks, and incorporates three levels of difficulty.

When the students decided to make the walk through the residential part of town, the next step was to receive permission from the city. Students chose a representative to speak with the Mayor and contact town council members. After receiving permission and an offer of aid from the town council, the students set about to measure off the distances. Again a representative from the club was chosen to visit the Water Company to ask to borrow a specific measuring tool for this task. The West Virginia American Water Company graciously allowed us to use their equipment and offered us their assistance, as well.

With distances measured and the track decided upon, the group began designing a pamphlet to describe the exercise track and why the program was important. Next the group worked on painting signs which were color-coded according to difficulty. This was the first problem encountered on the project. To color print the pamphlet map to match the signs would triple the cost of publishing. So far the project had been relatively cost free. The group decided that they would have the pamphlets printed and color the maps themselves to save money.

The club also designed a survey that would give them a general idea of the public's awareness concerning heart disease and the personal habits that may place them at risk. Students filled out an application for the WVU Institutional Review Board and had it approved by the University so they could conduct the survey on adults. The persuasion part of the project was to get this information out and educate the public that there were simple tasks they could do to prevent heart disease. The group decided they would survey various civic groups in the county, present their findings thus far, and also explain about the walking tracks. They hoped to pique the interest of the adults and also gain some publicity in the interim. The students divided themselves into two groups. It was decided that every club member would learn all aspects of the presentation. This way a sudden cancellation of one member wouldn't throw them into a frenzy. This was a terrific experience for the club. They presented to a wide variety of audiences and learned how to "play to the crowd."

My club has learned a great deal about the causes of death in West Virginia and the nation. They have taken this knowledge a step further and have attempted to do something about it. They have learned to present findings and field questions from the audience as well as educate their audiences about the interventions that can be taken to prevent heart disease. My club has learned leadership skills, how to set and reach goals, and now has an enormous advantage over other students when it comes to science and math. What wonderful ambassadors these students have become for the HSTA program. Because our community has seen such growth and self-confidence in these "once shy girls and boys," there has been a real push and demand for more students to be given the opportunities HSTA has provided. This prompted our county Board of Education to fund a second club with "school to work" monies.

HSTA has contributed to my professional development in many ways. The HSTA program has given me the boost I needed to get a Masters degree. As a child, I had always loved science and even had a mad scientists club in a dungeon-like basement. HSTA has rekindled my love for science as being fun. During my first summer with HSTA, I felt totally overwhelmed when surrounded by some of the best professors and teachers in the state. We were bombarded with information to digest and then put into action upon the students' arrival. However, the most satisfying feeling was when I managed to facilitate instead of teach. By the end of the second week I headed home exhausted and changed forever. The second year saw us all grow as a HSTA family. I had gained confidence and had direction. The teachers and staff became close and supportive, as the curriculum intensified.

The third summer was by far the greatest experience, because I was able to work in the gross anatomy lab. I was exposed to advanced Internet training and found two areas that make me want to work on continuing my degrees and certifications. I am now one of the better trained professionals in the county in terms of computer use with web boards, video conferencing, digital cameras, e-mail, HTML, and the Internet. This training continues to be an asset for grant writing, as well. I truly believe that HSTA has taken me to a new level of teaching and instruction, as well as increased my knowledge of science content. In conclusion I feel compelled to say that HSTA has been a major force in my growth as a teacher in the junior high classroom, as an adult working on a Master's, as a professional learning from other professionals, and as a facilitator.

Is There Too Much NO_x in the Air We Breathe?

Living in what we call the "chemical valley," due to a high density of industrial plants, my HSTA students were interested in what they might be breathing. In our science classes, we had been studying about stratospheric ozone and substances that contribute to the thinning of the ozone layer. Through research and discussing our project with university personnel, the students learned about "low level ozone". They were surprised to find that where stratospheric ozone is helpful, lower level (tropospheric) ozone may cause respiratory problems for humans as well as other living things. The students proposed testing the air in their valley to detect the presence of substances that might affect respiration and/or tropospheric ozone.

We made arrangements through the National Institute for Occupational Safety and Health (NIOSH) to get dosimeters for testing nitrogen oxides (NO_x). Each student received 3 dosimeters, each of which contained 2 testing receptacles. One was for nitrogen dioxide (NO_2) and the other was for nitric oxide (NO) to be measured in ppm. Each student was assigned a number that matched the number on the dosimeters so that the test results would be anonymous. The students were instructed to hang one in the room where the most "burning" would take place, one in the room where they spent most of their time, and one outside. All were to be up out of reach of small children and animals. In the school, we hung one in the boiler room, one in the second floor hallway, and one outside in a tree. After 7 days, the students gathered the dosimeters and sent them to NIOSH.

A NIOSH representative met with us to explain the results and what they meant. The students were surprised to find all the results of their tests were within safe limits. We also compared our results with those of another HSTA club further north, which obtained similar results. What did this prove? Only that the air was safe the week we tested. We are planning to run the tests again over a wider area and extended time frame. We took what results we had and wrote up our report using the "3 P's," presented at the annual HSTA fair, and even placed second in the Kanawha County Science Fair that spring.

The students were excited about the project because it reflected concerns within the community about living near the chemical plants. They learned how to research their topic using the library and the Internet, as well as about experimental design and presentation techniques. A math teacher worked with them on analyzing their results with box & whisker plots and how to find the mean.

All of this added up to a winning project and a lot of learning. Through the HSTA program, I received my master's and have been able to use the training I've received to improve my teaching techniques. The students in my classroom as well as the students I've worked with through HSTA are benefiting from my growth. It has been extremely rewarding to watch the change in my students as they grow and learn.

Discussion and Conclusions

The HSTA teacher's role as a facilitator of learning becomes dynamic, once the source of authority switches to the science experts and then to the students. Without the constraints of a classroom, there is no imperative to follow a required curriculum, hence students' interests can be honored. Further, teachers can allow an element of "fun" to enter the process of investigating a scientific problem, extending that joy to their students. Almost any investigation can be extended and offers students valuable junctures from which they can embark towards completion of a project to present at the annual HSTA Community Symposium. Because of the tremendous challenge of engaging underrepresented students in science and math enrichment, especially after a full day of school, it is critical that HSTA have such characteristics.

As HSTA increases in size and geographic location various problems surface, and finding solutions that maintain an adequate level of scientific rigor is crucial. It is important for the teachers and HSTA Curriculum Coordinators to take an aggressive stance towards professional development, ensuring that science education reform strategies are implemented. Through HSTA, teachers have opportunities to apply their professional skills and creativity through innovative curriculum design, such as the UV Rays and Global Changes modules, and the Secondary Level Interdisciplinary Curriculum (Campbell & Meyers, 1997), which was the source for the investigation about bacteria on hamburger.

HSTA students are involved in a personally meaningful learning experience, which increases their own scientific literacy, leadership skills, and awareness of how health issues can impact a community. Through the investigation of a problem, the teacher and students are able to take an additional step towards community issue resolution, thus providing a valuable "community service." The HSTA program and the evaluative research on the teachers and students involved, is an invaluable resource for designing curricula and future science learning environments.

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AUSUBEL AND PIAGET: A CONTEMPORARY INVESTIGATION

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Purpose of Investigation

The study was designed to allow the investigation of the following research questions:

1. What are the magnitude and direction of measurable significant differences in meaningful learning orientation and meaningful understanding of physics concepts between students with learning cycle (LC) instruction and those with meaningful verbal reception learning (MVRL) instruction?
2. What are the magnitude and direction of measurable significant differences in meaningful understanding of physics concepts measured by (a) conceptual questions, (b) problem-solving, and (c) mental models between students with the LC and MVRL instruction?
3. Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor of overall meaningful understanding of physics concepts?
4. Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor for each sub-measure of meaningful physics understanding?

This study was born from of the idea that the Piagetian theory of learning is very similar to Ausubel's theory of meaningful learning. This study is really a comparison of the two theories, the blending of the two theories.

Conceptual Framework

Meaningful learning is defined as "the formation of viable relationships among ideas, concepts, and information" (Williams & Cavallo, 1995). Students with a meaningful learning orientation attempt to make connections between concepts, whereas students not possessing a meaningful learning orientation memorize facts (Novak, 1984). Meaningful understanding is the product that may result when a person with a meaningful learning orientation and sufficient prior knowledge interacts with content that has the potential of being learned in a meaningful way (Novak, 1984).

The theory behind Ausubel's position espousing MVRL is based on several key concepts or processes: subsumption, progressive differentiation, superordinate learning, and integrative reconciliation. Subsumption is the process in which "new information often is relatable to and subsumable under more general, more inclusive concepts" (Novak & Gowin, 1984, p.97). Subsumption provides the "anchorage for new material". Progressive differentiation is the principle that "meaningful learning is a continuous process wherein new concepts gain greater meaning as new relationships (propositional links) are acquired" (Novak & Gowin, 1984, p. 99). Superordinate learning refers to the process in which a more general new concept subsumes previous subsumers (Novak, 1984). Previously learned concepts are subsumed and thus take on new meaning. Integrative reconciliation is the principle by which the learner "recognizes new relationships (linkages) between related sets of concepts or propositions" (Novak & Gowin, 1984, p. 103). Integrative reconciliation tends to break the isolation of concepts as relationships are formed between various previously isolated concepts or ideas. Often new propositional linkages between concepts displace misconceptions because a misconception is often simply the failure to integrate a particular concept.

Piaget believed that learners construct knowledge when a learner encounters input from the environment, the learner's schemes or mental structures incorporate the experiences (assimilation). If and when newly assimilated information conflicts with previously formed mental structures, the result is called disequilibrium (Marek & Cavallo, 1997). Disequilibrium motivates the learner to seek equilibrium. Regaining equilibrium or cognitive harmony results in what Piaget called accommodation. Accommodation is in the development of new mental structures. This "accord of thought with things" was what Piaget called adaptation (Piaget, 1963, p. 8). Thus, assimilation and accommodation represent the learner's adaptation to the environmental input. The learner must then organize the new or newly modified mental structure with previously existing mental structures. Organization is "the accord of thought with itself" (Piaget, 1963, p. 8). The LC, derived from Piagetian theory, consists of three phases: exploration, conceptual invention (or term introduction), and application (or expansion) (Marek & Cavallo, 1997).

Methodology

A quasi-experimental design using a non-equivalent control-group was used in this research. Such a design is characterized by the non-random assignment of subjects to groups and the administration of pretests and posttests to each group.

The sample consisted of college students enrolled in two sections of an algebra-based, first semester, freshmen level, physics course. One of the two sections was randomly chosen to receive the LC treatment, while the other section received the MVRL treatment. Statistical methods should eliminate any initial differences between the groups due to non-randomization. The researcher taught both sections of the lectures and all labs to minimize any effect of teacher variable.

Physics concepts taught were the same for each treatment. In the LC students: (a) experimented with materials to gather data (exploration), (b) constructed a concept from those data (conceptual invention), and (c) expanded this idea or concept (expansion).

In MVRL, students were taught how to construct concept maps. Topics and concepts were taught from the most general (energy and matter) to the most specific (i.e. acceleration and specific heat). Students were given information about the various concepts through verbal instruction, advance organizers, and the textbook or lab manual. Students then organized this information when they constructed concept maps.

Three concepts were chosen for analysis in this study: forces, Archimedes' Principle/density, and heat. All topics in the course were taught according to the prescribed treatment so students were accustomed to the treatment style.

The Test of Logical Thinking was used to determine students' reasoning ability. The Learning Approach Questionnaire is a Likert scale instrument used to measure students' meaningful learning orientation. The Force Concept Inventory was used to assess conceptual understanding of forces. Multiple choice exams on Archimedes' Principle/density and heat were constructed to assess conceptual understanding. Students' problem solving was measured by their score on novel problems. Mental models were also used to assess student meaningful understanding. Students were asked to write everything that they knew about the three physics topics. Correct items from mental models were placed on templates and scored. A student's overall physics understanding score was obtained by summing the student's conceptual question score, problem solving score, and mental model score. This overall score was obtained pretest and posttest for each of the three concepts (forces, density/Archimedes' Principle, and heat). Pretest scores were used as covariates or as measures of prior knowledge.

Data Analysis

For research question 1 to determine if any differences exist between the LC treatment and the MVRL treatment on the meaningful understanding variable, an analysis of covariance (one-way ANCOVA) was used. The effects of students' reasoning ability, prior knowledge, and meaningful learning orientation (all pretest measures) were covaried so that their effect upon their meaningful understanding was controlled. In order to determine if any differences exist between the LC and MVRL treatments on the meaningful learning orientation variable, a one-way ANCOVA was used. The effects of students' reasoning ability and their prior knowledge (pretest measures) were covaried so that any significant differences in meaningful learning orientation (dependent variable) between the groups were attributed to the treatments (LC or MVRL).

For research question 2 the procedure was the same as in question 1, except that it was done for each of the three measures of understanding separately. A one-way ANCOVA was used to determine if any differences exist between the LC and MVRL treatments on the meaningful understanding as measured by each instrument.

For research question 3, to determine which variable best explained students' overall meaningful understanding of physics concepts, a stepwise multiple regression was performed with students' reasoning ability, their meaningful learning orientation, their prior knowledge, and instructional treatment (LC or MVRL) entered as predictor variables in the regression analysis.

For research question 4, to determine which variable best explained students' sub-scale meaningful understanding of physics concepts, a stepwise multiple regression was performed as was done in question 3, but was used to predict student understanding on three understanding measures: (a) high level conceptual questions, (b) problem-solving, and (c) mental model scores.

Results

Question 1

Students from the two treatments did not significantly (at the .05 level) differ in their overall meaningful understanding of forces (p = .079), Archimedes' Principle/density (p = .097), or heat (p = .374) (conceptual question score + problem solving score + mental model score). For all topics studied, the LC and MVRL treatments did not differ significantly in their ability to change the students' meaningful learning orientation (p = .600 for forces, .830 for density/Archimedes' Principle, and .253 for heat).

Question 2

For forces, the students' concept scores, their problem solving scores, and their mental model scores did not differ significantly according to treatment (p = .258, .079, and .092 respectively). There were no significant differences in the students' conceptual and mental model understanding of density/Archimedes' Principle between the LC and MVRL treatments (p = .149 and .310 respectively). However, the LC and MVRL students did significantly differ in their density/Archimedes' Principle problem solving (p = .006). The LC students had a greater mean understanding in density/Archimedes' Principle problem solving than did the MVRL students. The magnitude of the difference was 1.492, which represents a 25% improvement over the MVRL treatment mean.

For heat, there were no significant differences in the LC versus the MVRL treatments in conceptual and mental model understanding (p = .871 and .396 respectively). However, the LC and MVRL treatments were significantly different in heat problem solving understanding (p = .019). The MVRL students were greater problem solvers than the LC students. The magnitude of the difference was .972, which represents a 16% improvement over the LC treatment mean.

Based upon this research if forces was the topic being studied, it made no difference which treatment (LC or MVRL) was used. However if density/Archimedes' Principle was studied, the LC treatment was better at producing understanding in problem solving. However, when heat was studied, the MVRL treatment was better at producing understanding in problem solving. Treatment success was dependent upon topic studied.

Question 3

For overall meaningful understanding of the force concept (posttest), treatment was the best predictor although it was not significant at the .05 level (r = -.263, F = 3.561, df = 48, p = .065) [r = correlation; F = F statistic; df = degrees of freedom; p = probability]. For posttest overall understanding of density/Archimedes' Principle, treatment was the best predictor (r = -.198, F = 1.878, df = 46, p = .177) although it was not significant. For posttest overall meaningful understanding of heat, the students' meaningful learning orientation was the best predictor (r = .157, F = 1.155, df = 46 p = .288) although it was not significant. Based upon these three findings, question 3 may not be formally answered as neither reasoning ability, learning approach, prior knowledge, nor treatment were significant predictors of overall meaningful understanding.

Question 4

Concept Understanding

For concept understanding it was found that for forces, prior knowledge was the most significant predictor in the model (r =.587, F = 21.861, df = 48, p = .000). However, reasoning ability was the next best predictor of force concept understanding (r = .451, F = 9.720, df = 48, p = .003). Together, reasoning ability and prior knowledge of force concept explain 45.6% of the variance in posttest understanding of force concepts. For density/Archimedes' Principle concept understanding, prior knowledge of density/Archimedes' Principle was the better predictor of students' posttest density concept understanding (r = .406, F = 6.479, df = 46, p = .014). Reasoning ability was the second best significant predictor (r = .387, F = 5.570, df = 46, p = .023) of students' density/Archimedes' Principle concept scores. Together reasoning ability and prior knowledge explain 25.7% of the variance in students' density concept scores. For heat concept understanding, reasoning ability was the only significant predictor of students' heat concept scores (r = .348, F = 6.355, df = 46, p = .015). Reasoning ability thus explains 12.1% of the variance in students' heat concept scores. In summary, students' conceptual understanding was best predicted by students' prior knowledge scores for forces and density/Archimedes' Principle. However, students' heat concept understanding was best predicted by their reasoning ability.

Problem Solving

For predicting students' problem solving score for forces, the students' reasoning ability was the only significant predictor (r = .391, F = 8.681, df = 46, p = .005). Reasoning ability explained 15.3% of the variance in students' force problem solving. For density/Archimedes' Principle problem solving, treatment was the only significant predictor of students' problem solving scores (r = -.277, F = 8.283, df = 46, p = .006). The MVRL treatment correlated with decreased problem solving scores, while the LC treatment correlated with increased density/Archimedes' Principle problem solving scores. Treatment explained 7.7% of the variance in density/Archimedes' Principle problem solving scores. The students' reasoning ability was the better significant predictor of heat problem solving (r = .356, F = 6.507 , df = 46, p = .014). Treatment was the next best significant predictor of students' heat problem solving (r = .338, F = 5.803, df = 46, p = .020). A MVRL class correlated with greater problem solving scores.

Together treatment and reasoning ability predicted 22.6% of the variance in heat problem solving scores.

Mental Models

None of the predictor variables (reasoning ability, learning approach, prior knowledge, or treatment) significantly predicted mental model scores. Thus, it is not possible to gain insight into predicting mental model scores from this work.

Conclusions

Conclusions for Question 1: Overall Meaningful Understanding

No measurable differences in meaningful understanding were found for forces, density/Archimedes' Principle, or heat. Separate *t*-tests comparing pretest and posttest scores of overall (conceptual + problem solving + mental model) understanding for each group revealed a significant ($p < .000$) increase in meaningful understanding of the three physics concepts (Williams, 1997). Therefore, the LC and MVRL students improved their meaningful understanding. The students from the different treatments had nearly equal overall meaningful understandings. The results were similar because Piaget and Ausubel specified similar criteria for meaningful learning. *Both theories explain learning but in different terminology.* Following are a description of Piagetian theory explaining learning within the LC treatment and a description of Ausubelian theory explaining learning in the LC treatment. Figure 1 illustrates both theories for the LC.

Figure 1.
The Learning Cycle (LC) and Piagetian and Ausubelian Explanation of How each Phase Led to Overall Meaningful Understanding

Piagetian	LC	Ausubelian
	Exploration	
assimilation disequilibrium		gives prior knowledge subsumption
	Concept Invention	
accommodation		progressive differentiation
	Concept Expansion (or application)	
organization		superordinate learning integrative reconciliation

In the LC, students took this experience, constructed the concepts and formed greater meaningful understanding of these physics concepts. According to Piaget's (1963) theory (left hand column Figure 1) , the concrete experience allowed assimilation (incorporation of experiences into mental structures) which led to disequilibrium (conflict between mental structures). During the conceptual invention phase of the learning cycle, accommodation (change or development of new structures) occurred. Piaget called the processes of assimilation and accommodation adaptation. The student adapted to the input from the exploration. During conceptual expansion, the student organized the new mental structure with structures previously developed (organization). Thus, the LC students increased their meaningful understanding of the concept.

Ausubelian theory (right hand column Figure 1) can also be applied to explain students' learning during the LC. In the Ausubelian interpretation (Ausubel, 1963), the concrete experiences during the exploration provided the relevant prior knowledge necessary for meaningful learning. The exploration also provided the opportunity for subsumption during which new information was related to more general ideas. During conceptual invention, the students made links between data which encouraged them to orient their learning toward meaningful learning rather than rote. Students were encouraged to link new terminology to the phenomena observed during the exploration (progressive differentiation). Superordinate learning (new links cause one idea to subsume previous one) and integrative reconciliation (new links form between the old and new ideas) occurred during the conceptual invention phase of the LC.

Similarly, each theory can be used to explain how the MVRL treatment led to students' meaningful understanding. Following are a description of Piagetian theory explaining learning with the MVRL treatment and a description of Ausubelian theory explaining learning in the MVRL treatment. Figure 2 illustrates both theories for MVRL.

According to Piaget (Piaget, 1963), the students who were in transition or who were formal operational assimilate input from verbal instruction (left column of Figure 2). Students were told to construct concept maps relating various aspects of the concept(s). The construction of the concept maps were based upon reading passages from the textbook. Students struggled with ways to relate the items in the passages from the textbook for additional assimilation. The laboratories provided the opportunity for the students to become disequilibrated and to accommodate to the data. Organization occurred during the students' efforts to construct a concept map that related their thoughts about additional concepts to their thoughts about the new phenomena or concept studied.

Figure 2.
Meaningful Verbal Reception Learning (MVRL) and Piagetian and Ausubelian Explanations of How each Phase Led to Overall Meaningful Understanding

Piagetian	MVRL	Ausubelian
	verbal instruction	
assimilation*		prior knowledge subsumption
	advance organizers & concept maps	
assimilation*		subsumption progressive differentiation
	laboratories	
disequilibrium accommodation		subsumption progressive differentiation
	advance organizers & concept maps	
organization		superordinate learning integrative reconciliation

* for formal operational sample only.

According to Ausubel (1963), prior knowledge and subsumers for concepts were provided by verbal instruction (right column Figure 2). Students were encouraged to orient their learning away from rote when they were asked to construct concept maps. Laboratories and concept maps also promoted subsumption and progressive differentiation as new links were created. More advance organizers or verbal instruction caused the students to link items to other, less specific items (superordinate learning). Furthermore, integrative reconciliation was accomplished as additional maps were constructed or revised by the student.

Piagetian *and* Ausubelian theory can explain how the students in each treatment achieved overall meaningful understanding. It appears that Piaget *and* Ausubel have viable theories of learning which appear to explain learning by using different terms. More research needs to be conducted to validate this premise.

Conclusions for Question 1: Meaningful Learning Orientation

The remaining part of question 1 deals with the meaningful learning orientation of the students in the two treatments. For all topics, the LC and MVRL students' meaningful learning orientation did not differ significantly. Ad hoc *t*-tests showed that there was not a significant change in meaningful learning orientation scores (pretest to posttest) for *either* treatment. Neither increased or decreased their tendency to learn meaningfully. Perhaps this is evidence that it is not possible to change the learning orientation of college physics students during such a short treatment. Dickie (1994) found that students' tendency to learn by rote *increased* after a college physics class. Perhaps the students from the treatments in this study left the courses with a greater tendency to learn meaningfully than if they had been in a course that was taught traditionally.

Conclusions for Question 2

There were no significant differences between the LC and MVRL treatments for students' concept understanding or mental model understanding of forces, density/Archimedes' Principle, and heat. These findings provided more evidence for the idea that Piagetian and Ausubelian theories are similar theoretically if their end-products (students' conceptual understanding and mental model knowledge) are not significantly different.

There were no statistically significant differences among treatments on the problem solving for forces. However for density/Archimedes' Principle data, the LC students had a 25% improvement in problem solving over the MVRL students' mean scores. This may simply indicate weaknesses in curricula for the two treatments. The LC exploration was a density problem solving activity similar to those on the assessment instrument. Perhaps the MVRL on density/Archimedes' Principle did not to provide suitable anchors, thus creating less problem solving ability by its students. A Piagetian explanation for the MVRL curricular weakness for density/Archimedes' Principle might be that there was no assimilation because of a lack of previous experience. A lack of experience could possibly have caused the MVRL students to lag behind in density/Archimedes' Principle problem solving.

For heat data, the MVRL students had a 16% improvement in problem solving over the LC students. From day one in the MVRL treatment, students were relating concepts to energy and heat. These students simply may have thought about heat more and made more connections which increased their problem solving ability. The LC students did not have an earlier LC to provide anchors about heat. Thus, the LC students had less experience with heat (according to Piaget) or less prior knowledge about heat (according to Ausubel). Whether explained in Piagetian terms (no assimilation occurred) or in Ausubelian terms (no subsumers were available), the LC students solved fewer problems on the heat concept than the MVRL students did. Why the same differences between treatment due to treatment weakness or strength did not appear on the conceptual and mental model assessments are unknown.

Conclusions for Question 3

Neither treatment, nor reasoning ability, nor meaningful learning orientation, nor prior knowledge were significant predictors of overall physics (concept + problem solving + mental model) understanding at the .05 level. Very little may be concluded from the results of question 3 aside from the fact that more research must be conducted with other instruments and well-tested curricula to determine what variables are the strongest predictors of overall physics understanding.

Conclusions for Question 4

For forces and density/Archimedes' Principle data, students' prior knowledge was the best predictor of concept understanding while reasoning ability was the next best predictor. Reasoning ability was the only significant predictor of concept scores for heat. Without prior experience, conceptual understanding decreased for forces and for density/Archimedes' Principle. That is to be expected by both theories, for without assimilation or subsumers, meaningful learning does not occur (Ausubel); or without adequate reasoning ability, abstract concepts such as forces, density/Archimedes' principle, and heat can not be learned (Piaget).

For problem solving understanding of force and heat concepts, reasoning ability was the best predictor. This can be explained if Piagetian reasoning ability and the Ausubelian term "potentially meaningful" have similar meaning. If forces and heat were presented in a potentially meaningful way, then according to Ausubel meaningful learning measured by solving problems could occur. If forces and heat were presented to formal operational learners, then according to Piaget problem solving understanding could occur. For heat, the next best predictor of problem solving was treatment, with MVRL treatment correlating with greater heat problem solving. For density/Archimedes' Principle, the best predictor was treatment, with the LC treatment correlating with greater density/Archimedes' Principle problem solving. This finding is consistent with the findings of question 2. For density/Archimedes' Principle, this may be explained by the apparent weakness of MVRL combined with the strength of the LC and the apparent strength of MVRL presentation of heat combined with the apparent weakness of the LC.

None of the predictor variables were significant predictors of the knowledge measured by mental models. Mental models should be examined further as tools to measure meaningful understanding of college physics students.

The analysis of predictor variables for concept understanding and problem solving further support the idea that Piagetian and Ausubelian theory are similar in their explanation of how learning occurs. All variables mentioned in theories by Piaget and Ausubel were not significant predictors for concept understanding or problem solving, so exact correlations of the theories are not yet possible based on the findings of this research.

Significance of this Study for Future Research and Instruction

Students need to be instructed in a way that promotes the abandonment of rote learning in favor of more meaningful learning approaches (McKinney, 1993; NSTA, 1993; Aldridge & Strassenburg, 1995). Students' tendency to learn more and more meaningfully and with meaningful understanding are desired outcomes of physics education. Thus, this study is significant to physics educators interested in improving students' meaningful understanding.

This study is significant in that according to this research, there were no significant differences between the Piagetian-based LC and the Ausubelian-based MVRL for college students' meaningful understanding of physics concepts. What the results of this research suggested is that although Piaget and Ausubel used different terminology to explain learning, these theories are very similar. This research is novel in that it attempted to blend the two theories. Far more questions were raised than have been answered. For example, where is the disequilibrium in Ausubel's theory? What is the motivating factor in Ausubel's theory that compares to the disequilibrium in Piaget's theory? Is the learning orientation sufficient to motivate the learner to make the necessary connections? If it is, what is the motivating force for organization in Piagetian theory? Further research is necessary to obtain answers to these critical questions.

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A CONTINUUM FOR ASSESSING SCIENCE PROCESS KNOWLEDGE IN GRADES K-6

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Assessing Knowledge About Science

Assessment of elementary school students' knowledge about science is essential for at least two reasons. First, if teachers are to increase both the amount of science content taught and opportunities for learning about processes associated with learning science, they need more accurate information regarding what a student does and does not know. Second, more accurate feedback regarding the content and process knowledge of students at all grade levels could inform many of the parties interested in science education reform such as teachers, policy makers, and administrators. While the National Science Education Standards (National Research Council [NRC], 1998) call for teaching more science content at all grade levels, they also recognize that students need to learn the processes associated with scientific thought as well. Accurate assessments in both areas would allow teachers to know more about how students are learning science, schools districts to know about the effectiveness of their enacted curricula, and policy makers to know about the effectiveness of their decisions to reform science teaching and learning.

In spite of the facts that curricular materials and assessment tools exist for science content and concepts at all grade levels, there is very little information on how to assess the science process skills students are expected to learn through science instruction. The continuum for assessing science process knowledge we developed offers a fresh approach to capturing this knowledge over time. We believe this continuum has the potential to provide additional information and more accurate feedback to students, teachers, school administrators, and policy makers in ways that traditional content assessments alone do not.

It is important to note that the assessment continuum we developed is not designed to evaluate everything a student could know about science. Knowledge of specific science content, for example, is not something this continuum is designed to assess. Instruments that document learning of specific science content knowledge are generally prepared to reflect the course of study adopted by a local school district (e.g., the Southwestern City Schools Science Course of Study, n.d.). In additional, many states have or are developing competency based examinations in science that evaluate unifying concepts such as systems, constancy and change, and form and function (see Science: Ohio's Model Competency Based Program, 1994). In Ohio, instruments that assess this type of information are required of all students in grades four, six, and nine. Frequently, the feedback provided on these types of instruments is "high-stakes" in that it is used as a primary source of data for evaluating students, teachers, administrators, and the decisions of policy makers. We, on the other hand, intentionally wrote our continuum for assessing science process knowledge to capture a different aspect of learning - the growth of an individual student's knowledge about processes that we believe are essential when learning science.

The assessment rubric that arose from our efforts to document changes in learning to learn science is presented in Appendix B. However, before describing the development of our continuum, it is necessary that we provide the reader with some of our assumptions about the ability of elementary school teachers to assess science process knowledge. Knowing that most elementary school teachers are keen observers of incremental change in process skills associated with reading and writing, we assumed they should also be able to observe and record information regarding science process skills once they understood the assessment items on our continuum. A second assumption of our efforts to produce this continuum was that repeated use of the continuum by a teacher would capture the development of a student's science process knowledge over time. Our intent here was to have an assessment rubric that could document changes in knowledge of science processes that were incremental and not easily captured by multiple choice or short answer instrument. Finally, we assumed that any instrument we developed would require few changes to the existing science instruction for an elementary school teacher. The point here is that we did not want teachers to think that their curriculum must change to address the items on our continuum. Rather, we wanted teachers who used the continuum to use the feedback they received from using the continuum to adjust their instruction as needed. Before presenting the science continuum we would like to describe some of the significant factors that contributed to producing the continuum for assessing science process knowledge.

A Framework for Assessing Learning

Construction of the assessment continuum took place at Highland Park Elementary (Southwestern City Schools, Grove City, OH) through the efforts of four Highland Park teachers, one teacher from Richard Avenue Elementary, and a university science educator. Highland Park is one of seventeen elementary schools in the Southwestern City School District with approximately 500 students, kindergarten through grade five. Most students live in the surrounding neighborhoods, although some attend by special request of their parent(s). The children come from a wide range of socio-economic backgrounds. Most of the teachers at Highland Park have been teaching at this school for more than five years, and most hold the master's degree in education. A child-centered school, the staff at Highland Park shares a developmental philosophy of learning that is not linked strictly to a student's age. The Highland

Park view of learning includes the notions that children are motivated and capable learners from their first enrollment at the school. Students experience elementary school as only one point on a learning continuum that begins with their preschool experiences. Students in all grade levels are free to follow their own interests through a curriculum that includes thematic units of instruction. During instruction, teachers work with individual students and collaborative groups of students to ensure that all areas of the curriculum have been covered.

Through their shared teaching experiences at Highland Park, these teachers have found that many children progress through stages of development that reflect increasingly complex ways of representing what they are learning. These teachers have settled on describing the progressive development of students as emerging, beginning, developing, advancing or consolidating with respect to how they represent their thinking on a topic (see the Literacy and Writing sections of Student Progress Reports in Appendix A). The teacher's task is to assess a student's stage of intellectual development and then expand upon that student's knowledge and abilities so that he or she develops competency in specific intellectual abilities as well as practical skills. In doing so, these teachers explicitly recognize that children learn at different rates and in different ways. They plan their instruction, both individual and whole class, in response to feedback they receive from applying assessment rubrics like the ones for reading and writing. Although the methods of instruction at Highland Park differ significantly from other schools in the Southwestern School District, students in the school are expected to follow the same course of study as other students in the district.

Applying their philosophy of learning to themselves, the Highland Park staff regularly seeks out professional development activities that suit their needs as teachers. In 1991, the College of Education at Ohio State University selected Highland Park Elementary as a professional development school (PDS). The model of PDS at Ohio State is designed to "connect colleges of education with schools; to establish working partnerships among university faculty, practicing teachers, and administrators that are designed around systematic improvement in practice; and to serve as settings for teaching professionals to test different instructional arrangements, for novice teachers and researchers to work under the guidance of gifted practitioners, for the exchange of professional knowledge between university faculty and practitioners, and for the development of new structures designed around the demand of a new profession." (Kirschner, 1995)

Highland Park's involvement in PDS allowed staff members to initiate and design experiences that contributed to their learning while earning graduate credit from The Ohio State University. In 1991, the Highland Park staff sought out Dr. Becky Kirschner, an Ohio State University professor, to assist with the coordination of their professional development interests. Among these interests was an action research project involving two teachers in redesigning the school's student progress report (Howlett & Kerstetter, 1995). The intent of this research was to make the assessment of reading and writing consistent with the Highland Park philosophy of learning. In brief, these teachers wanted to change "the way they assessed children, both for ongoing instruction and for 'reporting to parent' purposes" (Dickinson, Kirschner, & Rogers, 1995, p. 43). In light of these interests, they wanted to develop an assessment instrument that would communicate developmental aspects of learning in reading and writing in addition to answering the most commonly asked question by parents - "Is my child reading at grade level?" An assessment of this kind would also offer teachers feedback on their instruction, feedback that could be used when planning future instruction. In the end, these teachers developed a system of documenting student progress that included portfolios of student work to document growth as learners, a revised assessment instrument that could contribute to their ongoing instruction, and a revised reporting mechanism for parents (Dickinson, Kirschner & Rogers, 1995). Appendix A contains samples of the Primary and Intermediate Student Progress Report's that were fully developed for assessing reading and writing.

Developing a Continuum for Assessing Science Process Knowledge

Over the years, Highland Park teachers made many modifications to their assessment continua for reading and writing. However, other content areas such as social studies, science, and health remained lumped together on the student progress report under the heading of "Integrated Curriculum." In an effort to continue developing the student progress report, teachers at Highland Park (the co-authors of this paper) again contacted a science educator (the first author) to construct a continuum for assessing science that was similar in format to those already in use for assessing reading and writing. Our joint involvement began in 1996 by sharing each individual's ideas about what it might mean to be scientifically literate in grades K-6. Next we discussed processes of science we believed were applicable when learning a wide variety of science content. Among the processes we identified as necessary for K-6 students were observing, asking questions, naming and classifying natural objects, attending to details, familiarity with equipment, using resources, rational thinking, and integrating science with other disciplines. From this list we developed a rationale for why we thought each component was important to scientifically literate people (see Table 1).

We then illustrated each component of science with assessment items we felt a student might say or activities they might engage in that would indicate they were competent with a particular item at each developmental level (see Table 2).

Table 1
Processes of Science

Observing

Rationale: Scientific questions usually begin with observations of the natural world. Scientists observe objects, properties of those objects, and phenomena that objects undergo.

Asking questions

Rationale: Scientists ask questions about objects found in the natural world and the phenomena they undergo.

Naming and classifying natural objects

Rationale: Fundamental to all scientific investigations is communicating about the objects, parts of objects, and phenomena that occur in the natural world. Scientists give names to objects and phenomena so they can be precise when talking about the object or phenomena they are interested in studying.

Attending to details

Rationale: Scientists keep careful records of their observations. All scientists collect, organize, and analyze data in many forms to help answer their questions.

Familiarity with equipment

Rationale: Scientists use equipment to help them make more precise observations. They must be comfortable with the technology used in their investigation.

Using resources

Rationale: Scientists use existing resources to help them think about their current questions. Some of the resources they consult include people (colleagues or experts in the field), reference books, tables, printed reports of past research, and the Internet.

Rational thinking

Rationale: Scientific thinking involves reasoning about data and drawing conclusions. This reasoning may be either inductive (drawing conclusions based on specific instances) or deductive (establishing generalizations from which conclusions follow).

Integrating science

Rationale: Science includes using (and sometimes learning) mathematics, writing, thinking, reading, and working with others. More often than not, science involves teams of researchers with each member of the team contributing different strengths to the combined efforts of all.

Scientists report the results of their investigations in several ways --orally at conferences involving their peers and through written media such as journals and the Internet.

Table 2
Developmental Levels and Science Process Knowledge

<table>
<tr><th colspan="2">Science: Your child's learning progression as of:
Emerging Beginning Developing Advancing Consolidating</th></tr>
<tr><td>Emerging
-describes the gross physical characteristics of objects
-explores the physical capacity of containers or objects
-knows the names for (un)common physical objects
-asks questions of a factual nature
-defers explanation to others or authorities
Beginning
-asks questions about the characteristics of objects and phenomena
-explains how an object interacts with its surroundings
-uses science equipment to collect information (rather than as a toy)
-understands that phenomena can have names
-gives egocentric reasons as an explanation
Developing
-understands how to collect and organize data
-uses science equipment safely, appropriately, and effectively
-identifies variables that affect an experiment
-gives procedures for what was done
-explores the research of others
-gives increasingly more precise descriptions of common physical objects
-is thinking about objects and physical event from a perspective other than their own
-links explanations for an event with observations of the event</td><td>Advancing
-describes common physical objects in precise detail
-predicts how an object would behave if you changed the conditions
-uses science information books or resources in the library
-extracts useful facts or constants from reference materials
-recognizes the importance of the data or information collected
-selects appropriate science equipment to use during an investigation
-links events into a chain/sequence of events that explain some phenomena
-describes the outcome of an investigation
Consolidating
-uses scientific vocabulary appropriately and accurately
-is comfortable/confident using science equipment
-gives causal explanations for why something happened as it did
-beginning to reason about events that could happen hypothetically
-completes a series of investigations on one topic
-writes about questions they would like to study next
-communicates their findings and questions of interest to other

Nov Jan Mar Jun
EFFORT ___ ___ ___ ___</td></tr>
</table>

Testing and Revising the Continuum

In spite of our efforts to bring the continuum to this stage of development, the first attempt to use our continuum was met with several significant problems. First, the teachers found that some assessment items could not be assessed from a single interaction with a student. To address this problem we identified those assessment items that could be evaluated by a single interaction with (+) and those that need multiple interactions with (√). Second, we found that most of the data we attended when using the assessment were verbal or written statements made by students. This problem was addressed by adding four columns to the right of each assessment item. Information placed in these columns could come from a variety of sources including observation of a student's behavior, verbal statements, written text or illustrations. The intent of these columns was to force teachers to look for additional ways that students might represent their understanding of science process knowledge.

When using the continuum for the first time several teachers noticed that the students they rated higher on this continuum were not necessarily the same students who were placed higher on the continua for reading and writing. This seemed odd at first because there was an implicit assumption that an accomplished reader and writer should be accomplished in all subjects. However, as the teachers began to talk about the individual students who they placed higher on the science continuum, it became clear that the evidence for competency in science was not exclusively limited to competency with reading and writing. We believe that assessing across the four categories of teacher observation, verbal comments, written text, and pictures etc. offers a more complete and accurate assessment of a student's knowledge of science processes.

To further address the problems we recognized when first using the continuum we continued to add examples to the four evidentiary columns. These examples were placed in a grid that linked each assessment item to the data that could serve as evidence that he or she had achieved competency for an item (see Appendix B). This process required a considerable amount of time (and is still underway) but resulted in a much clearer understanding of the developmental aspect of learning we were attempting to capture with the continuum.

After completing the grid, we tested the continuum a second time and found it to be much easier to use and more informative. In particular, because the evidence we now accepted for competency in science can be demonstrated through multiple modes of representation, we believe our continuum is a more accurate means of assessing what a student does or does not know. Put another way, some aspects of learning how to learn science (e.g., uses science equipment safely, appropriately, and effectively) must be demonstrated, they can not be determined by paper and pencil assessments. A second benefit of using the revised continuum was that the teachers were starting to become much more aware of how the science activities students engaged in did or did not allow them to assess items on the continuum. While feedback from using this continuum allows teachers to provide students with more accurate information regarding their current development as a learner of science, it also allowed the teachers to examine their assessment practices related to science instruction. The formative nature of this assessment rubric was an unexpected outcome but one that fits well with the National Science Standard recommendation that there be a "match between the technical quality of the data collected and the consequences of the actions taken" (NRC, 1998, p.5).

Conclusions

Parents of students attending Highland Park have yet to receive Student Progress Reports that include the new form of science assessment. However, they have been very receptive to similar information about their child's development with respect to reading and writing.

Highland Park teachers believe that many parents use feedback from the Student Progress Report to help their children work on specific literacy skills outside of the school setting. We anticipate that feedback from the science continuum will have similar impacts on the parents of these students. It is also our belief that, in combination with district and state level evaluations of specific science content and themes, information obtained from our continuum can provide a more complete picture of the process knowledge a student needs to master in order to learn science well. The continuum for assessing science process knowledge was recently presented to all of the teachers at Highland Park Elementary with the expectation that they would use the continuum to assess students during the next term (Spring 1999). We plan to continue refining our continuum based on the feedback we receive from these teachers and to include the fully developed continuum on the Student Progress Report for the 1999-2000 academic year.

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Appendix A (follows)

Highland Park Student Progress Report
(Note format for assessing Reading and Writing processes)

KEY
for Levels of Achievement for INTEGRATED CURRICULUM, MATH, ART, MUSIC, & PHYSICAL EDUCATION

1-Applies skills and concepts independently
2-Is exploring skills and concepts
3-Is successful when assisted
4-Is experiencing difficulty
(Blank Space) Not applicable at this time

KEY
for EFFORT and SOCIAL DEVELOPMENT
O Outstanding I Improving
S Satisfactory N Needs Improvement

SOCIAL DEVELOPMENT	Nov	Jan	Mar	Jun
Works independently				
Works well with others				
Listens attentively				
Accepts responsibility for actions				
Can cooperate and compromise				
Follows directions				
Follows rules				
Organizes time, work, and belongings				
Works carefully and neatly				
Completes work in a reasonable time				
Effectively communicates ideas orally				
Art				
Understands key ideas/demonstrates skills				
Participates in activities				
Music				
Understands key ideas/demonstrates skills				
Participates in activities				
Physical Education				
Demonstrates appropriate motor skills development				
Participates in activities/demonstrates Sportsmanship				

LITERACY

READING Your child's learning progression as of:
Emerging Beginning Developing Advancing Consolidating

Emerging
-enjoys books and being read to
-reads from pictures rather than print
-tells a familiar story while turning the pages
-knows that books have a front and a back
-recognizes that print contains meaning
-responds positively to being read to

Beginning
-is building confidence as a reader
-is increasing ability to use reading strategies
-demonstrates knowledge of the conventions of print
-responds to stories
-recognizes sight words

Developing
-is achieving confidence as a reader
-is developing the ability to use a variety of strategies
-knows more print conventions
- responds to stories
-uses basic reference skills
-is increasing sight vocabulary rapidly

Advancing
-is a confident reader
-uses a variety of strategies successfully
-responds to literature and text
-expresses opinions and can support them with evidence from a book
-uses books to get information
- has a wide reading vocabulary

Consolidating
-is an accomplished reader
-can manipulate texts
-responds to literature texts in a variety of ways
-gathers information and ideas from texts
-has an expanded vocabulary

	Nov	Jan	Mar	Jun
EFFORT	___	___	___	___

WRITING Your child's learning progression as of:
Emerging Beginning Developing Advancing Consolidating

Emerging
-understands that language can be written
-knows some print conventions
-may try to read own writing

Beginning
-is building confidence as a writer
-is becoming aware of steps in the writing process
-tries limited forms of writing
-forms letters correctly
-applies some spelling knowledge
-uses some punctuation

Developing
-demonstrates growing confidence as a writer
-is beginning to use steps in the writing process
-begins to consider audience for each piece
-is trying different forms of writing
-writes legibly in print and cursive
-is increasing spelling knowledge
-uses more punctuation

Advancing
-is a fluent, confident writer
-is consistently using most steps in the writing process
-writes appropriately for different audiences
- controls more forms of writing
-spelling is generally accurate
-punctuation is generally accurate

Consolidating
-is an accomplished writer
-is effectively using all steps in the writing process
-writes for a wide range of purposes
-knows that the purpose and audience for writing
-spelling and punctuation are highly accurate

	Nov	Jan	Mar	Jun
EFFORT	___	___	___	___

INTEGRATED CURRICULUM
SOCIAL STUDIES, SCIENCE, HEALTH

Unit of Study: ____________

Nov. ____________

Jan. ____________

Mar. ____________

June ____________

	Nov	Jan	Mar	Jun
EFFORT	___	___	___	___

MATHEMATICS

Math Concepts

	Nov	Jan	Mar	Jun
Patterns	___	___	___	___
Numbers	___	___	___	___
Addition	___	___	___	___
Subtraction	___	___	___	___
Multiplication	___	___	___	___
Geometry	___	___	___	___
Measurement	___	___	___	___
Problem-solving	___	___	___	___
Graphs	___	___	___	___
Estimation	___	___	___	___
EFFORT	___	___	___	___

The Parent Handbook includes descriptions of each concept. See accompanying letter for specific math skills and concepts emphasized this reporting period.

Teacher Comments/Recommendations

____

Your child will be in grade _____ next year.

Highland Park Elementary
South-Western City Schools

STUDENT PROGRESS REPORT
PRIMARY

Name ____________
Teacher ____________
Grade Level ____________
Year ____________

Developmental Philosophy

At Highland Park we believe that all children are unique and capable learners. Our goal is to build and expand upon the knowledge and abilities that children bring to school. We also recognize that children learn at different rates and in different ways.

This document identifies the learning progression that children make as they move through the grade levels. It demonstrates that there is a range of normal development.

This document should be used with the Parent Handbook to follow your child's learning.

ATTENDANCE

	Nov	Jan	Mar	Jun
Absent	___	___	___	___
Tardy	___	___	___	___

Parent Signature

1____________
2____________
3____________

Developed by the Highland Park Professional Development Staff in conjunction with The Ohio State University, College of Education, Department of Educational Theory and Practice, 1994. Revised June 1996.

Appendix B
Rubric Sheets for Assessing Science Process Knowledge

Emerging (Grades K-1-2)
+ assessed by one observation, relatively easy to assess
√ assessed by more than one observation, adequately assessed over time

+	√	Assessment item	Observe	Verbal	Text	Picture, etc.
+		describes gross physical characteristics of an object	sorts and classifies objects based on physical characteristics	states obvious physical characteristic - *the bear is brown*	writes descriptive comments about an object - *the brown bear has big teeth*	draws a picture that resembles an object - colors a bear brown
+		explores the physical capacity of containers	pours water/rice/sand from one container to another	compares differing volumes - combines two or more volumes into one container	writes about the number of objects (i.e., counting bears) that fit in a container	
	√	knows the names for (un)common physical objects		gives names to objects - *this is a kangaroo, a crystal, the root of a plant*		labels or names objects in a drawing
	√	asks questions of a factual nature		questions can be answered with an undisputed fact _ *How many ...? What are the parts of ...?*		
	√	defers explanation to others/authorities		Defers explanation to others - *my parent said...*	cites the ideas of others - *in the book it said ...*	

Beginning (Grades 1-2-3)
+ assessed by one observation, relatively easy to assess
√ assessed by more than one observation, adequately assessed over time

		Assessment item	Observe	Verbal	Text	Pictures, etc.
+		asks questions about the characteristics of objects and phenomena		asks questions about the properties of an object - *Why is this rock shiny? What makes thunder? Which objects sink/float?*	writes questions as hypotheses - *We wanted to know why this rock is shiny. We wanted to know why things sink and float.*	
+	√	explains how an object interacts with its surroundings		mentions the interaction of two or more objects - *the plant needed sunlight to grow*	constructs a concept or idea map	draws before and after pictures
+	√	uses science equipment to collect information (rather than as a toy)	gradually spends more time working with (than playing with) equipment			
	√	understands that phenomena can have names				
	√	gives egocentric reasons as an explanation				

Developing (Grades 2-3-4)
+ assessed by one observation, relatively easy to assess
√ assessed by more than one observation, adequately assessed over time

		Assessment item	Observe	Verbal	Text	Pictures, etc.
+	√	understands how to collect and organize data			includes a summary of data as part of a lab report - includes a chart, graph or drawing	provides a title and labels the axis of a bar graph, pie chart or drawing
+	√	uses science equipment safely, appropriately, and effectively	uses equipment to extend senses - uses a magnifying glass, balance or eye dropper to make precise observations or measurements		writes about how equipment helped them extend their senses - *we measured exactly five drops of water...*	
+		identifies variables that affect an experiment		states which variable(s) they might investigate - *we could investigate the effects of water or light or soil*	writes about the variable(s) and control group they plan to investigate - *we studied how much water plants need to grow well by...*	
+		gives procedures for what was done		states procedures in sequential order - *first we... then we...*	writes procedures - *Step 1: prepare soil. Step 2: plant seeds just under the soil.*	

+	√	explores the research of others	consults existing resources - reads books, explores the Internet resources	identifies the questions that were important to an investigator - *these investigators wanted to know...*	cites information gleaned from more than one source in a lab report - *Smith said...and Jones said...*	
	√	gives increasingly more precise descriptions of common physical objects		knows the names for common parts - *the parts of a plant are the root, stem, leaf, and flower*	describes the functions of parts of an object - *the root absorbs water, the leaf makes food for the plant*	labels a drawing of an object - labels the parts of a plant accurately
	√	is thinking about objects and physical event from a perspective other than their own		explains how other might see an event - *if you were on the sun, the earth would revolve around you*		illustrates objects that are beyond their immediate perception - draws objects seen through a microscope or the planets in our solar system
	√	links explanations for an event with observations of the event		relates an observation to an explanation - *the puddle dried up when the sun came out and made the water evaporate*	explains how they think something happened - *the red dye went through the Celery and into the leaves*	

Advancing (Grades 3-4-5)

+ assessed by one observation, relatively easy to assess

√ assessed by more than one observation, adequately assessed over time

		Assessment item	Observe	Verbal	Text	Pictures, etc.
+		describes common physical objects in precise detail		uses precise terminology - *this is the femur*	describes objects in detail - *the crystals are clear, triangular, and shiny*	labels precise details in a drawing - labels the filament, anther, stigma, style, and ovary
	√	predicts how an object would behave if you changed the conditions	tests a prediction - puts hot water and cold in a freezer to see which turns solid first	states a prediction - *if I put hot and cold water...*	writes about the results that came from testing a prediction - *we put hot and cold water in the freezer and...*	
+		uses science information books or resources in the library	locates resources such as atlases, encyclopedias, and field guides	refers to an information resource they used - *we found this is in...*	uses information from resources in written reports - includes a bibliography in a report	incorporates illustrations from science information resources in written reports
	√	extracts useful facts or constants from reference materials			includes new facts in a concept or idea map	
	√	recognizes the importance of the data or information collected		reports on data collected - the sample of water we looked at had..	summarizes data - the data we collected tells us that...	

+		selects appropriate science equipment to use during an investigation	chooses equipment to measures precise volume, mass, etc.			
	√	links information into a chain/sequence of events that explain some phenomena		states events in a sequence that explains how a event happens - water, warmed by the sun, evaporates into the atmosphere, condenses around a dust particle, precipitates as rain, snow or dew, and runs back to the ocean	writes a sequence that explains how a event happens	
	√	describes the outcome of an investigation		talks about an investigation in several ways - to describe procedures, persuade peers, summarize data, etc.	writes about the what, when, where, and how of an experiment	

Consolidating (grades 5-6+)

+ assessed by one observation, relatively easy to assess

√ assessed by more than one observation, adequately assessed over time

		Assessment item	Observe	Verbal	Text	Pictures, etc.
+		uses scientific vocabulary appropriately and accurately				
+	√	is comfortable/confident using science equipment				
	√	gives causal explanations for why something happened as it did				
+		beginning to reason about events that could happen hypothetically				
	√	completes a series of investigations on one topic				
	√	writes about questions they would like to study next				
	√	communicates their findings and questions of interest to others				

PROBLEM-BASED LEARNING APPROACH FOR SCIENCE TEACHERS' PROFESSIONAL DEVELOPMENT

HsingChi A. Wang, CCMB, University of Southern California
Patricia Thompson, CCMB, University of Southern California
Charles Shuler, CCMB, University of Southern California
LaNelle Harvey, Ninety-Third Street Elementary School

Background

The Center for Craniofacial Molecular Biology (CCMB)—a research laboratory of the School of Dentistry at the University of Southern California—was announced as a site in 1990 for the California Science Project (CSP), a sub-division of the California Subject Matter Projects[1]. In 1991, the Center to Advance Pre-college Science Education (CAPSE) was funded by the National Science Foundation and also based at CCMB. The mission of CAPSE was to transform pre-college science education for children in the South Central and Eastside areas of Los Angeles with a large majority of minority and historically under-served populations. The goal was to improve science education through teacher training, thereby increasing the possibility of underrepresented minorities entering the scientific pipeline and pursuing careers in science.

Challenge

The USC-CSP formed a strong partnership with the Los Angeles Unified School District (LAUSD). In the past two years, the urban systemic initiative in LAUSD—Los Angeles Systemic Initiative (LA-SI)—challenged the USC-CSP to establish a cluster[2]-wide science education initiative to improve students' academic performance. The achievement will be enhanced through teachers within the cluster teaching inquiry-based and standards-based science.

Wheatley (1994) states that the current standards-based reform movement has brought to light a new instructional leadership that is guided by evidence. Thompson, Wang and Shuler (1998) state that an evidence-based quality instruction is contingent on a variety of factors, such as articulation strategies, instructional resources, and a wealth of pedagogical knowledge. The challenge we faced is three-folded: First, the coordination of science education between different grade levels and different schools represents an organization challenge even in small school districts. In major metropolitan districts like LAUSD, the lack of coordination can result in children entering middle schools and high schools with widely divergent science abilities. In addition, high students transition rate in LAUSD (in some LA areas, less than a half of the students are the same students who enrolled in the beginning of the semester) has forced the educators to look for effective strategies in school articulation. Second, similar to the other elementary teachers around the nation, the elementary teachers in Los Angeles devote so little instructional time in teaching science due to their insufficient preparation in science content training. Third, "inquiry" instruction to classroom teachers is often un-structured and has different meaning to different educators, thus most teachers resist an inquiry approach and still provide a traditional lecturing approach—students are hand-fed information.

Schmidt (1998) uses TIMSS findings to confirm the crucial role of educational standards in science teacher preparation and professional development. Accordingly, the lack of cohesive vision in the United States has caused students low performance in secondary schools. TIMSS findings echo the need for standards-based science education reform. Early on in the developmental stage of the cluster initiative, the USC-CSP faculty and teacher leaders[3] introduced the national science education standards to the teachers. The science educational standards are held as a tool for grade articulation. Moreover, a structured inquiry approach—

Problem-Based Learning (PBL) was introduced to teachers as a model for practicing inquiry-based instruction. Through the PBL format, teachers worked with curators of science museums, scientists in research laboratories, and faculty in higher education to acquire science content knowledge.

During the past two years, the USC-CSP has connected various venues and formed partnerships with local science education centers and informal science education venues to take the challenge. Through a program evaluation (Wang, 1998a), the impact on student science achievement was found to correlate with the following program elements:

- introduction of content and experiences required to develop teacher-leaders who will assist in institutionalizing the science education programs
- providing extended pedagogy experience in inquiry-based science education
- focusing on the national science education standards as a foundation for structuring new initiatives for science education
- building the background science content of teachers
- initiating K-12 articulated cluster-wide programs of science education
- establishing partnerships with informal science education centers, school district, and faculty of the university to maximize the resources available to aid students and teachers
- developing programs for student assessment and program evaluation to determine the impact of the initiatives

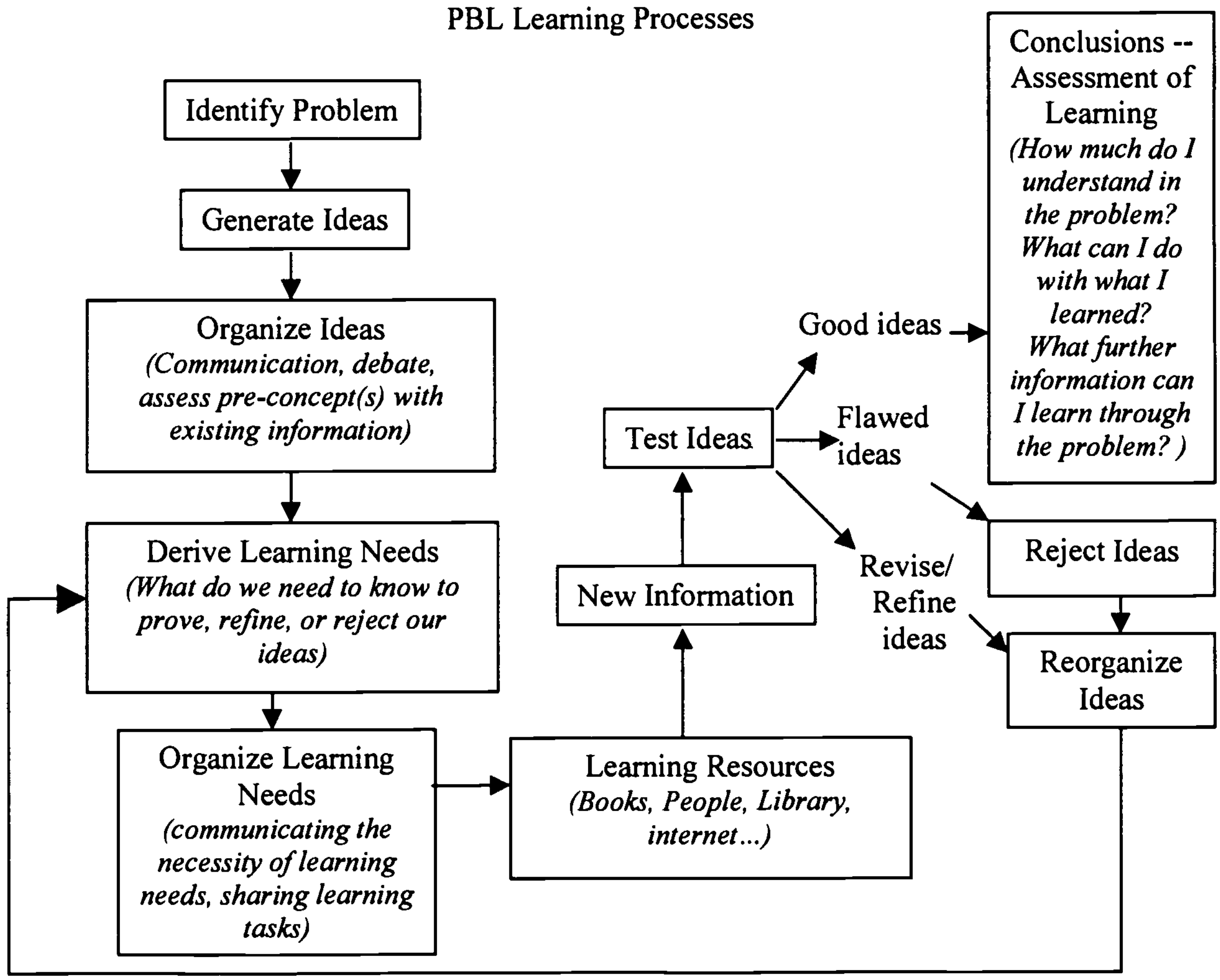
Wang (1998a) further concluded that all the above features were crucial to the success of the USC-CSP science education initiatives. However, for the purpose of this paper, we want to focus our discussion around a key feature of USC-CSP—Problem-Based Learning (PBL)—as it has created a paradigm shift in our beliefs and efforts in teacher professional development.

Problem-Based Learning

Problem-Based Learning was introduced in medical education by a Canadian medical school in 1968 (Neufeld & Barrows, 1974), and has recently begun to attract growing interest among K-12 educators as an exemplary inquiry approach (Checkley, 1997; Glasgow, 1996; Jones, Rasmussen, & Moffitt, 1996a; Jones, Rasmussen, & Moffitt, 1996b). PBL as an instructional model demonstrates that any learning can be accomplished through "learning prompts," which serve both to intrigue the learner and ensure high quality learning outcomes. PBL for inquiry learning has been widely reported as producing desired learning outcomes: students became responsible for their own learning, developed active inquiry habits, and learned effective research techniques (Albanese & Mitchell, 1993; Wang, 1998b). Inquiry-based instruction using the PBL approach has also produced significant improvements in student performance in multiple-choice examination (Shuler & Fincham, 1998). This distinguished PBL from other inquiry attempts that were criticized because they only enhanced students' attitudes and process skills, but did not significantly improve their acquisition of content knowledge.

There are three key components of PBL that were introduced to teachers involved in our professional development programs: (a) learning cases, (b) student-centered learning, (c) small group learning (Wang, Thompson, & Shuler, 1998). The *learning cases* are the core of PBL. Cases need to have specific learning outcomes embedded. In our cases, these learning outcomes are carefully aligned with learning standards described in the national science education documents. The *student-centered learning* component of PBL transforms teachers into group learning facilitators who facilitate the students learning process. One example of a teacher's task is to introduce to students various strategies to effectively utilize learning resources, another is to use questioning techniques to help stimulate student thinking. *Small group cooperative learning* in PBL means that students work within small groups, where they are responsible for both their peers' and their own learning. When learning needs are identified in a learning case, each member will take a small portion of the learning tasks and become "master[4]" of those tasks. It becomes their responsibility to share their findings with their peers. The responsibility of their peers is to expect and demand quality sharing in a scheduled group study session. Figure 1 is a flowchart that indicates the basic structure underlying this approach.

Figure 1.
PBL Learning Processes



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PBL for Teacher Professional Development

PBL was woven into the design of USC-CSP professional development institutes because of the belief that as the participants grew professionally in a PBL environment, they developed a deeper conceptual understanding of PBL and increased their confidence in using this type of an approach. In the summer 1997, 70 teachers participated in a two-week Summer Institute. During the Summer Institute the development of the problems used as vehicles for learning was directly tied to the national science education standards. Grade-specific content and performance standards were identified by each of the learning groups. These standards were used to generate problems that would facilitate student learning. Thus the standards-based science content became integrated into the learning objectives to be achieved in each problem making the standards essential to curricular development and K-12 articulation. Once the standards were identified and the problems were developed, teachers proceeded to identify specific instructional resources, including hands-on science kits, which would be necessary to complete the inquiry-based learning experience of the students. PBL inquiry allows teachers to achieve standards-based instruction through an inquiry process. The participating teachers created one PBL case per grade level in K though eight and one for grade nine to twelve. These cases were test-run on teacher participants and the outcomes used to modify the approach for greater effectiveness and correlation with the desired set of national content standards.

The teachers reported the test-run process helped them not only in understanding PBL, but also understanding the differences in science education objectives between grades. The process has effects on both horizontal and vertical grade instructional articulation. As teachers of the same grade worked together to prepare the learning cases, same grade teachers from different schools had the opportunity to communicate with each other and share their instructional objectives and come to an agreement based on the national standards documents. Furthermore, as teachers of different grades practiced and recognized what was expected in the learning cases crafted by other grade teachers, they also gained an awareness of their role in terms of the students' K to twelve education.

The Summer Institute participants applied these cases to their classrooms after the Summer Institute. The field observation (Wang, 1998a) information collected on the implementation of PBL showed strong evidence that elementary teachers, especially, increased instructional time spent on science lessons. Revised PBL cases were successful in positively affecting student attitudes toward science learning. Some advanced teachers even generated additional PBL cases for their own instructional objectives. Additional science content expertise, skills in integrating the instructional supplements such as science kits, and PBL pedagogy were regularly introduced during a "Wednesday at Westside" series for participating teachers as a way to provide continuous support.

In the summer 1998, the majority of participants from the previous year returned along with colleagues, so that Institute participation reached approximately one hundred. The USC-CSP teacher leaders designed eight PBL cases to provide the participants with an in-depth, adult-level inquiry experience. Prior to the Summer Institute, in a mini-institute held on April 28, 1998, approximately forty teachers were introduced to the PBL cases and used the PBL methodology to determine the necessary learning objectives to better understand the problem cases. This information shaped the planning of the inquiry-based investigations pursued by the teachers during the first week of the Summer Institute. The embedded content behind these eight cases is advanced science around the learning areas of archaeology, microbiology/ecology, molecular biology, marine mammal biology, marine plant biology, botany, and earth science.

Every group brought back their research findings and prepared posters and presentations in the second week. Moreover, the second week was focused on classroom adaptation of the science content, development of a common grade level matrix for their cluster and articulation of science learning throughout the K-12 schools in the cluster. The classroom adaptations of the new material were focused on approaches necessary to achieve the science education standards and to identify opportunities for learning through overlaps between multiple educational disciplines (e.g., literature, art, social science). Teachers investigated hands-on applications for the classroom, explored instructional materials and discussed how they fit into the matrix. Grade level groups built a "living" matrix (Parade of the Rooms) using a classroom as their canvas so that as a culminating activity for the institute, all grade levels could visit and see what constituted "teaching and learning" at each grade level coordinated by the cluster project[5] framework. All classrooms and grades emphasized the applicability of teaching activities through the mastery of science standards by the students.

The 1998 Summer Institute participating teachers were also involved in various evaluating processes. Three different surveys (Group Learning Survey, Facilitator Effectiveness Survey, and Daily Reflective Journal) were collected from teachers. Selected teachers were also interviewed. In addition, the research presentations were videotaped for further analysis. Our preliminary findings from analyzing the data collected, found teachers from the previous year reported that the institute assisted them in gaining more in-depth understanding of issues involved in implementing the PBL in their own classroom[6]. New teachers reported a significant increase in confidence in applying PBL as an inquiry-based instructional approach. The participants reported they were highly motivated to acquire more knowledge in those eight science areas and also enriched their perceptions of scientific research methods.

In the summers of 1997 and 1998, the teachers we worked with had been exposed to a simple format of problem based learning. Calverley (1998) presents a repot in USC Chronicle about his visit of the 1998 Summer Institute and describes the USC-CSP professional development activities. The article has brought attention to both the USC campus and LAUSD schools.

Transfer of PBL to the K-12 Classrooms

In our previous discussion, we assumed that teachers will implement an alternative instruction if they were actually exposed to the alternative instruction directly. The PBL professional development has been reported as a great success. We continue to investigate how such success is being transferred to the K-12 classroom. In the field observation, we found all the teachers' classrooms share one common feature—science was presented in FACT, IDEAS, & LEARNING NEEDS sheets. In Appendix A, a field journal from our project evaluator has painted a vivid example of how PBL was applied to the elementary students by one of our USC-CSP teacher leaders.

Epilogue

Many successful PBL cases have been applied in LAUSD's elementary schools. Michael Blount, Moni Olguin, and Nettie Pena created a video to document how PBL can be applied to both English- and Spanish-speaking students in science learning. Together with Ginnene Branch, an elementary science teacher who has a Master's degree in art, they produced a PBL case—*Sex in the Garden*—to show to the class the substance carried by the pollinators of plants and the anatomy of flowers. In 1997, at the California Science Teacher Annual Conference, they brought the *Sex in the Garden* workshop to the science teachers of California. This course has been accepted for a short-course format at the 1999 National Science Teachers Association Convention and will be open to teachers of the nation. In addition, LaNelle Harvey, another elementary teacher who is currently pursuing her Masters degree in science education, has written several PBL cases for her fourth to sixth graders to learn earth sciences, physical sciences, and social sciences. Lastly, teachers of PBL provided evidence that this pedagogical approach helped student learning outcomes. Vicky Seabold has used PBL for two years as an instructional approach for her bilingual 4th graders. She uses various problem prompts initiated by her students. Her PBL approach successfully helped her students distinguish themselves in various learning assessments during the past two years. In 1997, for their excellent performance, these Martin Luther King Elementary Students were ranked fourth for their grade level district-wide on the Stanford Nine test. It is believed that such exciting implementation reports will continue as more LAUSD teachers are introduced to PBL.

Notes

1. The California Subject Matter Projects (CSMP) are a network of subject matter projects providing professional development for teachers of students in grades K-12. Established in 1988, pursuant to SB 1882, the Projects have recently experienced significant change with the passage of AB 1734 (Ch. 333, 1998). The major changes in direction is to devote more efforts to improve student achievemnt, especially in low-performing schools.

2. LAUSD was divided into 27 "clusters." Each cluster constitutes one or two high schools and their feeder middle and elementary schools.

3. The seventeen USC-CSP teacher leaders are K-12 teachers from the LAUSD, some joined CAPSE institutes before others. They have been prepared and supported to provide professional services to other teachers in LAUSD. Most of them now are still classroom teachers and take heavy responsibility within their own schools as change-agents to assist the school transformation. The experiences we had in the preparation of this group have been documented and drawn dramatic attention from all the other sites of California Science Project.

4. Students will be asked to provide a brief presentation of their own research findings. Facilitators use multiple questioning strategies and a rubric of Learning Mastery Evaluation to assess and monitor student learning when students work with them.

5. The Venice/Westchester cluster developed a science project called Orchid Project in 1997.

6. The result from data analysis will be presented at the 1999 NARST Annual Conference at Boston.

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Appendix A.
Field Observation Journal

November 4^{th}, 1998
Observer: HsingChi A. Wang

Today, Patt and I went to El Centro Elementary School to visit a teacher who is in our CSP Leadership Cohort. She teaches 4^{th} and 5^{th} graders (it's a mixed classroom). Ms. Washington started her two-hour lesson with a video showing a taped news report on the *Exxon-Valdez* oil spill event that happened years ago near Alaska. Her instruction to the students was to LISTEN carefully to the reporter. The tape was about 10 minutes long. I thought the kids might not comprehend the news and they might start to lose focus after 5 minutes at most. Because that's what happens to me; when the news is too long and there are so many vocabularies that I don't recognize or relate to my field. I started to drift away and turn my attention to observe the students instead.

These students, beyond my expectation, were so quiet and so focused. That amazed me! Then I thought they might just be shy in front of us, two visitors with a video camera. They probably think that "what if mom and dad see this tape at the next parenting conference…?"

Ms. Washington started to put a blank poster on the wall and asked the students "what did you see and hear from the news? What are the FACTS?" Over 2/3 of the thirty-five students raised their hands up in the air, wanting to share what they saw and heard. "My gosh, they were really paying attention to the tape," I thought to my self. After the FACT sheet was completed, Ms. Washington asked students "what is the problem here?" Almost synchronously the students said: "The oil spilled in the ocean."

Ms. Washington pulled out another blank poster and asked students "what are your ideas to our problem? Remember, there is no idea as a crazy idea, or weird idea; whatever idea you have is a good idea. Sometimes scientists will think of something totally bazaar and yet it leads to a great discovery." Again, students quickly helped her fill out the IDEAs poster.

At first, their ideas were so "out there" and I said to myself: "they are just nine or ten years old, what do you expect?" As time went by, one student inspired the others—he said: "we can freeze the oil and break it into pieces and take it out of the water," another student said "we can ask scientists what is the solution to break oil and make it less toxic" another student said "we should find out if we can make the oil sink to the ocean floor." I thought to myself: "This is amazing, they are so creative and clever." The students quickly filled out two posters of ideas and they were great ideas!

Ms. Washington was so happy and she pulled out another blank poster and asked the class: "What do we think we need to learn to test our ideas? What tools do you need to test ideas?" Unlike the "silent moment" briefly presented at the previous idea generation process, students burst out with their learning needs one after another. The instrument, the tools, and the resources were listed on the board by these nine or ten year-olds in a short time.

Ms. Washington asked students to select a topic that they want to investigate and they formed into investigation groups. She then asked several students to bring in all the tools these students just listed. I was stunned, she had predicted what would come out from the students' discussions with only one or two items missed. What an incredible process!

Students started to be charged by their self-selected group tasks. Some of them worked right into their own investigations, some of them sat there for a long time not showing any eagerness to bring any tool to their tables. They sat there and looked around, then started to write things together and then decided their investigation plan. This group became hyper in their investigations. Of course there were students that simply had no clue about what is scientific process: they pulled all variables together and claimed, "we found it, we found the solution." As Ms. Washington rushed to the table, they could not show her what they had just found. They failed to prove their claim. Ms. Washington asked them to add one variable at a time and record what happened when a new variable is added. They needed to write as they conducted their investigation. She told her students "think before you act, write in your journal why you did every step you did."

At the end of the two hours, when all the students in the school heard the bell ring and all went screaming and rushing out of the school, guess what, Ms. Washington's class was sitting seriously with their groupmates and listening to every other group's presentation. They debriefed on what they have found so far in their own investigation. They stayed there for discussions and provided ideas to each other for another 30 minutes. "The school day is over" seems not an issue to these students.

These are not gifted students, their standardized test score from last years are ranked near the bottom of the whole nation. What made it so different in this classroom? I am positive that these students will perform better after this year with Ms. Washington. In the past few hours, the rate of increase in their knowledge and the habit of exercising their mind is accelerating. This is a Problem-Based Learning classroom.

THE MODEL AS A VEHICLE FOR UNDERSTANDING THE NATURE AND PROCESSES OF SCIENCE

Steven W. Gilbert, Indiana University Kokomo

Traditionally, science has been identified with the construction of symbolic models, especially mathematical models, but also theories (Bross, 1953). Analogical and metaphorical models have also historically played a crucial role in scientific work and are responsible for creative efforts, not only in science but in many fields (Black, 1962; Dreistadt, 1968). In fact, one only has to review any scientific journal to realize that models do not just play an important role in science--they are, in fact, at the heart of the scientific enterprise.

Despite their importance, Van Driel (1998), in a study of a limited sample of seven teachers, found few attempts by teachers to address the nature of models and practice of modeling as such in science. This paper presents three reasons why teachers should understand and actively use models and model building to frame science. First, since model building and testing is the heart of the scientific enterprise, an understanding of the process is crucial for developing science literacy. Second, models are a familiar framework through which to understand and explain knowledge from a constructivist perspective. Third, the processes required for developing models corresponds to processes of active learning in science.

This paper will briefly introduce a rationale for models based science and science education. It will then discuss the impact of a model building theme in an elementary science methods course on the knowledge and attitudes of prospective teachers of science.

Models and Science

A model is a representation of selected elements of one system, a target, by corresponding elements in a second system, the model. Usually, the model is more familiar to the learner than the target (Black, 1962). Various authors have categorized models differently, depending upon their purposes, but most include, in one form or another, mathematical models, representations, analogues (and metaphors, in language), simulations, procedures and conceptual/theoretical models (Gilbert, 1991). Some authors do not consider direct records of events, such as photographs, to be models (Van Driel, 1998) while other writers, such as Lunetta and Hofstein (1981) include them. Given that photographs are representations in another medium, and that they do not completely describe their targets but only certain perceptually salient features of them, I do not consider their exclusion to be justified.

By definition, a model can never be a complete representation of a target, or it would in fact be the target. Stevens and Collins (1980) observe that multiple models of varying sophistication may represent a single target, depending upon the builder's purposes. For example, the water cycle may be understood semantically, schematically, by physical models or through mathematics. They propose that learning is largely a process of refining models to make them correspond better with the real world. Models are refined by adding, replacing, deleting, generalizing and differentiating their parts so they correspond better to their targets. The criteria used to accept models varies according to the tenets of the field of study. In science, the test used to accept or reject a model is its perceived predictive validity (Bross, 1953).

While most people, when visualizing models, might think of dolls, toy airplanes or other constructs with perceptual similarities to their targets, models, in fact, do not need to look at all like their targets. Mathematical equations, arithmetic problems, and computer codes representing values and relationships look nothing like their targets, yet are considered to be models because their nodes and relationships correspond to nodes and relationships in their targets.

All of the essential characteristics describing scientific knowledge can also be applied to describe models. Rubba and Andersen (1978) created their six subscales in their Nature of Science Knowledge Scale on the assumptions that scientific knowledge is (1) amoral, neither good nor bad by itself (although its uses could be good or bad); (2) developed creatively; (3) developmental, constantly open to change; (4) parsimonious, in that the simplest of otherwise equal explanations is considered correct; (5) testable, not relying on metaphysical explanations; and (6) unified across traditional disciplines. Scientific models display these characteristics.

For example, the goodness of a scientific model depends upon its "fit" to its target, not on notions of moral goodness or badness (Black, 1962). The development of a speculative (hypothetical) model may be highly creative, combining perceptions (data) and evaluations in new and interesting ways. Some models that are now accepted by scientists, such as theories of global catastrophe, began as highly speculative models on the fringes of science. Of course the ultimate test of the scientific model is our ability to predict from it (Bross, 1953), so the creativity of science ultimately has to withstand tests not required of artistic creativity.

As mentioned earlier, models cannot be completely accurate representations of their targets, thus there are no complete models of any phenomenon (Johnson-Laird, 1983). Scientific models are always tentative, open to change and development. Models are parsimonious by nature, because the utility of a model depends upon our ability to simplify it (Johansen, 1980). Models are testable by nature, since they are human constructs, and tests are required to determine the fit of any model to its target. Finally, and perhaps most important, model building is a process that cuts across fields and the content of the targets. The same basic processes of construction and evaluation of models are used in chemistry, biology, physics and the earth sciences. The grand unifying model of the world ultimately sought by scientists, at least before constructivism cast doubt on our ability ever to find such a model, is not limited by artificial boundaries and must withstand the same evaluative processes regardless of the fields in which its components originate.

The theoretical paradigm of science as model building appears to have potential for conveying the important idea that science is more than the accumulation of facts (more properly the goal of exploration) and, at the same time, that it is not a search for ultimate explanation. Models are recognized as human constructs. They are artificial, like knowledge itself. The game of science, as McCain and Segal (1969) have pointed out, is the production of theories, concepts and other relational structures (all models) that hold up under scrutiny by the rest of the scientific community. Such constructs are discrete and sometimes have little meaning in and of themselves. When linked to other conceptual/ theoretical models, they are the sum of that which is considered scientific knowledge.

Mental Models and Constructivist Teaching

I do not suggest that model building is a useful way to describe science to prospective teachers just because model building is a good definition of scientific work. Certainly science can be described as model building because it explains and unifies the dimensions of science that might otherwise be presented as discrete processes and outcomes. A second and equally important reason for framing science as a process of model building is that this is a parsimonious way to convey to new teachers constructivist ideas about the way people know, think and learn.

Much of our current learning theory centers on the constructivist notion that human perceptions are fragmented and, therefore, reality must be constructed (von Glasersfeld, 1985). According to this argument, observation isolates elements of experience, not elements of an objective world. Since any science is determined by what the scientist sees, the way he observes, and the way he conceptually processes his experiences, science is necessarily subjective in nature.

Constructivism is based on the Darwinian idea that adaptation means only that the organism has found one way to survive and procreate within the limits of its environment (von Glasersfeld, 1985). Organisms do not evolve (or retain) ways of seeing and knowing that do not benefit them or which are beyond their genetic capabilities to evolve. Just as our observations of other animals may lead us to believe them unable to perceive or understand as we do, so our own perceptions and understanding may be very limited, an assumption that is supported by the previously unknown world that has been revealed as we extend our perceptual abilities with machines.

We understand our world only insofar as we perceive events and attribute meaning to them. Our perceptions are communicated to others by various means so that many people may agree on the general meaning of any particular event. Knowledge beyond that possessed by any one individual is a body of relationships and ideas individuals share, although the precise meaning of any one event may vary widely among individuals. Objectivity is achieved when the concepts, relationships, and operations seem viable both in the individual and group model. Individual models are constructed both from the individual's experience and the models of others communicated to the individual.

The question of whether or not objective reality really exists and is knowable has been the subject of debate (Osborne, 1996; Staver, 1998). Staver (1998) is careful to remind us that constructivism is a theory of knowing, not being. For practical purposes, most theorists, including Staver, choose to accept the idea that an external world exists and can be operated upon, even if we can never be sure that we are aware of its true nature. What is important is the understanding that our perceptions of existence are the products of internal representations and mental models (Johnson-Laird, 1983) rather than incoming stimuli alone. All perceptions, whatever their source, are filtered through the brain and given meaning by the generative processes occurring there (Osborne and Wittrock,1983). Learning is not just additive. The quality as well as the quantity of the resulting mental model is changing continually (Osborne and Wittrock, 1983; Shuell, 1990). Creativity results from mental processes that link models in novel ways. Humans, and perhaps some other animals, are able to produce imaginary models (Johnson-Laird, 1983).

Propositions, images, and mental models are three mental representations associated with thinking in humans: (Johnson-Laird, 1983). A *proposition* is a mental representation consisting of a string of symbols. They are most commonly experienced as words in a sentence, spoken or unspoken. For example, the assertion "cats have fur" is a proposition consisting of three symbols (words) corresponding to understood objects or relationships. Mathematic formulae are also considered to be propositions.

Propositions have little meaning by themselves, rather they must be interpreted in a larger framework. That framework is the *mental model*, a complex mental representation with nodes, attributes, and relationships corresponding to received from the perceived world (Johnson-Laird, 1983). When propositions are well integrated into this model, they have or acquire meaning, but propositions may also be stored without being integrated into the individual's mental model and may later be recalled and articulated without evident understanding. New propositions are generated by interactions in the mental model.

The third type of mental representation is the *image*. The image is a perceptual correlate of a mental model from a particular perspective (Johnson-Laird, 1983). Imagine an apple and certain perceptual features come to mind. The image is incomplete: it only represents certain attributes of the complete model. If the model is viewed from a different perspective, the image of the apple changes. Images created from our perceptions may be integrated into one or more appropriate mental models and stored as records of events.

Mental models are numerous and probably hierarchical. They may range in size and generality from your world view, with its many organizing propositions and images, to models as specific as your models of various kinds of apples. Miller (1979) argues that the process of creating an image from written text is both constructive and selective. First, a viewer constructs a general model from a set of attributes he or she perceives, then selects from among existing models that have the selected attributes. The meaning of the image is thus interpreted in relation to existing models.

Recent research demonstrates that the elements of our mental operations are neurons and configurations of synaptic connection strengths (Staver, 1998). In relating new research findings to the proposition that learning is a process of model building, it is important to remember that models need not take the same form as their targets. A complex mathematical model does not materially or spatially resemble its target. Similarly, the word "cat" is a symbolic model of the real thing, but bears no material relationship to the real thing. In fact, it can be argued that the word "cat" is a model of our mental model of the target animal. The encoding of our perceptions, or translations of our perceptions, is thus a model building process.

Model building and the Teacher of Science

Constructivism is identified by Dana, Campbell and Lunetta (1997) as one of the most important theoretical bases for the reform of science teacher education. Even critics of constructivist epistemology such as Osborne (1996) recognize its positive implications for science teaching, for example, its recognition of the influence of prior knowledge, of the need for active exploration, individual and group sense making, and consideration of alternative conceptions.

My goal in representing science and learning as model building, and knowledge as a conceptual model, is to effectively convey the general ideas of constructivism to prospective teachers, many of whom have a realist perspective, without threatening their world view. Because the concept of a model is a familiar construct to most prospective teachers, it should be an efficient theme for bridging the gap between the traditional realist philosophy and the newer, less popularly accepted, constructivist philosophy.

In addition to constructivist thinking, Dana, Campbell & Lunetta (1997) also suggest that reflection is an important theoretical basis for reform. They propose that teachers should be challenged to teach for meaningful understanding and that learners should be constructors of their own learning. However teachers should also challenge learners, even at the earliest grades, to think not only about what they are learning but how they are learning it (Novak and Gowin, 1984). Achieving this goal goes beyond using analogies and models while teaching science concepts. Model building should serve as a filter for teachers to determine both the content and processes of their science curriculum and should be a framework through which their students can understand science as an individual and social process for constructing a consistent, predictive knowledge structure.

Models as a Theme for Preparing Teachers of Science: A Study

The small elementary science program in which this preliminary research was conducted graduates 60–70 new teachers each year. These prospective teachers are generalists, completing only 12 credits of content study in earth, biological, environmental and physical sciences. The program is located on a small branch campus of a large Midwestern university. All students are commuters and the majority of candidates are older, nontraditional students.

The elementary science methods course is a three credit offering. It is organized into three parts: an introduction phase of approximately nine weeks followed by a short, two week, peer teaching phase, which leads to a practicum phase of approximately three weeks, during which students team teach in area classrooms. There is, thus, only a limited time during which students must be introduced to discovery and inquiry learning and related practices. About one-third of the way through the course, students form teams. Practicums are planned, developed and then taught by these small groups. Each group completes a portfolio and oral presentation of their practicum. The science methods practicum is thematically integrated with the social studies practicum.

During the 1997–98 academic year, the fundamental theme of models based science was introduced on the first day of the single fall and spring elementary science courses, and reinforced regularly during the activities of the introductory phase. This was accomplished by (a) an introductory session relating models and construction of knowledge; (b) readings specifically addressing the theme; (c) and regular framing of inquiry learning as a process of model building.

At the end of each course, following the practicum, students were asked to anonymously respond on a written instrument to three items. They were not aware beforehand that they would be given this assessment, so the responses are assumed to represent meaningful propositions rather than propositions memorized for recitation. The items were:

1. Throughout the semester, science (not science teaching) was described as a process of model building. Please explain why science as a process was described this way.
2. Did the concept and theme of models and model building in any way strengthen or change your concept of knowledge and the nature of science? How?
3. In your best assessment, did the concept of science and learning as a process of model

building impact the way you chose to teach science in your practicum, or will teach science in the future? How?

Overall, 58 students responded.

Results of the Study

The results of using the concepts of models and model building to describe science and science teaching has been largely encouraging. It was clear from the diversity of responses that students interpreted the importance of this idea in relation to their own prior understandings and willingness to entertain novel ideas. Almost, all, however, related the concepts in a positive way to the importance of active, hands on learning in childhood science. The idea of building or constructing knowledge was particularly apparent in many of the responses, as shown by the response of one student that "Model building is a way to describe science because we build on each lesson. We begin simple and build up and in the process [construct] more difficult concepts."

This was expected. Questioning early in the course shows that students generally understand that models are constructed entities, but they may not understand that knowledge is constructed as well. In the response just cited, model building is related to teaching rather than to the more general goal of understanding science. From a conceptual development standpoint, the idea expressed also demonstrates awareness of the hierarchical nature of the conceptual models built during science instruction.

The idea of a mental model is expressed by the student who stated "Model building is a thought process that requires the learner to process information and then create understanding by mentally creating a model that consists of facts, terms and concepts surrounding the subject at hand."

This response is interesting in that it is related generally to knowledge rather than science. The response shows awareness of the fundamental concept of individually constructed knowledge and the mental model each student builds. It relates the elements of thought (facts, terms and concepts) to a larger structure. The term "create" relates to active building and also relates to the proposition that science (and learning in general) is a creative activity.

A number of students were able to relate the concept of model building effectively to an understanding of the nature of science, as discussed earlier in this paper. For example, the tentative nature of knowledge is clearly explained in the context of models by the student who wrote: "There are different pieces to the model and we do not have them all yet. Each piece of new evidence in science connects with some other piece of evidence. We will never complete the model."

Several other students address the idea that scientific knowledge is testable and developmental in nature. One wrote, "All theories can be tested. Just because the test seems to prove the hypothesis to be correct does not mean it is scientific truth. Models are ideas we think are true. They are only models, subject to change." Another stated that "the theories of science are building blocks in which more extensive research and experimentation can be done. The theories and laws are represented as models for scientists to go by until another law or theory can better describe it."

One of the potential benefits to be realized from integrating models into our explanation of science is that some prospective teachers, at least, are able to go further and relate the idea to knowledge in general, as shown earlier. The two students following also generalize from model building in science to knowledge in general. One writes, "I feel that it is not just science that is made up of models. Everything that we do we have created some sort of model for. I feel that in science it is more common to think of things in the form of a model." The other student asserts that "people of all ages possess individual models of life and life's events, objects, and students/ people build or change their models throughout life."

In a number of cases, the responses of the students show they did not clearly delineate the concept of science as model building from the idea of using models to teach science. A number of respondents felt they better understood the reason for using hands on, active learning when it was framed in the context of model building. One student felt that "it is important for children to understand *how* things work and this is best done with model building. This way, facts are not just presented, but also displayed in a manner that enables students to actively learn."

Some students appeared to relate the concept of model building primarily to the development of the inquiry activities and the learning cycles they were required to construct and use in their practicums. When asked if the concept and theme of models and model building in any way strengthened or changed her concept of knowledge and the nature of science, a student replied: "*It did*, but it kind of takes the fun out of things. I know there must be a method or rationale behind things -- especially learning cycles -- but sometimes it is nice to do things that are interesting without all the research-based justifications."

In the end, however, she acknowledges that there may be considerations other than fun. Asked if the concept of science and learning as a process of model building impacted the way she chose to teach science in her practicum, or is likely to teach science in the future, she responds: "Yes, because it was required, at first, but then I did see the value of well reasoned and planned science. It allows for more student discovery."

Not all students fully understood or accepted the idea of mental model building, at least overtly. A number accepted the idea that science consists of building and testing models, but did not relate this to the more general idea that knowledge itself is a model. Others focused on the idea of model building as a teaching approach rather than a process of science. Even in these cases, it was clear that the model paradigm provided justification for hands on active learning.

In both semesters, almost all students indicated that the concept had influenced their ideas of what science is about and would probably influence the way they taught science. Some students appeared to grasp the idea that model building applies to the construction of knowledge in general, not just to science. For example, one student wrote that "everyone has different concepts and thoughts. You have to take that into consideration. Using models can help build concepts and understanding." This response was echoed by a second student, who wrote: "The concept of models and model building was confusing at first, but now it makes sense. Life, in general, is about referring to our own notion of models."

The potential impact of this approach on the teaching of science was apparent in a number of responses. One student responded that "my goals of teaching science have been altered by wanting to use many demonstrations, using a hands on approach and using discovery learning in my classroom," while a second said: "I realized that models are a must with science. They strengthen the ideas and concepts and help the ideas stay with a student."

Summary

The result of this work over two semesters has been very satisfying, even as the results are difficult to define precisely. If the responses of prospective teachers on these questionnaires are a valid indication of their beliefs and intentions, then it appears that the models based approach is an effective way to develop their mental models in relation to their (a) knowledge of science as inquiry; (b) understanding of the nature of scientific knowledge, and knowledge across fields; and (c) ability and willingness to apply constructivist approaches to teaching.

Work over the two semesters covered by this assessment appears to support the hypothesis that students can relate the concept of models to a more general concept of knowledge. In addition, model building, used as a framework for describing science, appears to strengthen the resolve of prospective elementary teachers to use active learning with students and provides them with an acceptable rationale, in their minds, for doing so. As might be expected, not all students embraced the more abstract implications of the models based theory of knowledge. However, almost all respondents on the assessments articulated a justification for active learning by referring to models on some level. In addition, the responses of prospective teachers leave little doubt that framing science (and learning in general) as model building promotes acceptance of the idea that knowledge is constructed rather than merely learned or discovered. Finally, this approach promotes the acceptance of certain defining attributes of scientific knowledge: that it is tentative, testable, creative, and so forth.

This project was undertaken to assess a potential remedy for a concern that only presenting the conception of science as a process of active inquiry to prospective teachers does not adequately or efficiently describe the results of these processes, the nature of science or the properties of human knowledge that must be understood to fully understand science. The results reported here indicate that the introduction of science as model building holds promise as a way to relate constructivism, as an epistemology and an approach to science teaching, to the goals, processes and outcomes of science.

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ELEMENTARY AND SECONDARY STUDENTS' PERCEPTIONS TOWARD SCIENCE AND THE CORRELATION WITH GENDER, ETHNICITY, ABILITY, GRADE, AND SCIENCE ACHIEVEMENT

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Attitudes associated with science appear to be affecting student participation in science as a subject (AAAS, 1989; Koballa, Crawley, & Shrigley, 1990) and impacting performance in science (IAEP, 1992; Weiss, 1987; Linn, 1992). An international assessment of nine-and-thirteen-year-old students in twenty countries (IAEP, 1992) revealed that positive attitudes toward science influence student performance. Positive student attitudes toward science were related to higher science performance by the majority of 13-year-old students in 15 countries (IAEP, 1992). In Korea there was a notable exception; only one-quarter of the top-performing students exhibited positive attitudes toward science (IAEP, 1992).

Students in the international assessment were asked to what extent they agreed with the following statements:

- Much of what is learned in science is useful in everyday life.
- It is important to know some science in order to get a good job.
- I am good at science.
- My parents are interested in science.

A significant majority of the twenty countries had positive attitudes about the utility of science learning for both males and females despite a gender performance gap that was prevalent in nearly all of the countries (IAEP, 1992). The performance of males and females was equivalent in only two participating countries, Taiwan and Jordan (IAEP, 1992). In the Russian-speaking schools 74 percent of the students believed science was equally important for males and females (IAEP, 1992). In Korea less than two-thirds of the students believed science was equally important for males and females (IAEP, 1992); this was one of few countries in which fewer than 90 percent of the students perceived science to be equally appropriate for males and females (IAEP, 1992).

An examination of the major goals for science education reveals a unanimity of opinion that the development of scientific literacy includes the development of positive attitudes toward science (Lederman, 1992; Linn, 1992). One of the goals for school science that underlies the *National Science Education Standards* (1996) is to educate students who are able to experience the richness and excitement of knowing about and understanding the natural world. This development of positive atiitudes toward science is a critical component of science instruction (Gardner, 1991; NAEP, 1987). It is judged imperative that students develop, at an early age, favorable attitudes toward science (NAEP, 1987); and that this favorable orientation be maintained (Anderman & Maehr, 1994; AAAS, 1989).

Studies on gender roles and school subjects reveal the avoidance of additional science courses by females (Maple & Stage, 1991; Archer & McDonald, 1991). Schibeci (1984) reported that females exhibit more positive attitudes toward biology and males toward physics. Current data from the American Association of University Women indicate the need to focus more attention on the development of positive attitudes toward science with females (AAUW, 1992). As females progress through secondary grades, they become less confident of their academic skills; thus, their career aspirations are narrowed (AAUW, 1992; Linn & Hyde, 1989). Data from the National Science Foundation (NSF, 1994) indicate that females comprise 46% of the labor force with only 22% of the scientists being female.

Race and ethnicity may influence science achievement and attitudes toward science. In the international study (IAEP, 1992), the highest-performing 13-year-old students were those in Korea, Taiwan, and Switzerland; students from seven countries including France, Scotland, Spain, the United States, England, and China performed at the IAEP (1992) average of 67 percent. Mickelson (1990) found in his study an attitude-achievement paradox among black adolescents. Despite low levels of achievement in science, minority students, especially African-Americans, exhibited positive attitudes toward science as a subject (Mickelson, 1990). The African-American students responded that they look forward to science class and that science will be useful to them. This paradox has been reported by other researchers (Clewell & Anderson, 1991). The purpose of this study was to determine student attitudes toward science and to examine the correlation of attitudes with ability, gender, ethnicity, grade, and science achievement

Measures

The measure of students' achievement was the end-of-year scores on the science subtests of the standardized achievement test, Science Research Associates (SRA) Survey of Basic Skills published by Science Research Associates. The contents of the science subtests of the SRA are based on learner objectives most commonly taught in science courses in the United States. The normal curve equivalent scores (NCEs) from the science subtests are represented on a scale from 1 to 99 with the difference between two successive scores on the scale having the same meaning throughout the scale.

To measure elementary and secondary students' perceptions toward science as a subject a modified form of the Osgood Semantic Differential (1957) was used. The evaluative attitudes selected were important/unimportant (1), valuable/worthless (S2), understandable/confusing (S3), exciting/boring (S4), and easy/hard (S5). The instrument included seven additional adjective pairs that were used as distractors.

The attitude scores for an individual were determined from the five evaluative scales producing a range of one, negative attitude, to seven, positive attitude. Any score of five or greater represented a positive value for an attitude. The most positive ratings for important, valuable, understandable, exciting, and easy were assigned a value of seven.

Intercorrelational Analysis of Attitudes

An intercorrelational analysis applied to the means showed significant relationships (Table 1) with the attitudes toward science and the variables of ability, gender, and grade. Ethnicity did not correlate with any of the attitudes toward science. Gender correlated with only one attitude toward science. Every attitude examined correlated with science achievement.

Ability correlated with the four attitudes: important (S1), valuable (S2), understandable (S3), and easy (S5). The attitude which did not correlate with ability is exciting (S4). Three of the attitudes toward science correlated with the high ability group; the high ability-grouped students considered science as valuable, understandable, and easy.

Table 1
Correlates of Science Attitudes

Variable	Science Attitudes				
	S1	S2	S3	S4	S5
Ability	-.0898*	.0877**	.0915*	.0212	.1025*
Gender	.0638	.0491	.0690	.1332**	.0511
Ethnicity	-.0406	-.0250	.0558	.0261	.0241
Grade	-.1421**	-.1165**	-.1500**	-.1243**	-.1690**

* Significant beyond .05 level of confidence
** Significant beyond .01 level of confidence
S1 = Important/Unimportant
S2 = Valuable/Worthless
S3 = Understandable/Confusing
S4 = Exciting/Boring
S5 = Easy/Hard

There was a significant difference in the ratings of one attitude toward science based on gender. The analysis revealed that science was rated as more exciting (S4) by males than females. The significance was beyond the .01 level of confidence as noted in Table 1.

The intercorrelational analysis showed that there was no difference in the ratings of the attitudes toward science based on ethnicity. Nonminority students in that school system did not significantly rate science more positively nor negatively than the minority students. Minorities represented 21% of the student population.

Grade correlated significantly with every attitude toward science as noted in Table 1. The Scheffe test was utilized to identify comparisons between grades. Grade comparisons of the attitude important (S1) indicated that students in grades four, five, and six rated science as a more important subject than the students enrolled in grades nine, ten and eleven. The students in grades four, five and six rated science as more valuable (S2) and understandable (S3) than the students in grade eleven.

Discussion

There were no significant differences between the attitudes toward science as a subject and gender with one exception. Males rated science as a subject more exciting than females. Conversely, the findings of other researchers show that male students in the United States demonstrate more positive attitudes toward science than do females (Czerniak & Chiarelott, 1984; Kahle, 1983; Schibeci & Riley, 1986). Recent research by AAUW (1992) reveals that although female students receive equal, or sometimes better, grades in science courses, the females exhibit less interest in science subjects than male students.

Ethnicity did not correlate with any of the five attitudes toward science as a subject. Studies that have examined race and ethnicity report that African-Americans and Latinos enrolled in middle schools responded positively to the importance of mathematics and science (Clewell & Anderson, 1991; Mickelson, 1990; Catsambis, 1994). In science, Latinos exhibit a gender gap with respect to looking forward to science class; Latino males have a more positive attitude toward science than Latino females (Catsambis, 1994).

Grade significantly correlated with each attitude toward science; the grade comparisons measured by the Scheffe test indicated that students enrolled in grades four, five, and six perceived science more positively than secondary students. A recent study reports that no significant changes have occurred in the secondary schools at Grade 10, in terms of increasing students' positive attitudes toward science as a subject even though the constructivist and science-technology-society (STC) approaches had been emphasized in that area (Ebenezer & Zoller, 1993). As reform for preservice education and professional development continues, future studies should reflect the impact of the reform.

With multiple correlation, science achievement correlated with attitude toward science. Much of the research concerning attitude toward science and its relationship to science achievement shows low positive correlations (Schibeci & Riley, 1986; Keeves & Morganstern, 1992). Early research by Eisenhardt (1977) found that the predominant causal sequence was that a change in achievement causes a change in interest level. Further research examining psychological effects found that a student's self-concept of his ability to perform in science positively correlated with achievement (Oliver & Simpson, 1988). Further investigations should provide more evidence that science educators will be able to use in course revisions with respect to instructional strategies.

A dimension worth studying is the question of how the affective relationship is fostered in science instruction (Lederman, 1992; Haladyna & Shaughnessy, 1982). Research studies on teacher behavior patterns that promote cognitive and affective domains of science could provide data to be used with professional development models (Smith, 1990).

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PREPARING HIGH SCHOOL BIOLOGY TEACHERS FOR STANDARDS-BASED CURRICULA

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This paper describes a preparation program in which sixteen high school biology teachers in widely diverse settings across the country have successfully implemented a new, standards-based biology curriculum.

Background

The concurrent development of the *National Science Education Standards* by the National Research Council and the *Benchmarks for Science Literacy* by the American Association for the Advancement of Science have been major funding efforts by the National Science Foundation. They are in response to what is widely perceived as very inappropriate teaching of science in elementary and secondary education. A large part of the problem is that secondary science has historically been taught primarily through lecture as a long list of rather trivial facts and vocabulary words which are to be memorized and that this practice is widely supported by traditional, encyclopedic science texts.

Both AAAS and the NRC have attempted to aid science curriculum developers in both content selection and pedagogical approach by identifying a smaller subset of the most important science concepts rather than a long set of facts which attempt to cover an entire subject, as is the case for many traditional science curricula. Also, very much unlike the dominant traditional curricula, AAAS and NRC strongly recommend that science curricula devote significantly more time to developing scientific thinking skills and understanding the nature of science thus promoting student learning by engaged investigation as opposed to passive listening.

Science curricula recently funded by the National Science Foundation have tried to align themselves to the Standards and Benchmarks by reducing concepts and topics and by trading off treatment of more concepts and topics for activities which develop scientific thinking skills and understanding the nature of science. That is why these new curricula are highly activity-oriented and engage students extensively in scientific inquiry.

Biology: A Community Context (Leonard and Penick, South-Western Educational Publishing, 1998) was one such curriculum. This curriculum for introductory high school biology was developed under a $2.3 million NSF grant awarded to Clemson University. Part of the grant's requirements was a teacher preparation and evaluation component. There was much interest in knowing if teachers using standards-based curricula would result in any greater student learning of selected science concepts identified in the Standards and Benchmarks and any greater learning of scientific inquiry skills than do traditional curricula that dominate the schools today.

Procedures

During the summer of 1997, sixteen high school biology teachers representing very diverse educational settings in the United States were given an intensive, one-week training on the methodology and contents of *Biology: A Community Context* by the authors (Leonard and Penick) and Project Manager (Speziale) of the curriculum. They were immersed in all the components of the curriculum (student text, teacher guide, initial inquiry video, and assessment package). Activities from the student text were by the authors. These were then completed by the participating teachers, followed by a discussion with the authors of the relevant biology concepts, science process skills, and understandings of the nature of science. Specific discussions of the curriculum's instructional methodology, namely the nature of scientific inquiry, a constructivist view of learning, active learning, and the critical sequencing of the different kinds of classroom instruction were also emphasized.

During the 1997-98 school year the same sixteen high school biology teachers each taught at least one class using the Standards-based curriculum *Biology: A Community Context* and at least one class using their existing traditional curriculum and text. During the first week of school, teachers administered two different pretests: A Test of Understanding Biology Concepts and A Test of Science Process Skills. The tests were constructed by the authors, reviewed by biology teachers and revised accordingly. The classes which used each curriculum were not chosen randomly, but were selected by the teacher as having a "typical" composition of students at their school for an introductory biology class. Specific attention was paid to assuring that the intact classes using the two different curricula were as equivalent in student ability as possible.

Teachers used the *Biology: A Community Context* and their existing traditional curriculum with the corresponding intact classes during the entire school year. They attempted to use classroom methodologies consistent with *Biology: A Community Context* (BACC) and their traditional curriculum respectively.

All students in the study repeated the same two tests as posttests during the last week of the school year. Data were analyzed for differences in mean scores between BACC versus traditional classes. Also during this school year, all sixteen teachers were visited for a full teaching day once early in the year (August to October) and once later in the year (March to June) by one of the developers of the BACC curriculum. Attempts were made to note the relative differences between student and teacher behaviors of BACC and the contrasting traditional classrooms. Further, a seven-item free response questionnaire was given at the end of the school year to all students of the sixteen teachers using the BACC curriculum.

Data and Results

The major differences observed between the implementation of the two curricula were:

- Biology content in BACC classes was more selective and focused on fewer biology concepts whereas there was an attempt to cover as much content of the traditional textbook as possible in the traditional classroom.
- Laboratory, field and group research activities on given concepts were done prior to reading, lecture and discussion in the BACC class, whereas laboratory, field and group activities were done after lecture and discussion in the traditional classes.
- All student activities were of an investigative and inquiry nature in the BACC classes, whereas activities were mostly prescriptive and verifying in the traditional classes.

- There was extensive emphasis on development of science process skills and in understanding the nature of science in the BACC classes and there was nearly a total emphasis on biology content in the traditional classes.
- Students spent approximately 75% of classroom time directly engaged in inquiry activities in the BACC classes and at least 75% of the time engaged in listening to teacher lecture and discussion in the traditional classes.
- The BACC curriculum was in a context of community applications of biology concepts whereas the traditional curriculum was primarily in the context of scientific concepts.

The results of pre- and posttests are shown in Table 1. There were no statistically significant differences between BACC and traditional classes on the pretest for understanding of key biology concepts. However, there were statistically significant differences on the pretest for science process skills. BACC classes scored significantly lower than traditional classes on this pretest.

Table 1
Student Pre- and Posttest Scores for Tests
for Biology Concepts and Science Process Skills

	Mean	N	SD	t	p
TEST ON BIOLOGY CONCEPTS (40 questions)					
Pretest - BACC Classes:	13.38	372	5.59	1.68	.90
Pretest - Traditional Classes:	14.06	368	5.45		
Posttest - BACC Classes:	18.50	365	8.03	3.43	.005
Posttest - Traditional Classes:	16.50	298	6.96		
TEST ON PROCESSES SKILLS (30 questions)					
Pretest - BACC Classes:	10.52	395	4.79	3.95	.005
Pretest - Traditional Classes:	11.97	379	5.39		
Posttest - BACC Classes:	14.06	376	5.65	3.07	.005
Posttest - Traditional Classes:	12.69	308	5.93		

There were statistically significant differences between the BACC and traditional classes on both posttests. BACC classes scored higher on both tests. It was notable that, although the BACC classes scored significantly lower on the science process skills pretest, they scored significantly higher on that posttest. Of particular interest were the differences between pre-and post-test gain scores for the two groups. BACC students gained 2.68 more points than the traditional classes on the biology concepts test and 3.83 more points than the traditional classes on the test for science process skills. These differences in gain scores represented approximately one-half standard deviation.

Student responses on the seven-item questionnaire are shown in Table 2. They revealed that students liked BACC, felt they had done well, and enjoyed the activities. Their comments were consistent with what we observed as we visited the classes. The comments (and percentage of students responding in this manner) were consistent with our observations.

Table 2
End-of-Year Questionnaire Responses by BACC Students

1. The activities in the text were: too difficult (6) about right (89) too easy (5)
2. I found the activities: interesting & helpful (77) uninteresting (23)
3. The readings were: too difficult (13) about right (81) too easy (6)
4. The amount of work for this course was: too much (23) about right (72) not enough (5)
5. Compared with other science programs, I performed: better (86) worse (8) same (6)
6. Compared with other science programs, I learned: more (80) less (16) same (4)
7. I enjoyed using this material: agree (76) disagree (23) sometimes (1)

Inferences

Experienced biology teachers can successfully implement a standards-based high school biology curriculum. They can also differentiate their behaviors to match the philosophy and methodology of the respective curriculum. Moreover, these teachers appeared to be persuaded that a standards-based approach is desirable, reasonable and practical to implement.

From the limited population used in this study, this standards-based biology curriculum appears to be more productive in teaching students understanding of key biology concepts and ability to carry out science process skills. This study may provide some evidence that NSF-funded curricula are accomplishing the goals of the *National Science Education Standards*.

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AN STS APPROACH TO ORGANIZING A SECONDARY SCIENCE METHODS COURSE: PRELIMINARY FINDINGS

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Science Methods Course: The Need for Reform

The current science education reform agenda represented by documents such as the National Science Education Standards (National Rescarch Council, 1996) and Science for All Americans (American Association for the Advancement of Science, 1994) is focused on the teaching and learning of science which goes far beyond the simple transmittal of scientific facts, figures, and processes. The appeal is for science instruction which enhances student understandings of the nature of the scientific enterprise, enables them to critically analyze scientific information as well as apply it in real-life situations, and sets them on a path of life-long learning in science. In order to prepare teachers who can facilitate this kind of science instruction, substantial reform of both preservice and inservice science teacher education must occur. This paper describes an attempt to organize a secondary preservice science methods course around a science-technology-society (STS) approach.

Typically, a critical component of preservice science teacher (PST) education is the science teaching methods course. The intent of this course usually is to help PSTs develop an understanding of various aspects of science instruction such as pedagogical approaches, management strategies, and assessment techniques. Traditionally, PSTs have learned about these aspects in a somewhat isolated manner in the sense that these are taught as separate instructional units. Since the methods course is taken prior to student-teaching and not all methods courses have a field component attached to them, PSTs rarely get an opportunity to see how these different aspects interrelate in the actual classroom context. Also, due to the fragmented approach, methods courses often fail to help PSTs develop a concept of science instruction which can successfully implement current reform proposals (such as relating science to the daily lives and interests of students, accurately portraying the nature of the scientific enterprise, and generating life-long learning habits). In order to alleviate these drawbacks, I tried an STS approach in my secondary science teaching methods course. This approach is defined by the National Science Teachers Association as the teaching and learning of science in the context of human experiences (National Science Teachers Association, 1990-91). The overarching goal of the course was to have PSTs experience the type of science instruction promoted by the current reform agenda as characterized above.

Science for Life: The Course Organizing Module

The module, 'Science for Life' was used as an organizer for the secondary science methods course in the sense that most topics included in a science teaching methods course (such as assessment, cooperative learning, etc.) were experienced by the PSTs within the context of this module throughout the course of the semester. This module was developed with the assumption that the most desirable instruction in the sciences during current times is that which relates science to the lives of students in ways that enables students to see the relevance of science outside the classroom and apply scientific knowledge, principles, and processes to deal with real-life issues, problems, and concerns at both personal and societal levels. To this end, 'Science for Life' engaged PSTs in exploring and experiencing science during a methods course in much the same ways as they should engage their students in secondary science classes. Elements of the Constructivist Learning Model (CLM; Yager, 1991) were employed in engaging in scientific explorations aimed at dealing with a real-life issue, concern, question, or problem selected by the PSTs. Several major aspects of science instruction such as assessment and classroom management were addressed during the course within the context of the module. The module also involved extensive use of modern communication and information technology, thus providing PSTs with experience in integrating technology to enhance science instruction. At the end of the course, PSTs developed an instructional module, based on their own explorations, for use in secondary science classes so as to engage secondary students in science learning which has direct relevance to their lives. They are expected to use their instructional module during student teaching.

Goals of the Module

The goals for school science that underlie the National Science Education Standards (National Research Council, 1996) "define a scientifically literate society" (p. 13). The challenge for preservice science teacher education is to train PSTs in instructional approaches which they can effectively use for the furtherance of these goals in secondary science classrooms. Drawing from NSTA's definition of the STS approach, this module aims to engage PSTs in experiencing science explorations based on real-life issues, concerns, questions, or problems. It is designed to accomplish the following goals with regard to preservice science teacher preparation, which in turn are expected to enable PSTs to further the goals of scientific literacy in secondary science classes.

1. PSTs will learn to engage their students in scientific exploration and inquiry in the natural environment, stimulated by real-life situations, concerns, issues, and questions.

2. PSTs will learn to relate science to the daily lives and interests of their students.

3. PSTs will learn to create effective learning opportunities for students in a community of diverse learners, enabling them to construct meaning from specific science learning experiences.

4. PSTs will develop an understanding of the national, state, and local science standards and will be able to organize science instruction that meets these standards.

5. PSTs will learn to use a variety of authentic and equitable assessment strategies to evaluate and ensure student learning in multiple domains of science.

Resources for the Module

Several resources are important for this module. They can be divided into the following categories on the basis of the nature of resource.

Technology-Related Resources: The module requires availability of computers with internet connection so that PSTs can (a) communicate electronically with the instructor, their peers, and resource persons/organizations around the world and (b) access the world wide web for locating information and other resources. PSTs should have active e-mail accounts. They should also have access to word-processing, graphics, and presentation software.

Human Resources: The module involves communicating with scientists, experts, and organizations involved in work related to the specific problem, issue, or question selected by the

PSTs. The purpose of this communication is to get first-hand expert information, learn about actions being taken, and get feedback from these experts on PSTs proposals of solutions and actions. PSTs are expected to locate appropriate human resources themselves.

Literature Resources: Research-based literature related to STS and the CLM in various forms (journal articles, books, monographs, electronic journals, etc.) would be used. Some would be referred to or provided by the instructor and some located by the PSTs.

Major Learning Activities

PSTs work in self-selected pairs throughout this module. Since the module design is based on the constructivist learning model, learning activities can be classified into the following phases.

Invitation: During this phase, PSTs are invited to brainstorm, search, and select one issue, question, or problem (henceforth referred to as TOPIC) based on real-life situations which will form the basis of the rest of their explorations. Each pair of PSTs may select a different topic. The topic may be based on either a global or a local situation but should be such as would arouse the interest and curiosity of high school students. PSTs must provide a rationale for their topic selection. Ideas for some current topics may be found at the following internet web sites: *http://www.whyfiles.news.wisc.edu;* and *http://www. sigmaxi.org.*

Exploration: PSTs explore their topics in terms of the following two components:

1. Identifying critical questions that need to be addressed in order to explore the topic.

2. Gathering and analyzing scientific information and/or data needed to address the questions identified in 1 above.

This phase involves the use of internet and the world wide web as well as traditional print resources to locate and collect relevant information. PSTs identify several agencies, groups, or scientists who are studying issues and questions relevant to their topic and communicate with them electronically to gather latest information as well as to share their own findings, positions, and action proposals with them.

PSTs design hands-on/minds on investigations to conduct original research into questions that emerge. These can be in the form of laboratory experiments, computer analyses, model building, etc. The exploration phase provides the basis for formulating hypothesis, designing explanations, and proposing solutions.

Proposing Explanations and Solutions: During this phase, PSTs synthesize information to formulate hypothesis, design explanations, and propose solutions. This phase involves communicating information and ideas to peers and to the external experts they communicated with during the exploration phase. Feedback from peers and external experts is used to refine hypothesis, explanations, and solutions. Finally, these are assembled in an electronic presentation format.

Taking Action: Based on the synthesis in phase 3 above, PSTs make informed decisions, take specific positions, and suggest appropriate actions. In essence, this is the application phase in which the knowledge gained is applied in terms of actions. Proposed actions may be at the local level such as starting a new recycling program in the school or at a more global level such as communicating with policy-makers to influence decisions regarding environmental issues. PSTs present these action proposals to their peers in the methods class; however, in the secondary classroom setting, they would actually involve their students in carrying out these action proposals.

The learning activities described above are designed to have PSTs experience the constructivist learning model for teaching science. During each of the phases described above, issues such as assessment of student learning, managing cooperative learning groups, and effective use of modern technology, would be discussed and analyzed within the context of the module. These discussions too ought to model the constructivist approach in that the said issues should be discussed at appropriate time as the need to discuss them emerges during the progress of the module and the discussions should be facilitated rather than controlled by the methods instructor. During the course of the module, PSTs maintain a journal to record the learning activities and to write reflective analyses of their own learning experiences. Based on their own explorations within this module, PSTs eventually create an STS instructional module for a secondary science class, which they can use during student teaching.

Assessment

The assessment within this module is designed to gather information on PSTs understanding of reform-oriented science instruction with regard to the following: Constructivist teaching and learning principles; STS principles; nature of the scientific enterprise; and effective use of technology to enhance science instruction.

Both quantitative and qualitative approaches are used to collect assessment data. Quantitative approach includes the use of questionnaires with Likert-type rating scales. These are administered as pre-tests at the beginning of the semester and post-tests at the end of the semester. The following questionnaires found in *The Iowa Assessment Handbook* (Enger & Yager, 1998) were used: Perceptions of Science Teachers about Science; NAEP Questionnaire for Student Views about Scientific Theories and Scientists; What you think about the Nature of Science; Science, Technology & Society Attitude Scale.

Additionally, a questionnaire regarding technology use was administered to collect data on PSTs understanding of effective use of technology to enhance science instruction. This questionnaire was developed by the *Learning with Technology in Higher Education* project of the Northcentral Regional Educational Laboratory (NCREL).

Qualitative approaches include data collection through PSTs presentations of their STS instructional modules at the end of the semester, reflective journals during the semester, and in-depth interviews at the end of the semester.

Preliminary Findings

The quantitative data from the Fall 1998 group have not been analyzed as of this writing. Only preliminary analysis of qualitative data, which involved looking for trends in PSTs thinking about the use of the STS approach, has been conducted. This analysis indicates that PSTs predisposition influenced the quality of their modules as well as their views on the usefulness and effectiveness of this approach in science teaching and learning in the secondary classrooms.

The Fall 1998 group consisted of 8 members. One of them was a practicing middle school teacher taking this course to complete the high school certification requirements. He had already been doing some STS type projects in his middle school classroom. He created an elaborate STS module on the *quality of drinking water* in his town. He found the process very useful in terms of being able to understand what students would experience in an STS approach. The following comments summarize his views.

> As a student (of this methods course), I feel that understanding the process that the student would go through helps design how the teacher should be thinking when designing what he/she expects of the students. Understanding this process of research and development of the topic from invitation to taking action has forced me to take the student's role. I can now say that I do understand what they would encounter.

Another member, who conducted an investigation of the Asian Longhorned Beetle infestation in the Chicago area for his module titled, *Beetlemania*, said that he had been thinking and feeling the same ideas (STS, Constructivism, etc.) for several years. Now he has a name for them. He found it reassuring to discover that other people (the course instructor and authors of literature used in the course, such as P. D. Hurd and R. E. Yager) think the same way. His previous work experiences taught him that you learn by doing things yourself and remember that which you are interested in and apply. So the STS approach and module "clicked" in his own mind. Here is what he said about the STS approach.

> Having completed the STS module, I now have a tremendous appreciation for STS; an appreciation based on experience. The STS approach offers several important benefits including real world experience and relevance to the student's life, but most importantly, STS creates a context in which students find themselves with a need to learn and a use for what is learned.

To include an example of PSTs who did not feel very comfortable with the STS approach and the module, I mention one who, at the end of semester, claimed to be "more confused". He said that he entered the course with a particular style (of science teaching and learning) that "worked for me". This particular style happens to be the didactic, lecture-oriented approach. He has been a research scientist in the field of medical pharmacology, has a Masters degree in Chemistry and was frustrated till the end of semester about adopting the more student-centered, constructivist approaches promoted through the use of the STS module. He claimed he saw the utility in the STS approach but was unable to adapt it within his own personal mind-set perhaps developed through his years of graduate education and research work. His comments in the reflective journal after the completion of his module titled, *Death: An inquiry into man's mortal weakness*, betray his feelings of apprehension.

> Overall, our module had potential. However, the topic itself was too broad and did not lend itself immediately to projects outside of the classroom. Projects inside the classroom required materials that may or may not be accessible to the high school student.

Another pair of students conducted an investigation regarding human nutrition, titled *Tell me what you eat and I'll tell you who you are: A journey in nutrition.*

Once the quantitative data have been analyzed and the qualitative data have been analyzed more thoroughly, a complete picture of the effectiveness of this STS approach in the science methods course will emerge. Further investigation of the quality and extent of the use of the constructivist principles by PSTs during student teaching this spring will indicate the extent to which they have really learned these principles, for real learning connotes use (Reinsmith, 1993).

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CONNECTING THE CURRICULUM THROUGH NATIONAL SCIENCE AND MATHEMATICS STANDARDS: A MATRIX APPROACH

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Curriculum Integration at the National Level

The need for both a connected curriculum and the implementation of the national mathematical and science standards is acknowledged by organizations and content experts throughout the educational system. Organizations including the National Council of Teachers of Mathematics, National Science Teachers Association, American Association for the Advancement of Science, Association for the Education of Teachers of Science, the Association for Supervision and Curriculum Development, and many others have sponsored publications indicating the need for, and benefits of, both the connected curriculum and the national standards in mathematics and science.

Connecting the curriculum is a phrase used far and wide by educators and researchers alike. It has many meanings and many different levels of implementation. For this work it is intended to mean the linking of conceptual understandings denoted by the National Council of Teachers of Mathematics (1998) in their publication *Standards 2000 Project* (draft) and the National Research Council's (NRC) National Science Education Standards (1995). Although each document approaches the topic from a slightly different perspective. Both indicate the need for connections to build understanding and learning by students.

The connected curriculum leads to more time spent on active student learning, increased retention of conceptual ideas, increased practice time, and greater potential for student application in all content areas. The connections build upon each other and make the process and the learning more powerful to the individual.

Intervention: The Connections Matrix

The process for connecting the curriculum is simple and effective. The Connections Matrix, first published in JSTE (1996) is a grid format which allows educators to examine the content standards and components of two different content areas and discover the areas where the two mesh together. First one content standard is defined, then the other is defined, and then the connections are identified.

Completing the Connections Matrix

To complete the Connections Matrix, select one of the national standards, either mathematics or science. For this work science will be examined first. Then select a standard which has a particular meaning or importance to your classroom curriculum. For this example Content Standard B:5-8,Physical Science from the *National Science Education Standards* (NRC, 1995) has been selected. This standard reveals that, "as a result of student activity in grades 5-8, all students should develop an understanding of the properties and changes of properties of matter, motion and forces, and transformations of energy."

Next, identify three critical components of the standard which students must understand in order to be able to demonstrate an attainment of the standard. For this example these components could include: A) understanding properties and changes in properties of matter, B) understanding motion and forces, and C) understanding transformations of energy. These are the components used to build the connected curriculum. These components are recorded on Chart 1.

The same process should be repeated with the mathematics standards. For this example Standard 2 of Principles and Standards for School Mathematics: Draft Discussion (1998) by NCTM is used. Standard 2 includes: Mathematics instructional programs should include attention to patterns, functions, symbols, and models so that all students understand various types of patterns and functional relationships; use symbolic forms to represent and analyze mathematical situations and structures; mathematical models and analyze change in both real and abstract contexts.

The three components of this standard could include: 1) exploring relationships between symbolic expressions and graphs, 2) become fluent in generating equivalent expressions for simple algebraic expressions and in solving linear equations and inequalities, and 3) use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships (NCTM - Draft, 1998). These components are recorded on Figure 1.

Figure 1 demonstrates the format for developing the matrix used to connect the curriculum. The matrix allows the user to decide upon the standards to be used and then select connecting activities which help students learn about each standard in each content area by actively participating in learning experiences which fit into both content areas and are designed to align with the content standards. Additional samples of completed versions of the Connections Matrix are located on the World Wide Web (www.oit.cmich.edu/rfrancis/research/).

Figure 1. The Connections Matrix

Science ⇒ ⇓ Mathematics	A. understanding properties and changes in properties	B. understanding motion and forces of matter	C. understanding transformations of energy
1. exploring relationships between symbolic expressions and graphs	A1	B1	C1
2. become fluent in generating equivalent expressions for simple algebraic expressions	A2	B2	C2
3. use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships	A3	B3	C3

Selecting the Learning Events and Activities

Once the parameters of the Connections Matrix have been selected, it is time to identify learning experiences that are appropriate to the developmental level of the students involved in the class. First examine Cell A1. Read the two components listed and brainstorm the possible activities through which students could learn about both components. Only spend two to three minutes brainstorming about any one cell, and then move on to the next cell. By the time you finish you will have identified nine, and probably more, activities which students can complete which will help them learn about the identified goals and objectives.

Summary

The national standards in mathematics and science are a reality. As teacher educators we must position our future teachers to enable them to deliver a meaningful and effective curriculum in science. To do this we must make use of mathematics in the science curriculum. It follows that science is the context in which we learn mathematics, and that mathematics is the language of science. The two are forever connected, and should be approached as both a knowledge base and an application of process skills.

The Connections Matrix and the process of connecting the curriculum works equally well with state level learning objectives or outcomes. The intent of the process is to help educators see the overlap and connection between what we say we teach and what, in reality, students need to experience. As educators we need to be reminded of the idea that we do not learn in isolation. Bits of information connected to other bits of information help us to remember and learn. By connecting the curriculum through the national standards in science and mathematics we are providing better opportunities for our future teachers to approach teaching in a thorough and meaningful manner. By using the Connections Matrix process to connect science and mathematics we are enabling teachers to create and deliver such a curriculum.

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Review of connections matrix steps

1. identify a standard in a content area

2. identify three critical components of the standard

3. list the critical components on the Connections Matrix

4. identify a standard from a second content area

5. list three critical components of the standard

6. list these three critical components on the Connections Matrix

7. brainstorm possible learning events

8. select the most appropriate learning events

THE NATURAL SCIENCES PROGRAM AT THE UNIVERSITY OF NEW MEXICO: PERSONALIZING SCIENCE FOR ELEMENTARY EDUCATION MAJORS

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The mission of the Natural Sciences (NatSci) Program at the University of New Mexico (UNM) is to provide pre-service elementary and middle school teachers with the understanding of science content and processes necessary to teach science confidently and competently in their future classrooms. This is accomplished by addressing diverse learning styles and assisting students to build scientific concepts in personally meaningful ways through modeling of effective teaching techniques. Because they will be teaching children, whose natural curiosity causes them to question the workings of the world around them, our students must have the skills to help their future students find the answers to their questions. They must be able to guide children through investigations and observations and aid in understanding the natural world.

Program Philosophy

All instructors in our program are dedicated to the NatSci philosophy that says "Because our students will be elementary and middle school teachers, they will have the most important job in the world. That makes our students the most important people on campus." We assume that our students are intelligent and have the ability to comprehend science. However, a majority of our students are science- and math-phobic. We must overcome their resistance to science by demonstrating the utility of scientific knowledge, and more importantly, scientific processes. We do not weed out the unwilling, but attempt to convert students who are open to new ideas and willing, even eager, to find the answers to their own questions. In many cases, this requires that we prompt them to *ask* questions in the first place.

Our program is housed within the Department of Earth and Planetary Sciences, in the College of Arts and Sciences. We teach science content, not science methods. Our students take their science methods class once they are accepted into the College of Education (CoE), either just before student teaching or while they're student teaching. What they do get from us is the science content background, the inquiry and research skills they need to understand what's going on in their science methods course, and the confidence to investigate science topics on their own. We differ from standard introductory-level, single-discipline science classes in that we provide an experience that is specifically tailored to the needs of future teachers.

Course Sequence

The NatSci sequence consists of three semesters, required of all elementary education majors at our institution. In designing our curricula, we have struggled to strike the difficult balance between covering the basics in a variety of sciences, while investigating them deeply enough that our students truly understand them. We would like to at least introduce the major points of each major science area, so that our students will know where to look up the answers to their future students' questions. Yet, if we employ a broad, shallow-level introduction to all of these sciences, our students won't come to comprehend any of them in sufficient depth that they'll be able to teach them.

To better establish what content should be taught in every section of our three courses, instructors of the Nat Sci program spent last summer in a collaborative effort with Albuquerque Public School master and novice teachers, and some of our students, funded by the New Mexico Collaborative for Excellence in Teacher Preparation (NM-CETP). This effort also delineated methodology recommendations to be used in the three courses and formalized our course requirements. While the Nat Sci program feels strongly about preserving instructor autonomy, these guidelines result in better consistency among the different sections of our course.

Course content builds from one semester to next. Nat Sci 261 (Physical Science) is a prerequisite for Nat Sci 262 (Life Science), which is a prerequisite for Nat Sci 263 (Environmental Science). Integrated, cross-disciplinary issues (e.g., waste disposal and global warming) are revisited and reinforced throughout all three semesters.

Commonalities Among the Three Courses

Each class meets 5 hours a week, comparable to a lecture + lab course, but the lecture and lab components of our courses are integrated. Each section of each class varies greatly in its collective prior knowledge. Constructivist learning requires that we assess quickly what each of our students knows, so that we can help them build on that, or rebuild after confronting previous misconceptions. Our classes are inquiry-based, activity-based and issues-based. Instructors guide students to develop their own understandings on a personal level. This personal approach is facilitated by relatively small class sizes (24 students maximum).

We utilize the Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996) extensively in all three classes. These guidelines demonstrate to the students what their students will be expected to learn at different age levels for each of the scientific subjects we teach, as well as ways the different sciences are integrated with each other, with math and with technology. Use of these documents teaches our students how to make informed decisions regarding what and how to teach in their future careers. The standards also provide NatSci instructors with an appropriate answer to the often-asked question "Why do we have to know this?".

We utilize peer instruction methodology extensively. Students work in groups to answer questions (in the first semester, mostly questions posed by the instructor; in the third semester, mostly questions developed by the students themselves; and a fairly even mix of the two in the second semester). When one or two students in a group who "get" a concept explain it to others, the explainers clarify it for themselves, often discovering even more about the concept while doing the explaining, and the listeners receive the benefit of hearing how the explainers figured it out. In addition, NatSci instructors listening in on these discussion learn better how our students process information.

All students also participate in field trips. Some field trips meet within class time and others take place on Saturdays. The trips are designed to enhance student understanding of class work by demonstrating its applicability to the world around them. These field trips serve as an introduction to the locally available resources our students will use in their future careers. In all three of our courses, our students gain experience working with children in real classrooms.

A disturbing number of our students have never written reports before. All of our students write reports about their field trips and classroom experiences. As part of each report, they research science education standards and include those that touch upon their experiences. They cite the standards and benchmarks, and any other references they use in writing their reports. We also set aside some class time for students to share with others what they did/saw/learned on field trips or in their classroom experiences. This allows the students to process their experience through talking to others about it, which helps them to prepare for writing their reports. All three classes also develop student use of technology, through use of email assignments, Internet searches, designing of student web pages, etc.

<u>Nat Sci 261: Physical Science</u>

The first semester covers physics, astronomy and geology. A large percentage of our first-semester students have recently come from a structured high school environment, are used to being spoon-fed information and are reasonably good at memorizing and regurgitating on exams. They tend to work best in a structured environment initially: reading textual materials before class, short lectures in class to clarify target concepts and vocabulary, then hands-on laboratory exercises. Over the course of the first semester, we gradually wean them away from structure by encouraging them to ask questions and to perform scientific inquiries to help them find the answers.

There is a Saturday geology field trip associated with this class. The Albuquerque area is a fabulous outdoor classroom for a lot of different science areas, especially geology. Nat Sci 261 students are also required to attend a "star party". Every Friday night during the school year, the UNM Astronomy Club sets up a multitude of telescopes, and numerous professional and amateur astronomers share their knowledge and enthusiasm with our students. This assignment generally meets with a lot of grumbling at first. Our students do *not* want to give up a Friday night. However, once they go to one of these parties, we get almost unanimous conversion. Our students discover the joy of exploring the night sky and are eager to share this experience with their future students.

A very important part of the student's grade is the in-classroom experience. In 261, students find or design a lesson plan for an activity that is geology, physics or astronomy-related. They practice their activities with each other in our classrooms, and provide each other with feedback, then go to a K-8 classroom and present the demonstrations. The classrooms are split into groups that cycle through all the demos. This committee arrangement allows our students to present their demos a number of times.

We also assign a number of email projects. While some of our students are well versed in the use of computers, a majority of them have not used email, the Internet, CD-ROMs or other computer resources. Our email assignments introduce the students to these resources. In addition to the research students need to do for their science demonstration, they have one more small research project on some body in the solar system.

Nat Sci 262: Life Science

In our second semester, chemistry is integrated with biology topics. We encourage increasingly more independent thought, and require students to complete some research on their own and present it to the class, then to schoolchildren. As we wean our students away from the structured style of the first semester and direct them toward more independent work, students keep journals of what they learn from their reading and in-class activities. These journals take the place of the daily homework and exercise sheets required in the first semester. The journals are collected and reviewed by the instructors periodically, so this feedback is not as constant as it was in 261. This process places more of the responsibility for learning on the students.

In 262, the required field trips are: a) a Saturday group visit to the Rio Grande Nature Center to study biological diversity, biological classification and ecological relationships between organisms; and b) an independent, outside-of-class-time judging of a science fair. Students also complete two important research projects. One is to research a particular organ system, write a report about it, and do a short presentation in class. The other is the construction of a giant cell. Each student researches a cell organelle, makes a model of it to fit into a giant cell model built by the class. The giant cell is constructed of a huge sheet of plastic (about 7 X 10 meters), folded over on itself, and blown up on one corner by a box fan, leaving another corner open to use as a door. Students enter the cell and put their organelles in place, and explain the function of the organelle to the class. After the test run in our classrooms, they show the whole cell to an upper elementary or middle school classroom.

Nat Sci 263: Environmental Science

In our third semester, physical and life sciences are integrated. By this time, students are generally willing and able to be self-driven. The depth and focus of their questions, and their innovative attempts at solving their problems demonstrates this. In this third semester, students are able to integrate what they have learned into a coherent world view. This is the most interesting class for most of our students and the most fun to teach.

These students take a number of in- and out-of-class field trips. For example, we go to the UNM nuclear reactor, the landfill, and the Albuquerque Water Treatment Center (aka the sewage plant). Students also participate in a science curriculum program such as Project Wild, Project Wet, or Project Learning Tree. At these training sessions, they learn not only content and teaching methods, they also learn that these sorts of training sessions exist! Many students, having completed one of these sessions, want to go to all of the others.

The classroom experience for 263 students takes place at the Sandia Mountain Natural History Center (SMNHC), which is run jointly by Albuquerque Public Schools (APS) and the New Mexico Museum of Natural History. Every fifth grade student in the APS system, and many others from surrounding school districts, spend one school day at the center. Our students spend the day with one of the student groups. They join these students on a hike and participate in environmental learning activities throughout the day. In a typical group, there may be 16-20 kids, their teacher, one or two parents and the SMNHC teacher. When our students are there too, that increases the adult-to-kid ratio. I've had great feedback from the SMNHC staff, telling us that just having an extra adult to show an interest in what the children are doing, finding, discovering, enriches the experience for the children enormously.

They also do a substantial research project that requires them to synthesize what they've learned in all three semesters. The main inquiry-based project in 263 is to research an issue, write an outline for a classroom discussion, provide their classmates with the reading materials they need to prepare for discussion of the issue, and then lead a seminar-style discussion of the issue in class. All students evaluate the others' discussions and their own discussions. Examples of issues that are covered range from: global warming to human population growth and control to recycling. Each of these issues can be found in the daily news and really bring home the importance of science in our students' every day lives. They are also interrelated. For example, one group may cover urban planning, relating it back to what another team said about paving reducing the amount of infiltration into the aquifer, thereby reducing local water supply, and to another team's discussion of energy conservation though carpooling and public transportation. Students learn about the costs and benefits of every day choices and decisions, and the importance of making informed decisions. They become even more convinced of the importance of education in assuring that we have a world we want to live in in the future.

In this course, students see how important science is to so many of today's issues. They see how all of the sciences they have learned interrelate and make up complete, coherent pictures of how the world works as a whole. Students leave this class with a deeper than ever understanding of science concepts, science processes, and most importantly, they leave knowing that they, as teachers, have the power to make a real difference in the world. They know that the solutions to the vast majority of today's problems lie in education, and the solutions to environmental problems lie in understanding science.

Assessment

At this time, most of the feedback on our program is qualitative and anecdotal. We have always given our students instructor- and course evaluations at the end of each semester. These provide individual instructors with the information they need to improve things for the following semesters. We have not had time to look at the results of these evaluations for the program as a whole, but we will be doing so in the near future.

We have recently designed and tested a more quantitative assessment. This survey instrument will be completed by all students upon entry to the program in 261, and again upon completion of the program at the end of 263. The survey includes demographic and science/math background questions. The bulk of the survey consists of very basic science content questions, about 20 questions for each course. Testing what they know upon entry to the program and what they learn while taking our classes will allow us to quantitatively evaluate our program. In addition to the pre- and post-assessments, we will be embedding some questions that test for the same content in midterms and finals within the course in which the individual content material is taught. Student responses to each of the questions at the pre-assessment, embedded, and post-assessment steps will be tracked. We also plan to distribute the surveys again to our past students, to see how well our material is retained a couple of years after completion of our program. We recognize, however, that those data are likely to be skewed in our favor, because the students most likely to respond to our surveys are the ones who learned the most, and are the most interested in science.

Preliminary Results

Upon entry to the program, the majority of our students do not want to take science. They had a little science in high school and they didn't like it. It was confusing, boring, or too nerdy. They have no current interest in science at all. Most view science as a collection of data to be memorized, regurgitated on exams and then forgotten. They think science is something only a few, really brilliant, often really boring, detail-minded, stodgy, European men wearing lab coats can do. They don't think of science as fun, creative, and interesting. They don't think of it as comprehensible or do-able by everyone. We consider it our job to change these attitudes over the three semesters we have them. Some quotes from the free-response portion of the beginning of last semester's survey of entering Nat Sci 261 students are:

> I hate science and am only taking this class because I have to.
> I don't have to learn science because I'm only going to teach 1st grade.
> I don't like science, but realize I'll have to teach it, so I have to learn it.

At the end of the semester the same students were saying:

> In this class, I learned that science can be fun, and even I can do it.
> Before this class I hated science, but because of this class, I've come to enjoy it.
> I am actually excited to teach science and I never thought I would.

At the end of Nat Sci 263, some student quotes are:

> I never knew science could be so fun and interesting!
> I like this program because it is designed for teachers and it gave me what I need to succeed."
> I look forward to using what I learned here in my classes.

However, our classes are *not* all fun and games. We could gee-whiz them to death with fun activities and demos, thereby changing their attitudes about science, but without providing them with any solid science content. Some sample content questions from our progress surveys, along with the percentage of students getting the question correct (at the beginning and end of the semester), are shown in Table 1:

Plans for the Future

In addition to gathering and tracking the quantitative results of our progress survey, we

Table 1
Sample Content Questions from Natural Science Program Progress Survey
Beginning and End of Fall, 1998 Semester

Course	Sample Survey Question	Percent Correct August, 1998	Percent Correct December, 1998
NS 261	You have a refrigerator in a perfectly sealed 75°F room and nothing (including heat) can get in or out of the room. You open the refrigerator door, set the refrigerator thermostat to 50°F, and leave the refrigerator door open. The refrigerator starts working. What happens to the temperature of the room? A. It goes up. B. It goes down to 50°F. C. It goes down, but not all the way to 50°F. D. It doesn't change. E. I have no idea.	17	78
NS 262	In mammals, oxygen is carried to the body tissue by means of the: A. digestive system. B. respiratory system. C. circulatory system. D. nervous system. E. I have no idea.	44	92
NS 263	Greenhouse gases: A. are gases released by plants during photosynthesis. B. are only artificial pollutants accumulated in recent times. C. are located just outside of the Earth's atmosphere. D. are substances in the Earth's atmosphere that absorb infrared radiation. E. I have no idea.	9	85

are also expanding and improving the resource base available to our instructors and students. Unfortunately, we have a pretty high instructor turnover rate, so we have established an ever-expanding file system to which instructors add new materials, ideas, activities, exercises, background material, etc for each of the topics we teach. These files allow new instructors to quickly learn from the experiences of past instructors. Although no regular faculty teach the NatSci classes, the instructors of these courses are professionals with a minimum of a M.S. degree in a pertinent area of science, and many are Ph.D.'s. Most importantly, NatSci instructors have a deep commitment to a pedagogical style that is relevant to our students as future educators.

Another thing that may significantly shape the future of the program is the soild realization reached by most of us this past semester that the targets established during last summer's curriculum refinement effort are still too broad to provide adequate coverage of all the target areas. It is not possible to teach all of the science our students need to know in only three semesters. A new approach allowing students to determine content is being tested this semester. Our students' first homework assignment will be to rank the NM science education standards and benchmarks applicable to the class in terms of importance/interest. Our students will see what will be required of them as teachers, and tell us what they are most interested in learning. This will increase the students' sense of responsibility for their own learning, and tell us what to focus on. While focusing on the areas the students choose, we will model the inquiry processes and teach the inquiry skills they will need to learn on their own the material we cannot cover in class. By doing this we will emphasize depth in favor of breadth. In order to teach science successfully, our students will need to know the topics they teach thoroughly, and truly comprehend not just the facts about that area of science, but how we know what we know about it.

Summary

Our small classes, emphasis on concept-building, integration of sciences, attention to diverse learning styles, use of constructivist teaching techniques, and introductions of students into classrooms are ideally suited to the needs of our students. Although data are preliminary, pre-course surveys followed by post-program assessments indicate that our methods are successful in delivering the science content and process skills that our students need. In addition, student evaluations of courses and instructors indicate that our goal of increasing student comfort levels with science is also being met. The majority of our first-semester science-phobes are science enthusiasts by the time they complete the program!

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ADDRESSING EQUITY WITHIN SCIENCE EDUCATION COURSES: SHARING APPROACHES AND IDEAS

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Peggy Hammrich, Temple University

Sharon Lynch, George Washington University

Randy McGinnis, University of Maryland

Eric Pyle, West Virginia University

Orientation to Session

The purpose of the session was to provide opportunities for individuals involved in science teacher education to exchange approaches and ideas about how equity issues in science teaching and learning were being addressed in their science teacher education courses. Several questions served as a framework for panelists' contributions and subsequent discussion:

- What conceptions of "equity in science education" underpin our individual approaches?
- What approaches are we using to address issues of equity in science education?
- What issues and challenges are we confronting in our teaching related to these issues?
- How are we resolving these issues and challenges?

Conceptions of Equity in Education: The Many "Faces" of Equity

Equity can be defined as having "many faces," and mean different things to different people (Division of Elementary, Secondary, and Informal Education, 1997). Kohl and Witty (1996) suggest that equity is a "value," and is not synonymous with equality. Equity in education has been described as "equal distribution of resources" or "equal quality of the educational experience," encompassing a set of beliefs about how people should be treated and schools should be teaching children (Division of

Elementary, Secondary, and Informal Education, 1997). Grant and Billings (1997) assert that equity in education goes beyond equal opportunity, and addresses learners' individual differences and needs in curriculum and instruction. According to Secada (1994), equity refers to examination of social arrangements underpinning schooling to judge the extent to which these arrangements are consistent with standards of justice.

Educational equity has been identified as a principle of the modern multicultural educational movement in the United States (Hidalgo, Chavez-Chavez, Ramage, 1996), and education in general (Kohl & Witty, 1996). It is also highlighted in the current rhetoric of science education reform. Educational equity is embedded in the idea of quality science for all students, and is mentioned in several national standards (NRC, 1996). At the state level, learning frameworks or standards are giving varying levels of consideration to the goal or principle of equity in science education (e.g., CCSSO, 1997; GIMS, 1996). In contrast, Rodriguez (1997) argues that the National Science Education Standards "uses a *discourse of invisibility* to lay out its massive science education reform" (p.19) which compromises the intended goals of this contemporary reform effort.

Regardless the level of the student – practicing teacher, prospective teacher or K-12 student – creating equitable education continues to challenge the educational community (Division of Elementary, Secondary, and Informal Education, 1997). The dialogue about equity in education includes groups with interests in gender, race/ethnicity, learners with special needs, class, language, religion, and sexual preference. The inclusion of students with special needs has emerged as an equity issue of particular interest, particularly as our abilities to detect and measure special needs are becoming increasingly efficient. This has created a revenge effect (Tenner, 1997), such that as our capacity to detect special needs has increased, so has our moral and legal responsibility to accommodate students with special needs in schools.

Session Format

Panelists and participants engaged in an interactive forum primarily organized by the use of small group discussion. Panelists described their approaches or practical ideas for addressing equity issues in science teaching and learning, challenges and resolutions. Sharon Lynch facilitated group discussion about a model for characteristics of effective teachers of diverse populations for science education reform. Katherine Wieseman and Lynn Bryan co-facilitated a discussion about their approaches for addressing equity from a "holistic" perspective. Penny Hammrich facilitated discussion that was "all over the board" as well as focused on two questions. Are teachers' expectations about participation equitable practice? What are useful resources to cause students to examine their beliefs and teaching practice? Schedule conflicts and adverse weather conditions prevented the discussion focused on equity from an inclusion perspective from taking place, though it is partly represented in a paper by Eric Pyle. Two panelists, Wieseman and Pyle, each prepared papers or handouts; respectively, "Equity from a 'holistic perspective' based on student-generated artifacts" (see Appendix A) and "From parallel universes: Building equitable classroom environments from the ground up through science and special educators' collaboration" (see Appendix B).

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APPENDIX A
EQUITY FROM A "HOLISTIC" PERSPECTIVE BASED ON STUDENT-GENERATED ARTIFACTS

Katherine C. Wieseman, Western State College

Visualization and art can be powerful means for reconstructing life and professional experiences in order to examine their meaning and reveal beliefs underpinning action. I ask my education students to use their visual memory as a basis for self-reflection and analysis. I would like to open our examination of equity from a "holistic"perspective with a modification of a strategy that I use in my teaching, and have it serve as a way to introduce my approach to addressing equity in science teacher education. Subsequently, I will describe the conceptual framework underpinning my approach and the approach. Finally, I will overview what I have learned from my education students about their visions and understandings of themselves as equitable teachers of science.

<u>Visualize Yourself ...</u>

I ask you to shut your eyes and listen to the questions posed. As I pose these questions, paint a mental picture. Your picture may be in color or in black and white. It might be a series of still snapshots or a series of moving images. The goal is to reconstruct a recent teaching experience in one of your education courses.

Ready? (Pause) Okay, shut your eyes.

(In a quiet and soothing tone, and pausing at the end of each statement or question) What was the last course you taught? See yourself in one of the class sessions with your students. What is the topic of the session? What are your goals for today's session? What are your intentions? What do you hope your students will understand? Where are you? Is it a room or the outdoors? Are their any smells? Any sounds? What are they? If you are in a room, what is in the room and how is it arranged? What is beyond the room? Where are the students situated? What are they doing? Where are you? What are you doing? What are you thinking? Let the class session begin and progress. Just watch the scene as it unfolds and minutes go by. Notice body language – posture, facial expressions, gestures, movement, and interactions. Notice verbal language, voice tone, and inflection. Watch more minutes pass. Now what's happening? As you get closer to the end of the class session, notice how it ends. How does it end? When you arrive at the end of the class session, raise a finger or your hand and open your eyes.

Jot down on a piece of paper what it means to you to be an equitable teacher. (Pause) How are these ideas reflected or not reflected in what you visualized? Whose learning was favored and disfavored during your visualization, and how did this occur? (Time for sharing)

A Conceptual Framework

Equity is a word with many meanings and evokes thoughtful as well as emotional discussion and debate. Equity in education has been described as a value (Kohl and Witty, 1996), "equal distribution of resources" or "equal quality of the educational experience" children and a set of beliefs about how people should be treated and schools should be teaching children (Division of Elementary, Secondary, and Informal Education, 1997), a commitment to addressing learners' individual differences and needs in curriculum and instruction (Grant and Billings, 1997, an examination of social arrangements underpinning schooling to judge the extent to which they are consistent with standards of justice (Secada, 1994), a principle of the modern multicultural educational movement in the United States (Hidalgo, Chavez-Chavez, & Ramage, 1996) and and goal of contemporary education (Kohl & Witty, 1996; NRC, 1996).

Equity in science education – what does this phrase mean to me? Kohl and Witty's suggestion that equity is a value most closely relates to the conceptual framework underpinning the approach that I use in my teaching. Equity is a value guiding my actions and interactions in all realms of life, both professional and personal, and is based on seeking and celebrating diversity! This celebration demands awareness, sensitivity, a commitment to practicing nonjudgmentalism, valuing the uniqueness of each individual whose life path intersects with my own, and seeking and understanding commonalties we might share.

Awareness, sensitivity, respect and valuing diversity has constituted the fabric of my existence. The environment in which I was raised was multicultural. My father immigrated to the United States. My mother, born and raised in America, has a longstanding and deeply rooted appreciation for cultures of other countries. My parents chose to raise my two sisters and me in yet a third country, Venezuela. Political and geographic boundaries were irrelevant to the childhood friendships and social relationships I established. Later, as a young adolescent and adult living and working in the United States, I continued to live betwixt cultural and social groups. I lived in "multiple worlds" and was a "border crosser" (Aikenhead, 1998). I still am. Four and a half years ago my professional identity began to be defined through responsibilities as a science teacher educator, first as a doctoral student at the University of Georgia and now as a teacher educator at a liberal arts college nestled in a mountain community in Colorado.

Beforehand, I posed the question, "Equity in science education – what does it mean to me?" I return to this question. The foundation for my response to this question rests in what it means to be human in the context of schooling and education. To be human is to be a composite representation of a spiritual, intellectual, emotional/affective, physical being (Wieseman, 1998). To be the teacher educator I want to be calls for an ongoing and lifelong commitment to learning about and acting with conscious awareness and understanding of this definition of humanity. It is a journey of revealing, evoking, articulating and changing beliefs and attitudes (Rokeach, 1968). The nature of this journey is spiritual and holistic in orientation (Halford, 1998;Palmer, 1998) and must be evident through congruence between verbal language and action. The journey is oriented within (toward self) as well as toward others. My dream and desire is that the education students who sit my courses and who I advise engage in lifelong journeys of a similar orientation.

One Approach

In the teacher education classroom, as a facilitator of my and my students' journeys, I endeavor to provide diverse opportunities for students to: (1) express and examine their world views and teaching philosophies; (2) become informed of the social, cultural, psychological, and emotional dimensions of preparing to be a teacher; and (3) develop their professional knowledge (Connelly & Clandinin, 1988; Shulman, 1986). I embed attention to equity issues into discussions, actions and interactions when and wherever possible throughout the course, as well as highlight equity in science teaching and learning as an independent class sessions. This framework could be labeled as an equity-based approach (Bailey, Scantlebury, & Letts, 1997).

Besides the stories and cases that I share from my professional experiences as a teacher, I ask students to generate artifacts to guide their reflective processes. Their artifacts serve as a primary source for their explorations of self and others, and have included:

- Two-dimensional graphic representations of students' visions of themselves as teachers of science accompanied by a written narrative;
- Representations of students' visions of themselves as "equitable" teachers using any form of expression accompanied by a written narrative;
- Written reflective narratives about their teaching experiences during the methods course
- Written responses to questions such as, (1) When you think of "fairness" in teaching, what does this mean? (2) What does equity in learning science mean to you? (3) What does equality in learning science mean to you? (4) Are equity and equality the same or different things? (5) How do equity and/or equality relate to "fairness" in teaching?
- Analysis of their artifacts in relation to professional literature as synthesized in course handouts disseminated during the class sessions specifically highlighting equity issues in science teaching and learning (e.g., Aikenhead, 1998; Anderson, 1988; Keller, n.d.; Melear, 1995; Murfin, 1994; Ogawa, 1995)

Students ' expressions, using diverse media, stem from visualization, life experiences and the professional literature.

Prospective teachers' visions and understandings

Student-generated artifacts can be a powerful vehicle facilitating their endeavors to articulate, express and understand personal world views and teaching philosophies. The following synthesis reports themes in students' visions and understandings of themselves as teachers of science. The synthesis is based on three diverse groups of prospective teachers. One group, prospective teachers of middle level science, were education students in an Early Childhood program at the University of Georgia. The two other groups, prospective elementary teachers and secondary science teachers (middle and high school), are education students in the Teacher Education Program at Western State College.

Emergent themes in students' graphics and narratives communicating their visions of themselves as teachers of science were goals of science teaching and learning, the nature of the science learning environment, the nature of science, developmentally appropriate ways to learn science (e.g., hands-on), the nature of learners, teacher roles and responsibilities, and school-family connections. Emergent themes in students' analyzes of their teaching for types of learners favoured and disfavoured centred on learners prospective teachers disfavoured, namely learners who have difficulties (as a function of English language proficiency, cognitive ability, special learning needs), are "bright" and "have a great deal of knowledge," are less interested or enthusiastic about learning, hold creationist views, and/or have learning styles or thinking approaches different from the prospective teacher.

In their visions of themselves as teachers of secondary science, the prospective secondary teachers (N=6) communicated their views about the goals of science teaching and learning and the nature of the science learning environment. For them, it was important that their future students develop understanding of the world and scientific knowledge and understanding. As a prospective biology teacher indicated, "I believe students must be able to leave school with a certain understanding of the entire world and at least a hint of some direction that they may wish to pursue" (August 1998). As a prospective earth science teacher wrote, "My goal is to make them realize that what they see on the Earth today is not how it always was, and it will not remain the same. ... They should understand that the rock that makes up the mountains they see was once the bottom of a shallow sea or the surface of a desert" (August 1998). The science learning environment, though predominantly set in a classroom was not restricted to this physical space. When students were mentioned, they were referred to as aggregate entities; for example, "I want to apply my teaching to the students' futures as well as their present life situations" (August 1998).

In the analyzes of their teaching for types of learners they favoured and disfavoured, most of the prospective secondary teachers reported that they disfavoured students who "don't get the material quickly" and "who needed more assistance." This tendency was attributed to "the problem of not fully understanding the cognitive ability of the student" or lack of awareness until the prospective teacher had observed their video taped lessons. They also thought they slighted students less interested and enthusiastic in science, which, according to several prospective teachers, were the girls in the classroom. One prospective teacher also indicated disfavouring students whose thinking approaches (i.e., relational and holistic) as well as views of science (i.e., "a creationist point of view") were different from his own.

The prospective middle school teachers (N=48) expressed their views about goals of science teaching and learning, the nature of the science learning environment, the nature of science, developmentally appropriate ways to learn science, teacher roles and responsibilities, school-family connections, and/or the nature of learners in their visions of themselves as teachers of middle school science and as equitable teachers of science. Like the prospective secondary level teachers, middle level teachers believed it was important that their future students develop a scientific understanding of the world in which they lived. Like the prospective elementary level teachers, they emphasized hands-on science.

Two emergent themes for this group of prospective teachers, unlike the other two groups, were learner differences and "treat[ing] them [students] all equally." The most commonly mentioned attributes of learner differences were race, ethnicity, gender, disabilities, "way of learning" and religion. In the words of one prospective teacher, "children are unique and have different interests, abilities and needs ... and it's my job to adapt to the students' way of learning." Other students, however, claimed they would "treat them [students] all equally," regardless of differences between learners. Equal treatment of students was regarded to be equitable practice: Equality = equity. For instance, "I will not discriminate against any race and will treat everyone as an equal" and "treat them all the same -- with love." With respect to their perceptions about themselves as equitable teachers, essential qualities included being flexible and able to assume diverse roles ("wearing many hats"), and exhibiting respect, concern, compassion and sincerity toward their students.

Based on their analyzes of teaching experiences, the prospective middle level science teachers reported disfavouring several types of learners. This list included: students having difficulties (stemming from limited proficiency in English, learning disabilities, attention deficit disorder, and physical and mental challenges); students not in close proximity of the teacher; students who are "quiet" and do not volunteer comments or ask questions, nor do they raise their hands; students with a creationist orientation; students "who may know it well;" and students with learning styles different from the prospective teacher's (i.e., kinesthetic and/or visual learners).

The prospective elementary teachers (N=3) focused on the goals of science teaching and learning, developmentally appropriate ways to learn science, and the nature of the science learning environment in their visions of themselves as teachers of elementary science. For these prospective teachers, the best way to learn science and for children to develop an understanding of their world was through hands-on learning. Their initial conception of hands-on learning, commensurate with an "activity-mania" orientation (Moscovici & Nelson, 1998), at the end of the term shifted to an inquiry orientation (NRC, 1996).

They perceived that they disfavoured the "bright children who already have a great deal of knowledge," the "more advanced students because I think they can 'get it on their own' " (December 1998) or the "independent" child in their teaching. They thought they focused on those children who were "not staying on task" or "need[ed] more help and assistance" (December 1998). Additionally, one prospective teacher indicated that, prior to explicit attention to equity issues in science teaching and learning during the course, he had "never thought about much [equity in science learning]" (December 1998).

Challenges and Questions of Curiousity

Becoming aware, articulating, examining and changing beliefs, an elusive construct (Pajares, 1992), is difficult, complex and not well understood. I suggest a corollary, that becoming aware, articulating, examining and changing beliefs about equity in education in general and science education in particular is difficult, complex and not well understood. Major contributing factors stem from the diversity of conceptions of what equity in education is and the significance assigned to examination of equity issues in education. Nevertheless, creating equitable education continues to challenge the educational community, regardless who the learner is (Division of Elementary, Secondary, and Informal Education, 1997) – practicing teacher, prospective teacher, K-12 student, or teacher educator.

As a reflective teacher educator, I ask myself, "What connections are my students making when equity is addressed from a 'holistic' perspective? How can I help my students understand that equity is more than a checklist for developing teaching practices or a mechanism for analyzing curriculum materials and assessment tools? How can I help my students understand that equity is a way of relating within the social worlds of which they are members, their past and current worlds of schooling, and their future as classroom teachers?" These are my personal challenges and questions of curiousity.

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APPENDIX B
FROM PARALLEL UNIVERSES: BUILDING EQUITABLE CLASSROOM ENVIRONMENTS FROM THE GROUND UP THROUGH SCIENCE AND SPECIAL EDUCATORS' COLLABORATION

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As a high school science teacher, I faced many challenges. The school system that I taught in shared many characteristics with both rural and inner-city schools, and so resources were often tight and many students faced limited options once they had completed high school. One of the most vexing issues was providing adequate and appropriate instruction for the students with special needs that were included in my classes, often with little or no support from the special education teachers. Other than the occasional invitation to meet with a student' parents and other teachers, I often was on my own to meet a particular student's educational needs. Very rarely was an individualized education plan (IEP) made available to me if I was even informed of a student's special needs at all. When we discovered that our son had special needs, the perspective was suddenly changed. Now I was forced to be on both sides of the table.

My role as a science teacher educator brings me into contact with large numbers of teachers in diverse schools. West Virginia has made a considerable investment in school building in the last few years, but considerable disparities still exist in terms of the resources available within those schools, both material and personnel Yet in these schools I have found a sincere desire for most science teachers to effectively promote learning by student with special needs that have been included in their classes. This desire to serve their students' needs is often offset by an intense frustration with their lack of time or expertise in dealing with specific disabilities in the context of their own classroom and the demands of the state-mandated curriculum. Many of these teachers felt that inclusion was "just one more thing" to draw upon their already limited time during the day.

Conversations with my colleague in special education revealed similar concerns coming from the special education teachers that she worked with, but from a different perspective. The special education teachers expressed frustration over not having a sufficient depth of content knowledge to their students to learn content. We thus formed a theory that a paradox existed, such that teachers might be driven to provide either content instruction without student-centered pedagogy or pedagogy without content.

Toward our interest in better preparing science and special education teachers to deal with such a paradox, we decided that teachers from both groups had a considerable depth of expertise from which to draw on. By creating an opportunity for these teachers to collaborate from a position of strength and not deficit, a project was developed such that science and special education teachers would be paired to bring together their knowledge of science content and the science curriculum as well as disability-specific pedagogies.

One problem that was faced was developing the means of communication. My colleague and I needed to develop a negotiated sense of role, communication, and time management that paralleled the early work to the teacher pairs. We had the basic educational lexicon in common, but the stylistics of communication necessary for effectively completing our collaborative goals were lacking. We were able to share our terminology and approaches but not all the meaning behind them. We began to use the tools of collaboration suggested by Finson (1998), though our intrinsic motivation, commitment, and valued knowledge base. What was required to go beyond abstract products, such as lists of accommodations for special needs students divorced from specific settings, was a common currency to focus on, a context that provided concrete support to the abstract nature of our discussions.

The currency became short cases or vignettes that each represented a student with a special need or needs, as well as a prototypical Individualized Education Plan (IEP). The cases that we developed and subsequently had the participants in our project develop, each represented a student that someone in the group had had direct personal experience with. The cases described the student's background, academic and family history (to the extent known), the nature and extent of the student's deficits, strengths, and categorized disabilities. The case was completed with an overview of the student's IEP and appropriate modifications and accommodations.

Using the case one focal point, the participants developed lessons that included by design specific accommodations matching the IEP. The lessons were based directly on the state science curriculum and were coordinated by a content theme used across grades, which served as a second focal point. The lessons thus reflected a synthesis of two sets of mandates, the state curriculum and the dictates represented by the IEP. Each member of the pair brought together their own specialized teaching lexicon and developed a stylistic language that was manifested in their lesson plans.

It became evident as the lessons were developed that the very notion of inclusion was no longer intimidating to the science teachers, nor was the science content a source of deep concern for the special education teachers. In fact, they came to realize that through their efforts of inclusion by design, they would be creating an environment that would enhance the learning for all of their students, whether they had identified special needs or not. Teachers now have a potential to develop a clear means of collaboration and everyday language so that time need not be expended on learning the other teachers point of view with respect their students' needs. Ideally, science and special education teachers can work towards co-teaching and co-planning that the actual, day-to-day instruction is seamless and it becomes difficult for outside observers to distinguish one teacher or one student from another. And where school resources do not allow for such daily contact between teachers, what little time to co-plan that exists for the science and special education teacher can be maximized in that they know exactly how to stylize their discussions to meet their students' needs in the limited time frame.

We are each provided with different strengths and weaknesses, but when the instructional environment supports each student's use of their strengths to work towards their maximum potential, we set the ground work for equitable conditions beyond school. Close collaboration between professional educators in the interests of students must be supported and maintained if an equitable environment is to be created in schools. Not only does the inclusion arena offer a great potential for supporting equity, equity is mandated by the laws and regulations supporting special education.

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HOW MUCH IS ENOUGH? PREPARING ELEMENTARY SCIENCE TEACHERS THROUGH SCIENCE PRACTICUMS

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Introduction

Science education and the preparation of science teachers have been of great concern over the past two decades (AAAS, 1993, 1989; NRC, 1996;). The professional literature clearly notes a lack of science preparation and literacy for elementary teachers being prepared by universities. (Fort, 1993; NRC, 1996; Tobias, 1992 & 1990). In an early study Weiss (1978) found that only 28% of elementary teachers felt qualified to teach science and that on the average 90 minutes per day were spent on reading instruction versus an average of 17 minutes on science instruction. These results have been corroborated by Stefanich and Kelsey (1989) who found that less time is spent on science instruction in elementary schools than any other subject. Of the time spent on science instruction, an earlier study found that 90% of the teachers relied on textbooks for about 90% of their science instruction (Stake & Easley, 1978). Yager and Lutz (1994) found similar results and further explained that science instruction was comprised of students listening to lectures, reading from textbooks, memorizing, repeating and confirming scientific facts. Although the shortcomings of teachers and teacher preparation programs are well documented, strategies of preparation related to the practice of becoming an elementary science teacher, specifically the practicum experience, has not been well documented.

Some examples of practicums have been briefly discussed in the literature. Mason (1989) explained a teaming situation of a scientist, science educator, science teacher, and a student teacher in a practicum situation. Bagheri and Hoosho (1991) explained about an integrated practicum for science and math with the accompanying benefits of combining theory and practice. Although these references deal with practicum situations, neither focus on the length of the experience. Only one citation was found that dealt with length as the primary issue of the research which was done in an elementary social studies practicum where an eight week placement was compared to a sixteen week placement (Carter, 1989). No direct literature has been found to date recording how much practicum or how little practicum is enough to produce a competent elementary science teacher. In fact, in the article entitled *The Purpose, Value and Structure of the Practicum in Higher Education; A Literature Review,* Ryan, Toohey, and Hughes (1996) stated that "So little quality research has been undertaken on the effect of the length,structure and placement of the practicum that no clear recommendations can be made with confidence" (p.370). Ryan et. al additionally state that satisfaction surveys have been the most common method for evaluation in practicum courses. They suggest that more specialized surveys be given to look at specific skills and developments gained during the practicum in addition to more longitudinal studies.

Various research projects have investigated science selfefficacy beliefs from preservice through veteran teachers' service. Most report very positive experiences by students in practicum experiences, however, few reports search out whether a prime time exists for enhancing science selfefficacy throughout a preservice teacher's preparation. This in-depth study explored both quantitatively and qualitatively specific lengths of three different practicums over three years and the progression of teacher self-efficacy of preservice elementary education majors in each of the science practicum durations.

Year one of this study explored a two hour only practicum experience where a single science lesson was taught in an elementary school setting (Cannon, 1997). Year two of the study explored an "extended practicum" defined as a 12 week long course comprising 12 hours per week (totaling 144 total teaching hours). Although the practicum students were assigned primarily to teach science, other subjects were taught as well in this elementary setting (Crowther & Cannon, 1998). Year three, explored and compared the prior years of research to an elementary science teaching practicum which lasted for 15 weeks, but only 3 hours of contact time per week (Wednesday afternoons) for a total of 45 hours of practicum experience.

Methodology

Quantitative Research Design - Year One

Subjects

Subjects included 64 preservice elementary education majors. 46 students were from a large Midwestern university (41 females and 5 males) and 18 (14 females and 4 males) were from a land grant university in the west. The subjects' level of academic preparation varied by institution.

The students from the Midwestern university were in their final semester before student teaching and were enrolled in a 3-semester credit elementary science methods class that required a single, one-time only science teaching practicum experience. The students from the western university were enrolled in a 3-semester credit Supervised Elementary Education Practicum course open to juniors, seniors, and graduate students. The teacher preparation program of the western university included Masters degree, first time licensure graduate students in the practicum course. None of the preservice teachers taking the practicum course were concurrently enrolled in an elementary science methods course. Both groups of students were determined as being from the same population (elementary education majors) based upon the lack of statistically significant differences of their Preprofessional Skills Tests scores in reading($t = -1.78, p = .10$), writing($t = 9.36$, $p = .92$), and mathematics($t = -1.63, p = .11$).

Instrumentation

The STEBI B (Enochs & Riggs, 1990), which is the preservice version, was administered to both groups of preservice elementary teachers. The STEBI B includes 23 Likert-scaled statements relating to personal beliefs about teaching science. Response categories are "strongly agree", "agree", "uncertain", "disagree", and "strongly disagree." The STEBI B measures two sub-scales inhering to Bandura's (1977) theory of self-efficacy and applied to teaching by Gibson and Dembo (1984). The two subscales are personal science teaching efficacy beliefs (PSTEB) and science teaching outcome expectancy (STOE). The sub-scale for PSTEB numbers 13 statements. A full account of the reliability and validity measures for STEBI B can be found in

Enochs and Riggs (1990). This study resulted in a Cronbach's alpha of .83 for the PSTEB and .77 for the STOE.

The administration of the STEBI B occurred at roughly the same time for both groups. The Midwestern completed the STEBI B after teaching one science lesson in a public school. This lesson was taught near the end of the university semester. The lessons lasted approximately 1 and a half to 2 hours in length.

The western preservice teachers completed the STEBI B after an extended practicum experience in a local public school. The practicum experience ran from 8:00 a.m. to 12:00 noon on Tuesdays, Wednesdays and Thursdays, for 12 weeks, totaling 144 hours of pupil contact time. Although the primary responsibility of the preservice elementary students in the practicum was to teach science lessons from the adopted public school science curriculum, they also were responsible for daily management routines and any other planned content area lessons with the permission of the cooperating classroom teacher.

Analysis

A modified quasi-experimental pretest-posttest design with nonequivalent groups was used in this research. PSTEB data obtained from the Midwestern university was compared to PSTEB data collected from the western university. The independent variable was the different university preservice elementary teacher groups (Midwestern and Western). The dependent variable was the PSTEB scores from the STEBI B for both groups. The experimental group was the western university's preservice teachers. The experimental treatment was the length of the practicum experiences (12 week long practicum experience as compared to a single 1 and a half to 2 hour practicum experience). The control group was the Midwestern university preservice elementary teachers.

Due to the small sample size and ordinal nature of the STEBI B data, nonparametric analyses were deemed appropriate. Mann-Whitney U tests were performed on both pre and posttest PSTEB scores from both university's preservice teachers. Results of these analyses can be seen in Table 1. No qualitative data were taken during year one.

Table 1
PSTEB Pretest Scores of Midwestern and Western University Preservice Teachers before a Practicum Experience

Group	N	Sum of the Ranks	Z	*p*
Midwestern*	46	533.5	.38	.70
Western**	18			

* median PSTEB score = 54
** median PSTEB score = 56

Quantitative Research Design - Year Two

Subjects

Subjects included 19 preservice elementary education majors (17 females, 2 males) enrolled in a practicum experience in a local elementary school. The students were enrolled in a 3-semester credit Supervised Elementary Education Practicum course open to juniors, seniors, and graduate students during the spring 1997 semester. The practicum experience ran from 8:00 a.m. to 12:00 noon on Tuesdays, Wednesdays and Thursdays, for 12 weeks, totaling 144 hours of pupil contact time. Although the primary responsibility of the preservice elementary students in the practicum was to teach science lessons from the adopted public school science curriculum, they also were responsible for daily management routines and any other planned content area lessons with the permission of the cooperating classroom teacher.

In addition, the practicum students were responsible for leading and presenting a science festival at the school. While science festivals resemble science fairs, this festival differed in that only whole class, or group projects were presented. No formal judging took place, and each child received a special certificate and was recognized for some contribution to the project, (i.e., best lettering, best construction, etc.) at a science festival assembly held at the school after the festival.

A form of the time-series design called an *equivalent time-samples design* was used in this study. Tuckman (1972) writes, " ... the equivalent time-samples design is used when only a single group is available for study and the group's pattern of experience with the treatment is highly predetermined -- that is, the researcher must expose the group to the treatment on some systematic basis" (p. 116). The manipulated variable, or treatment, in this study was the practicum experience and teaching children science lessons on a daily basis. The responding variables were the practicum students' scores on the Science Teaching Efficacy Beliefs Instrument (STEBI-B) by Enochs and Riggs (1990) and the Science LOCus of Control I and II (SciLOC I and II) by Haury, (1988).

Clearly, test sensitivity was a major threat to internal validity. In an attempt to lessen this threat, the SciLOC I and SciLOC II instuments were adminstered during weeks 8 and 9. The 18-item SciLOC questionnaires measure a participant's LOCus of control (LOC), or belief about the internal or external responsibility for learning, in relation to science education. Reliability measures for SciLOC I and II were established by internal consistency coefficients of .73 and .75 respectively (Cronbach's Alpha) (Haury, 1988). Haury (1988) states, "An assumed benefit of increased internality is increased success as a teacher" (p. 234). A postive correlation was found to exist between the SciLOC I and STEBI B questionnaires ($r = .43$; $p < .01$) supporting the speculation that both measure similar constructs (Cannon, 1992). Therefore, the SciLOC I and II instruments were deemed appropriate as additional data collection instruments for perhaps revealing and additional facet of relationship between the STEBI B and SciLOC instruments.

Qualitative Research Design - Year Two

The qualitative parameters of this study included pre and post interviews, supervisor and cooperating teacher observation notes, and student journal analysis. For the qualitative part of this study 6 students were purposefully selected and studied in-depth in a multiple case study design (Merriam, 1988) (See Table 2). For further investigation of the differences in the PSTEB quantitative analysis, two students were selected who had taken the elementary science methods course before the elementary science practicum course, two students were selected who were concurrently enrolled in the elementary science methods course and the elementary science practicum course, and two students who had not previously taken nor was concurrently enrolled in the elementary science methods course. This information was then compared to the qualitative part of the Crowther and Cannon (1998) study for further comparison of the data. Some very interesting themes emerged with wonderful dialogue and anecdotal data.

Table 2
Selected Participants and Science Methods / Practicum Status

Participant	Methods / practicum status
001	Concurrently enrolled in science methods and practicum
002	Previously completed science methods before taking practicum
003	No previous or concurrent science methods to practicum
004	Previously completed science methods before taking practicum
005	Concurrently enrolled in science methods and practicum
006	No previous or concurrent science methods to practicum

Quantitative Research Design - Year Three

Subjects

Subjects included forty-nine preservice elementary education majors (45 female, 4 male) enrolled in a practicum experience in one of three local elementary schools. The students were enrolled in a 3-semester credit Science Practicum in the Elementary School course open to juniors, seniors, and graduate students during the spring 1998 semester. The practicum experience ran from 1:00 p.m. to 4:00 p.m. on Wednesdays for 15 weeks, totaling 45 hours of pupil contact time. Although the primary responsibility of the preservice elementary students in the practicum was to teach science lessons from the adopted public school science curriculum, they also were responsible for daily management routines and any other planned content area lessons with the permission of the cooperating classroom teacher.

These practicum students, as also in year 2, were responsible for leading and presenting a science festival at the school.

Instrumentation

The STEBI-B was used again for data collection in year 3 of the study. Due to the reduced number of times the STEBI B would be adminstered during the semester (3 in total: pre, middle, and post practicum experience), test sensitivity was deemed a lesser threat than in year 2, and consequently, no similar instrument was administered (e.g., SciLOC).

Qualitative Research Design -- Year Three

The qualitative parameters of this study included pre and post interviews, survey questions, supervisor and cooperating teacher observation notes, and student journal analysis. For the qualitative part of this study 22 students were purposefully selected and studied in-depth in a multiple case study design (Merriam, 1988). The purpose of the qualitative study was to explore efficacy progression in the practicum experience. Thick and rich descriptions were developed from the participants which helped define the statistical analysis.

Results

Quantitative Results - Year One

No differences were found to exist in PSTEB pretest scores (pre-practicum experience) between the Midwestern and western preservice teachers as seen in Table 1. Therefore, both groups were considered to be equivalent in efficacy beliefs.

Table 3 reveals a statistical difference in PSTEB posttest scores (post-practicum) between practicum experiences (one-shot 2 hour experience vs. 144 hours of classroom teaching). . Effect size was calculated to be .57 (reject practical significance if < .33) (Borg, Gall & Gall, 1993).

Table 3

PSTEB posttest scores of Midwestern and Western University Preservice Teachers after a Practicum Experience

Group	N	Sum of the Ranks	Z	*p*
Midwestern*	46	1363.5	-1.96	.04
Western**	18			

* denotes group with a single, one time only practica experience 1 and a half to 2 hours in length; median score = 56
** denotes group with a 144 hour requirement of elementary science teaching practica experiences; median score = 60

A corollary facet of the data analysis of the PSTEB posttest scores revealed no significant difference in variance. This result suggests that previous enrollment in an elementary methods course has little influence on preservice teacher's personal science teaching efficacy beliefs (see Table 4).

Table 4

Analysis of Variance of PSTEB Posttest Scores of the Western University Preservice Teachers (Methods vs. Non-methods students)

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error
A (METHODS)	1	40.5	40.5	2.74	0.1173	ERROR
ERROR	16	236.44	14.78			
TOTAL(Adj)	17	276.9445				

Quantitative Results -- Year Two

Descriptive results of the STEBI B and SciLOC administrations can be found in Tables 5 and 6. Figures 1 and 2 show the line plots of the STEBI B subscale scores.

[Due to space limitations, see Figures 1 and 2 in the online paper at http://www.ed.pse.edu/CI/Journals/1998AETS/s3_2_crowther.rtf]

Figure 1. Line plot of Personal Science Teaching Efficacy Beliefs Scores (PSTEB) scores for weeks 1 - 7, and 10 - 11.

Figure 2. Figure 1. Line plot of Science Teaching Outcome Expectancy Scores (STOE) scores for weeks 1 - 7, and 10 - 12.

Table 5

Descriptive statisitics of STEBI B scores for Practicum Weeks 1 - 7, and Weeks 10 - 11.

FIELD	N	MEAN	STD	SEM	MIN	MAX	SUM
EFFWK1	19	50.89	6.28	1.44	40	62	967
OUTWK1	19	40.11	5.31	1.22	32	50	762
EFFWK2	19	51.84	6.26	1.44	40	64	985
OUTWK2	19	40.89	4.72	1.08	34	50	777
EFFWK3	19	53.53	5.44	1.25	42	65	1017
OUTWK3	19	40.21	4 .30	.99	35	50	764
EFFWK4	19	53.53	5.44	1.25	42	65	1017
OUTWK4	19	40.21	4.30	.99	35	50	764
EFFWK5	19	57.68	5.16	1.18	46	64	1096
OUTWK5	19	41.68	4.57	1.05	33	49	792
EFFWK6	19	55.05	4.70	1.08	44	64	1046
OUTWK6	19	41.58	4.74	1.09	35	50	790
EFFWK7	19	54.84	4.68	1.07	46	63	1042
OUTWK7	19	40.47	6.16	1.41	26	50	769
EFFWK10	19	59.74	4.21	.97	53	65	1135
OUTWK10	19	42.11	4.62	1.06	34	50	800
EFFWK11	19	59.89	4.07	.93	52	65	1138
OUTWK11	19	42.21	5.74	1.32	33	50	802

EFF = Personal Science Teaching Efficacy Beliefs Scores (PSTEB)
OUT = Science Teaching Outcome Expectancy Scores (STOE)

Table 6

Descriptive statistics of SciLOC I and II scores for practicum weeks 8 & 9

	N	MEAN	STD	SEM	MIN	MAX	SUM
Week 8 LOC	19	25.632	2.608	.598	21	31	487
Week 9 LOC2D	19	49.000	3.697	.848	44	57	931

Table 7 reveals a statistically significant difference in PSTEB scores between weeks 1 and 12. Table 8 displays a similar statistically significant difference in STOE scores between weeks 1 and 12.

Table 7

Wilcoxon's signed rank test results between PSTEB scores from week 1 vs. week 12

Sum of the positive ranks = 0.
Sum of the negative ranks = 190.
Number of samples = 19
Using Wilcoxon table lookup, p <= 0.005 (one tail)

Table 8

Wilcoxon's signed rank test results between STOE scores from week 1 vs. week 12

Sum of the positive ranks = 32.5
Sum of the negative ranks = 103.5
Number of samples = 16
Using Wilcoxon table lookup, p = .037 (one-tailed)

Quantitative Results -- Year Three

Data were similarly analyzed in the third year of the study as in previous years. Pre and post gains in PSTEB scores were investigated. Due to the nature of this longitudinal study, effect sizes became more important in determining if an *ideal* length of practicum experiences for preservice elementary science teachers did exist. Results of year three can be seen in Tables 10 and 11.

Table 9
PSTEB Posttest scores of Elementary Preservice Teachers during a 15 week, 45 hour science practicum experience

Variable	Count	Mean	Std. Deviation	Minimum	Maximum
School 1	8	54.85714	3.48466	51	61
School 2	18	54.375	4.529533	47	65
School 3	22	59.0625	3.872445	52	65

Table 10
Analysis of Variance of PSTEB Posttest Scores of Elementary Preservice Teachers during a 15 week, 45 hour Science Practicum Experience

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A (...)	2	195.6861	97.84306	5.82	0.0065	ERROR
ERROR	36	605.5446	16.82068			
TOTAL(Adj)	38	801.2308				

Scheffe's Procedure
Factor(A): ... Error: ERROR
Summary Results alpha = .05 Level Codes

Code(Level)	Mean	ABC
A(School 1)	54.375	. . S
B(School 2)	54.85714	. . .
C(School 3)	59.0625	S . .

Note: An "S" in the above table represents a statistically significant difference between groups at the .05 level

Table 11
Effect sizes of length of practicum experiences (in hours) -- Years 1-3
PSTEB scores

Year	Time Length	N	Pre	Post	*SD*	Effect Size
One	1.5-2	64	52.76	55.28	4.74	.57
Two	144	19	50.89	59.89	6.28	1.43
Three	45	60				
School 1			48.55	54.85	6.61	.95
School 2			51.57	54.37	4.40	.63
School 3			53.95	59.06	4.20	1.32

Schools 1 and 2 were new schools added to the practicum experience and the longitudinal study during year three. School 3 was involved in the study for all three years. While only speculation, the effect size for School 3 might be higher than Schools 1 and 2 due to the fact that it has been in the study the longest and that the practicum teachers at School 3 were very well versed on the purpose and method of the practicum experience. Consequently, there was far less of a learning curve in School 3 than Schools 1 and 2.

Qualitative Analysis

Due to the excessive length of year two qualitative analysis, only year three will be presented here. There were no qualitative data taken for year one. Please see Crowther and Cannon (1998) for the full explanation.

Qualitative Results --Year Three

Elementary science methods or science practicum - Which should come first. . . .(a validation from year two)

Qualitative results from year two of this study were interesting in the fact that we compared the effect of a formal methods experience taken before the science practicum, concurrently enrolled in science methods and science practicum, and having no methods experience before taking the science practicum. (See qualitative results section - year two) The students who had previously taken a formal methods course in science had more in-depth answers to the questions and seemed to get more out of the science practicum. The year three study only admitted students into the science practicum who had taken a formal science methods course prior to the practicum experience.

This thinking was validated by all of the students enrolled in the practicum. In the final interview at the end of the semester, several of the responses from the practicum students in the year three study included the following comments.

Kara stated specifically that, "The methods class was fun, interesting and exciting, but having this chance to now turn these around and implement these techniques into a class of my very own was very easy."

Nakonia stated, I think that the most important thing that I have learned this semester is how to teach science. By taking the Methods course and then the practicum, it has opened more avenues for me. Now I was able to implement what I learned from my methods course, I can see why hands-on is so big. I found that teaching hands-on science is the only way to go. I really feel that by having the students do an activity, it actively engages them and makes them think and come up with their own theories. When I taught I used the 5E format. I believe that by using this format, it helps you as the teacher interact more with the children.

Jessica mentioned that,

> "My favorite episode with this practicum class was on the very last day. I taught the *Yeatie Beastie* lab. The kids loved crushing the cereal and then observing the (zip lock) bags inflate as a result of the gas (carbon dioxide) created by the yeast. I think that this lab went so well is because I had actually done this lab in the methods class and I knew how the children were going to respond. The management went really well and I think that a part of that was because I had seen it done before.

From the instructor point of view, it was also an easier experience in that all of the students knew how to write lesson plans in the Learning Cycle format and knew the expectations of teaching inquiry / discovery hands-on science because they had previously experience a semester where that was the primary focus. We can conclude from the third year of practicum experience, where all practicum students were required to take science methods previously to the practicum course, that having the methods first cut down on many problems such as understanding lesson planning, hands-on teaching methodologies, and general understandings of developmentally appropriate science lessons. All of which were problems previously encountered by students who had not taken methods prior to practicum in previous years.

Efficacy - Does 100 hours in the classroom make a difference?

What is Efficacy

Bandura (1981) showed that people's beliefs in their own abilities had an effect on their performance. He found that behaviors occur when, a) people believe in their own ability to perform that behavior and b) people expect, based upon their own life experiences, that this behavior will result in a desirable outcome. The first belief, in which people believe in their own ability, Bandura called self-efficacy (Schoon & Boone, 1996). The second belief is closely connected to the confidence that one develops based upon their efficacy.

In year two of this study all of the participants had great gains in efficacy in teaching science. None of the students felt that they had spent too much time in the classroom and many felt that spending 144 hours for a practicum was sufficient enough to learn how to teach science. So, how would students respond after a 45 hour practicum? The quantitative data showed that self efficacy scores on the STEBI B were high in both practicums and that in the 144 hour practicum the effect size was half again as large as the effect size of the 45 hour practicum.

However, the qualitative responses seem to be just as strong. During the 15 week (45 hour) practicum the students responded to their experiences in a weekly journal. The journal format that was used was the Posner (1993) format which uses a logical formula by which the journaling assignments were based upon: (E + R = PG) "experience plus reflection equals personal growth." As part of the class stipulations, each student was required to keep a reflective journal of the activities, and events of the practicum in a two way dialogue format. Each week the journal entries were read and responded to by the instructor. Each time the journals were read they were evaluated by the researcher on a scale developed to determine efficacious statements (See Table 11).

Table 11
Three Point Journal Rating Scale

Reflection Rating	Explanation of Rating	Examples:
1	No efficacious statements	Facts only "Today I taught bubbles. It took 35 minutes. Next we discussed . . ."
3	Efficacious statements non specific or alluded to:	"The kids really got into the lesson today which made me feel good."
5	Specific efficacious statements	Specific words used in reflection - such as confidence, enjoyment, ability, etc. "I am really feeling confident in my teaching ability."

During the first two weeks of the practicum course the majority of the reflections were rated as primarily 1 and 3. However, beginning with the third week, only one 1 and five 3's were given with the rest of the responses being 5's. This pattern continued throughout the semester. Not surprisingly, the last three entries recorded all 5's.

At the end of the practicum in exit interviews of the experience, all of the participants in the year three study discussed how much more confident they were to teach science now that the practicum was over. A representation of responses from each grade level is shared below.

"I can do this . . ."

Alisha had the opportunity to teach in the first grade. Many students think that teaching in the first grade would be easy. After the first week they realize that teaching must be adapted and that age appropriate lessons are a lot of work. Her cooperating teacher was also exceptional in that she taught in a very integrated manner. Alisha was a natural and adapted fast to the situation. She explained her experience in first grade with new appreciation.

I feel that this practicum has helped me believe more in myself that I can do things that I never thought were possible. I never realized how much hands-on exploration of science I could offer to a group of children. Now when I have my own classroom, I will be able to integrate that lesson with science math and social studies.

I feel that the single most important thing that I learned this semester is to be flexible. I realized as I got going what I could offer to the kids about science in ways that I never thought were possible. This is the greatest thing that I have learned. . . That learning is all around us in places and things you never thought about. It just takes a little more thought to figure it all out.

Erin had an unusual practicum experience. She was placed in a second grade classroom with 33 children. She had two cooperating teachers in a team teaching situation. The thing that made Erin's experience different was that she did whole group instruction by herself and learned management skills in a big hurry, especially for the quiet and shy personality that she began with. After her experience was over Erin perhaps had more of a real understanding of crowd control, but the fact that she was successful showed that she really was a good teacher.

Erin was brief, but concise.

"I feel that this practicum was the best one that I have had. I feel more confident in my abilities as a teacher due to the experiences that I had in this practicum. When I first entered this classroom I was very nervous about being in front of thirty-three students and two experienced teachers. I feel that I have gained the experience needed where I can walk into any classroom and not worry."

Deanna was in a third grade classroom. She began this experience with some hesitation, as everyone did, but the progress that she shared at the end of the experience was particularly insightful. Deanna explained:

"I have always known that I wanted to be a teacher. It wasn't until this semester that I allowed myself to say, "I am good at what I do." I truly believe I am a good teacher. I realize that I still have a lot to learn, but I am confident in my ability to do my job well.

This semester brought all of my past education together. In this past semester I was able to actually get into the classroom and use what I had learned on my own. I was responsible for the class's learning. I felt like I was actually treated as a teacher this semester; this allowed me to fully realize my potential to be a great teacher.

I think that the single most important thing that I learned from CI 365 is that no matter how daunting a task may seem, it is always possible. When I began planning my science lesson on the solar system I actually thought "How on Earth do I make the solar system fun and hands-on." When I remembered that I thought I just had to laugh, because I realize now that my fear should have been "How on Earth do I ever choose from all of the fun and hands-on activities I can do with the solar system?" I learned that if a person is dedicated they can turn anything into a fun and hands-on activity for students, it just takes some concentration and determination."

Terri is a dual (Special and Elementary Education) major. Therefore her assignment was in a self contained special needs third grade classroom. She did not consider herself great in science, but did have an interest in science as it applies to real life, especially as it applies to skiing as she is an avid skier and currently works in a ski shop.

Terri spoke of her experience:

" I was always amazed on what the students actually learned. I never knew I could teach so all the students could participate and learn. It was interesting because at the beginning of the semester, my planning of the lessons took at least 2-3 hours to generate a lesson. By the time I was done with the practicum, my lesson planning began to shorten to 1-2 hours! It seemed as if it was getting easier."

Kate is not new to the education world. Kate's mom is an elementary teacher and so she grew up with the experiences of "living in the classroom." Kate mentioned that she always knew she was going to be a teacher and would even play school at a young age where she would invite friends over and she would write on the chalkboard for them.

Kate taught in a fourth grade classroom and spoke of her experience:

"I feel that my potential for becoming a teacher keeps growing with each class that I take. I've always spent time in classrooms, not just as a student, but as an observer, since my mom's still teaching. However, I never really understood just what it took to get the day's lessons ready and make the work. I believe that I will just keep getting better, I certainly feel confident enough as I embark on my student teaching. I feel really confident in my abilities as a teacher, even though I know that I still have a long way to go.

I think that the thing that I learned most from my 365 experience isn't really science related. It's that I have the ability to make such a big difference in so many lives, and that I'm good at teaching! I love it, and the kids really seem to relate to me well. They treated me with respect, but seeing their faces light up when they see me there, really made me realize that I'm doing the right thing."

Nakonia had the opportunity to teach in the fifth grade. She was very nervous before the experience began. Several weeks before the class she called and was very concerned about her ability to teach science, she was basically looking for reassurance that she could actually do this practicum. Many preservice teachers feel this way, especially in science. Nakonia prepared herself and began teaching just a few days after her honeymoon. At the end of her practicum she described her experience:

"I have never really been great at science and was nervous to teach the subject. Since the methods class focused on teaching hands-on science, I wasn't given the opportunity to go out and test these activities. With the practicum, I found it to be very beneficial. I started out very nervous and told my cooperating teacher, she was so understanding. The more I taught, the more I felt comfortable teaching science. It is a learning process and you learn as you teach. The part that I was nervous about were kids asking me science related questions that I didn't know. I don't have a strong background of science, but when a question came up and I didn't know the answer, we found out together as a class. . . . With this experience, I feel that I'm ready to teach and have enough confidence and experience to go on to student teaching."

Kara did her teaching in the sixth grade. Kara was not sure about teaching the "big kids" at first. However, after her experience was completed, she not only felt confident teaching sixth grade, but also confidence in learning and teaching fairly sophisticated science content as well.

Kara explained:

"I feel very confident for my potential to be a teacher. When I first started this education program, I was very hesitant about teaching science. I have never really been a "science geek, " so for me to turn and teach the different areas of science seemed to be quite a challenge for me, before I ever even began. Well ,some good news!! I have really changed my mind about teaching science, and this practicum experience influenced this change to an extreme. I think the single most important thing that I have learned from this practicum would be that I ***can*** teach a subject I am unfamiliar or uncomfortable with, it just takes initiative, motivation, preparation, planning, creativeness, and an open mind! I feel that I have demonstrated all of these techniques during this practicum."

All of the 22 participants that were involved in the qualitative study had similar comments as the seven examples above. As can be seen from the above samples from exit interviews, students engaged in the 45-hour practicum seem to have a strong feeling of confidence and self-efficacy towards the teaching of science and progressing on to student teaching. When the post interviews of the 45-hour practicum students were compared to the post interviews of the 144-hour practicum students, the statements sounded qualitatively the same. In fact, the year 2 study concluded that:

> In response to the anxieties about teaching science, all of the participants had high anxiety in the pre interview. Responses ranged from "oh yea" to "I have taught kids before, but I am still just as nervous as I was the first time." By the end of the practicum all of the students were *very confident* in their ability to teach elementary science. All of the participants felt that the time in the classroom was just right and that very few improvements be made on the course" (Crowther & Cannon, 1998, p. 11).

We could basically write the same conclusion to the third year of the study. If the post efficacy statements were basically the same from the 144-hour and the 45-hour practicum, then one would be forced to wonder about the extra 100 hours in the classroom. When the students in the year two study were asked about the length or time in the classroom (144 hours), "the comments from the participants strongly support that the time in the classroom was just right. In an exit interview with all (22) of the students, no one said that the time was too long and the only response of the time being too short was a participant that really liked working with the kids and would miss them (Crowther & Cannon, 1998, p. 11). At the end of year three, once again all of the 22 participants stated that the time was just right. The only participant who said the time was too short was Kate who said, "We only got to see the students once a week, which didn't give us a lot of time to build a solid relationship with them. However, I feel that we did a good job working with the students and building rapport with them regardless."

Therefore, if the result of the practicum was to build prolonged relationships with children, the 144-hour practicum would be best. If the result of a practicum was to make an efficacious teacher, then there is no qualitative difference between the 144 and the 45-hour practicum from the students' point of view in this study. However, the cooperating teachers from the school where the qualitative study was performed in year 2 and year 3 had mixed emotions.

The cooperating teachers in the school were split evenly over the length of the practicum. The teachers that favored the year 2 practicum (144-hours) said that the students were able to have more continuity with the curriculum by taking a lesson from start to finish over several days. They also mentioned that the students were better respected as a teacher because they were in the classroom more and had greater opportunities for management resulting in carrying out rewards and punishments over several days.

The teachers that favored the year 3 practicum (45 hours) spoke about the unobtrusiveness of the practicum. University students coming in once a week didn't really interrupt the daily routine as the 3-day a week practicum. These teachers also spoke of how the practicum lessons seemed better and more intense than the previous year because they had to get a lesson done in one afternoon. The teachers also mentioned the elementary students reacted well because they knew the lesson was going to be very interactive and supplement the normal unit of study. When the faculty was asked which practicum they would prefer for the following semester, the vote was by far in the majority of the 45-hour practicum. Even though the 144-hour practicum had some great benefits, the teachers at this school seemed to prefer the less obtrusive, but intense science practicum experience.

Bandura (1981) proposed that self-efficacy could be enhanced through modeling and successful mastery experiences. Gibson and Dembo (1984) concluded from their studies on teacher beliefs and self-efficacy that "student learning can be influenced by effective teaching" (p. 48). They further concluded that teachers who also have confidence in their own teaching abilities (self-efficacy beliefs) should persist longer, provide a greater academic focus in the classroom, and exhibit different types of feedback than teachers who have lower expectations concerning their ability to influence student learning. The participants in this study (year 2 and year 3) did make large gains in both self-confidence and self-efficacy as was postulated by Bandura (1981). However, in order to capitalize and implement the effects of the increased confidence and efficacy as proposed by Gibson and Dembo (1984), the preservice teachers needed to feel empowered in both teaching and learning situations that seemed to take place in both the 144 and 45-hour practicum.

Discussion

We believe that a sign of valuable research is when more questions are raised from a project than were originally asked. This research study did exactly that.

Based upon the review of self-efficacy research, one could safely predict that an extended practicum experience would positively influence PSTEB scores more so than a shorter practicum experience. Many have suggested that "experience *is* the best teacher." What is interesting about this prediction is determining when, if ever, a point of diminishing return exists in field work or practica experiences.

Year one data noted that the Midwestern university preservice teachers' mean PSTEB posttest score was 56.28 (model response = 65) as compared to the western university's mean PSTEB posttest score of 58.94 (mr = 65). A difference of roughly 3 points demonstrated statistical variance. Effect size was calculated to be .57 (reject practical significance if < .33) (Borg, Gall & Gall, 1993). Borg, Gall, and Gall (1993) state that "an effect size of 1.00 is twice as large as effect size of .50. The mean of the effect sizes...can be calculated to yield an estimate of the effect of the experimental program or method... "(p. 171). Therefore, according to Borg et al. one could argue that the effect of the extended practicum was roughly twice as "effective" as the single, one time only practicum experience.

Year two's primary focus was what is the most ideal amount of practica experiences? The results of the year two data reveal that during an 12 week practicum experience, PSTEB scores continued to raise, except for weeks 5 -7, where the scores remained fairly constant. Approximately the same increase in PSTEB scores occurred during the first 4 weeks as occurred during the last 4 weeks of the study (9 points in total). While it is only speculation, the later increase in scores might be a result of the science festival presentations held at the elementary school just after mid-term of the semester. Students could have experienced enhanced self-efficacy through an additional, somewhat more exciting, science teaching experience (science festival) in conjunction with their daily classroom experiences.

Year three's focus shifted from the total number of hours required for an *ideal* practicum experience to investigating the effect size of each experience.). Borg et al. (1993) remind readers that "The mean of the effect sizes from different studies can be calculated to yield an estimate of the effect that the experimental program or method produces relative to a comparison intervention" (p. 171). While this study is not a meta-analysis in nature, it does, however, try to glean estimates from changing study parameters over a three year period.

But, yet another very important question arises. If the question raised above is reversed, could one argue for *less time* to be spent in elementary science teaching practicum experiences? It appears that 9 out of 65 total PSTEB points are gained toward "ideal" science teaching efficacy by increasing supervised practicum experience pupil contact teaching time to 144 hours. Does this result support the call for increased practicum experiences and time spent supervising such experiences by already overburdened university content area specialists? Perhaps, but we strongly suggests that "a point of diminishing return" someday will be determined through an expanded research agenda relating to science self-efficacy and practica experiences.

Collaterial Results

The inservice teachers' extracurricular experiences also had a great impact on the elementary students. The elementary school principal of the practicum school was quick to share that science has been progressively taught more in the school over the past three years. In fact, the Terra Nova standardized test scores for the fourth grade have increased from the 48^{th} to 62^{nd} percentile over the last two years.

The school's principal explained that the only science inservice done over the last two years was the summer professional development program that involved six teachers associated with the university practicum. There had been no changes in science other than the preservice science practicum students in the school and the professional development workshop. He concluded that the single biggest factor of the improved scores was due to the partnership between the university and his school that made the practicum possible. He said, "It is no mystery why the scores have improved. Having practicum students in the school and the excitement they continually bring to teaching science in this school has made the difference."

Conclusions

Westerback and Long (1990) investigated the impact of selfconfidence and anxiety on science attitudes and science teaching. They stated, "curriculum advances have little chance of success unless the background, comfort, and approach of these [elementary] teachers can be altered and upgraded" (p. 362).

Through practicum experiences, prospective teachers get the opportunity to interact and "practice" teaching. This study found that there was a notable qualitative difference in the experience of the practicum students who had previously taken science methods as compared to the participants who had not taken science methods or who were concurrently enrolled in the science methods course.

There are some great limitations to this study. Repeating the same instrument on a weekly basis, as in year two, results in the loss of some of the integrity of the instrument. The interviews helped to clarify the answers from the STEBI B and the practicum experience, but the interviewer was a professor that most of the students had taken courses from before and liked. That could cause some interview bias. Although there is no substitute for experience, the quest for the ideal length of practicum still remains.

Finally, it must be noted that there were some interesting differences between the 3 schools included in the third year of the study. The first two schools were in their first practicum experience. The third school, which was also qualitatively studied, was in its third year of having science practicum students. The teachers were well informed and were a part of the study. They knew what was expected for the experience and made it happen for the students. Moreover, nearly 1/4 (6 of 27) of the teachers in the school had been a part of a summer inservice elementary science program over the past two summers where hands-on science along with inquiry and discovery types of teaching were modeled and practiced.

This involvement over time strongly supports Enochs and Riggs (1990) ideas that self-efficacy needs to be sustained over time for best results. It is well known that results of an innovative workshop wear off over time. By involving the cooperating teachers during the academic year in the practicum and having them work during the summer in a professional development workshop, only to go back as specialists and teach a new semester of practicum students, enabled the efficacy of both inservice and preservice teachers to remain high.

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USING ENVIRONMENTAL SCIENCE EDUCATION CURRICULA AND EXPERIENCES TO ENHANCE SCIENCE TEACHING FOR ALL STUDENTS: CREATING AN INTEGRATED, INCLUSIVE LEARNING ENVIRONMENT

Linda K. Ramey, Ph.D.

The Miami Valley region of southwestern Ohio is a rapidly growing technical/industrial area with limited surface and ground water resources relative to human population and other water demands. This project was an initial attempt to involve area teachers, and ultimately their students in increased awareness of the natural resources, and surface and ground water issues in the region. The primary goal of the project was to provide elementary and middle level classroom teachers with knowledge and understanding of water-related issues and the wealth of natural resources available to them to teach environmental science education.

The Ohio Environmental Education Fund/Ohio Environmental Protection Agency funding for this project, was awarded May, 1997. Recruiting of teachers for the summer workshop commenced at that time. Thirty-three teachers were selected to participate and a graduate student was hired for the project. This project demonstrated true collaboration in numerous public agencies and institutions in the Montgomery/Greene county area namely: Five Rivers MetroParks, Greene County Parks, Lower Great Miami Watershed Enhancement Program, Greene Soil and Water Conservation District, the Dayton Museum of Natural History, Montgomery County Soil and Water Conservation, Wright State University, and several diverse public school districts as outlined herein.

Project Description

The Miami Valley Environmental Science Education Teacher Enhancement Project Summer Workshop was conducted as a combination of field-based activities and exploration of environmental curricular materials from June 19 – July 3, 1997. The two week summer institute was conducted at a variety of local natural areas depending on the day's topic of exploration. Several environmental education curricular materials were included in the training the teachers received during the summer workshop: *Project Wet, Project Wild* and *Project Wild Aquatic, Integrating Environmental Education and Science: Using and Developing Learning Episodes,* the draft version of Surface and Ground Water Resources curriculum, and a number of site-specific brochures and materials from the various agencies involved in the workshop. Supplemental curricular materials and backpacks with kits of water testing supplies and equipment were supplied to these teachers to facilitate outdoor student investigations and have proven to be very successful on the many field trips with students. The teachers used these and other materials from their classroom curriculum to develop integrated units related to water resources and environmental topics for implementation during the school year.

Eleven resource teachers were selected to act as the on-site facilitators that work closely with the other teachers within their school(s) to build a supportive network for the teachers during the project's year of follow up. Relevant readings and assignments were included for the resource teachers, to strengthen professional development in the area of teacher leadership skills to aid in implementation and delivery of the program. The role of these resource teachers also included assisting with collection field test data on the initial draft of the Surface and GroundWater Resources Curriculum (SGWRC) conducted during the school year. This teacher professional development model has proven to be powerful in implementing change within school settings because of its collegial nature—a fellow classroom teacher working with and supporting other teachers to bring about enhanced science teaching and learning.

Following the summer workshop, project participants met each quarter during the school year, (October 29, 1997, February 3, and April 28, 1998) to chart progress, share information, and to renew friendships developed over the course of the summer workshop. One of the most valuable, but unanticipated outcomes of the project was the collegial network that developed between the teachers from very diverse school districts, grade levels, and backgrounds. Another year-long effort was the development of the project presentation at the annual Science Education Council of Ohio (SECO) conference. This presentation took place in February and involved most of the teachers as they shared what they had done in their classrooms relating to environmental education and water/natural resources.

Classroom observations/visits were ongoing through out the year. Teacher participants have taken their students on many field trips that were closely connected to the wealth of water resources and environmental curricular materials they received and/or developed during the summer workshop. This project has directly benefited all of the 33 teachers and their students, the graduate student, and all associated with the project. More specifically, each group of teachers developed and are implementing a very specific Action Plan for integrating the newly acquired environmental science education (ESE) knowledge and teaching skills with existing classroom curriculum. The teachers' Action Plans were also based on the knowledge learned during the workshop of how various ESE curricula fulfill the requirements of the Ohio Science Model and state Proficiency Outcomes testing requirements. The teacher participants developed and shared their Action Plans for what ESE materials and experiences they would implement with their students as well as how they were going to implement their plan. These Action Plans clearly demonstrated what they had learned during the workshop and the knowledge of the curricular materials they now possessed.

Project Assessment and Outcomes

Initial data, collected on the final day of the workshop, was indicative of the overall positive tone of the two week workshop. Evaluation of the summer workshop (Table 1) in the form of comments and an exit survey were quite favorable with near perfect scores (overall average of 4.93 on a scale of 5). The overwhelming response from the comments on the survey forms and conversations with the teacher participants was for more opportunities to learn about environmental issues and available resources.

Table 1
Evaluation of the Summer OEEF Environmental Workshop

	Question	Mean Rating
1.	This workshop was beneficial to me as a classroom teacher.	5
2.	The materials I received will be helpful in teaching about water resources.	5
3.	This workshop was set up in a format that was conductive to my learning the content needed to teach about water resources/ environmental education.	4.82
4.	The material presented either on site or during field experiences was on an appropriate level.	4.82
5.	The workshop overall was a good learning experience that I will share with other teachers.	5
6.	The experience and materials from the workshop will benefit my students.	4.96

Note: Scale Used: 5=strongly agree, 4=agree, 3=undecided, 2=disagree, 1=strongly disagree

Table 1 (cont.)

From the collective comments; the three best things about the workshop were:

1. Great resources, people and materials, experiences, all delivered in a teacher-friendly manner.

2. Wonderful to have the time to learn and share with other teachers with similar interests and from a variety of schools. Also time to work and coordinate all the new material with other teachers in my school.

3. A wealth of new ideas to enhance my science teaching and on how to use natural areas like the parks to help students learn about the environment.

Participants stated they would change the following for the next environmental summer workshop:

1. Needed more time to focus on other areas of environmental education, and on other topics such as land use and development.

2. Have a naturalist to help us design and set up a land lab or natural area at our school.

Teachers' responses indicated that they saw the need for more in-depth environmental education, particularly school-based land labs that they could access more frequently and have their students involved in long term investigations. This prompted me to seek an extension of the funding period to explore issues relating to land labs and land use issues.

School visits, class observations, field trips, and other information from the 1997-98 school year indicates that the teachers continue to incorporate the water resources curricular materials in their teaching as well as to implement their Action Plans. As an indicator of the success of the project, a principal from one of the participating schools stopped to tell me how one of the students, who is normally in trouble and in his office frequently, came bouncing into the school building one afternoon, following a field trip and water testing at the Wesleyan Nature Center, and announced that he loved doing science and that that day had been his "best day in school"! This level of student involvement and interest has been recounted several times so far this year.

To me, this is exactly the type of enthusiasm that should be our goal in delivering high quality environmental education and in developing positive attitudes toward science while increasing students' conceptual understanding of the natural world.

The summative Project Survey instrument was more extensive, encompassing four categories: the summer institute, science teaching prior to the project, science teaching after the project, and general questions related to the project. Overall responses were once again positive (Table 2). This survey also called for the teachers to reflect on the changes that occurred in their teaching, and level of implementation of the environmental curricular materials in their classroom as well as how the program benefited their students.

Table 2
Miami Valley Environmental Science Education
Teacher Enhancement Project – Final Survey

Category 1 overall = 4.73

During the summer institute . . .

Question	Mean Response
1. The facilitators were knowledgeable of subject matter being discussed.	4.83
2. The facilitators were helpful.	4.77
3. The materials supplied during the summer institute were appropriate and useful.	4.77
4. I was supported in teaching environmental science and using the materials throughout the entire project.	4.67
5. The Project Wild, Project Wild Aquatic, Project WET and other curricular materials were helpful and worth spending time on during the summer institute.	4.93
6. The amount of time spent completing the institute was appropriate.	4.53

Category 2 overall = 3.83

Before my involvement in this program . . .

Question	Mean Response
7. I enjoyed learning and teaching science.	4.20
8. I spent an equal to or greater amount of time teaching science than other subjects in my classroom.	3.07
9. I felt science was just as important in a child's education as math, spelling, reading, writing, etc.	4.27
10. The majority of my science lessons were "hands-on".	3.86
11. My students generally enjoyed learning science.	4.24
12. My teaching performance in science or science-related areas was above average.	3.45

Category 3 overall = 4.38

After my involvement in this program . . .

Question	Mean Response
13. I enjoyed learning and teaching science.	4.63
14. I spent an equal to or greater amount of time teaching science than other subjects in my classroom.	3.76
15. I felt science was just as important in a child's education as math, spelling, reading, writing, etc.	4.66
16. The majority of my science lessons were "hands-on".	4.24
17. My students generally enjoyed learning science.	4.62
18. My teaching performance in science or science-related areas was above average.	4.37

Category 4 overall = 4.73

General Questions . . .

Question	Mean Response
19. I feel as though teachers could benefit from an environmental program similar to this one.	4.83
20. I would recommend this program to my colleagues.	4.73
21. I have utilized the materials and the knowledge gained from this program in teaching science.	4.66
22. I feel that my students have benefited from my involvement in this environmental project.	4.76
23. I would complete this or a similar environmental program again if possible.	4.47
24. My overall teaching performance in science or science-related topics has improved through this program.	4.75
25. My overall feeling of this program is very positive.	4.87

Note: Scale Used: 5=strongly agree, 4=agree, 3=undecided, 2=disagree, 1=strongly disagree

Comments:

- Thanks for the opportunity to learn and work efficiently in an area I felt uncomfortable/inadequate in as a teacher. I can't wait to participate again.
- This was a great program and I highly recommend it. The contacts and resources are a valuable asset to teaching science especially on environmental issues.
- I really enjoyed the summer workshop and the SEC experience. We used many of the activities and lessons in my classroom. The students really benefited from my experience last summer.
- I have had a great time. Thank you for expanding my environmental awareness!! The facilitators were excellent teachers. Their enthusiasm toward science was contagious. I really enjoyed the opportunity to meet and work with other classroom teachers. It was great!

- Graduate student was an outstanding support person. Whatever he is making – he deserves at least three times as much for all the assistance given to me this year from the facilitators of the Institute.

- Thanks for the extra set of hands with my classroom and students.

- Excellent program.

- Great program! Thanks for the wonderful opportunity!

- In my years of teaching, this was the most valuable, applicable project I have had the privilege of participating in! Meeting and collaborating with colleagues was a definite plus! The application of my readings of successful staff development was exemplified by the efforts of Dr. LR. She is truly a key ingredient to the success of this program. It was always organized with the students' and teachers' best interests in mind. Thanks for the opportunity.

- I already taught a lot of hands-on science. The program added to what I already did, especially in the water area. Thanks.

- My students really picked up on my enthusiasm and personal interest in our environment. WOW – the idea of running out of useable water and soil (and how long it takes to make new soil) was a "rendered speechless" concept for them.

Enhanced environmental education was evident in the amount of time and hands-on teaching of science occurring in participants' classrooms. It was also reflected in more than just field trips. The teachers reported an increase in the classroom time spent on topics related to surface waters environmental science. Examples included the use of owl pellet lessons tied to habitat and food web investigations and/or building an observation "pond" environment for students to study long term at one school.

Discussion and Conclusions

The "lessons learned" can be stated quite simply: collaborate with good folks; follow sound professional development and adult education principles; set high goals but have realistic expectations for the project and participants; value and respect diversity in a broad sense; and finally, don't create what already exists, e.g. many excellent, well-tested curricular materials.

This two week workshop, with year-long follow up and quarterly meetings proved to be a successful model for helping a wide range of classroom teachers to enhance their understanding, teaching and classroom learning environment. The model was based on the Teacher Professional Model of Trainer of Trainers and grounded in Adult Learning Theory as the overall delivery framework, coupled with sound environmental education content and curricular materials. This approach enabled the project facilitators to be successful in assisting 33 classroom teachers to grow in confidence, to gain conceptual understanding, and to develop a working knowledge of ESE related to water and natural resource issues.

The teacher participants were treated as valuable members of the workshop team and their initial knowledge was the starting point for a very capable group of ESE professionals who fully understood the need to present the information, experiences, and materials in a manner that helped the teachers to feel comfortable and capable of taking some risks to extend their surface waters and natural resources knowledge base. All in all, the group still stays in close contact and during the summer of 1998, we had a three day symposia to discuss and investigate land use issues and effective design of land labs at their school sites. Our next step is a big one as Wright State University is now a GLOBE franchise site and the MVESETEP participants will be first in line to take part in this newest ESE project for classroom teachers.

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WEATHER ACTIVITY SEQUENCES FOR CONCEPTUAL ACTIVITY

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Guiding children's conceptual development can often be a difficult process. Children are quick to figure out what the teacher wants as the "right answer," without understanding the underlying concepts or why that is an acceptable answer. This chapter presents a paradigm that early childhood educators can use to develop activity sequences to teach science process skills and related mathematics skills, as well as help children answer why. This paradigm draws upon the current knowledge and beliefs in science and early childhood education, and it allows teachers to apply the activity sequences to various contents or thematic topics. The philosophical basis for this paradigm is constructivism.

Constructivism

Constructivist practice takes many forms in the classroom, but at the heart of the forms of constructivism lies the notion that individual human minds build understanding. Williams and Kamii (1986) define constructivism as the formation of knowledge through acting on an object or the environment. Children are particularly adept at building meaning in their world; sometimes the meaning is agreeable and sometimes the meaning is not agreeable to the adult communities surrounding the children. Preschool, kindergarten, and most primary grade children are prelogical in their thinking. Young children sometimes explain things using a combination of their intuitive thinking and misapplied information. Regardless of the meaning that children form about a subject, concept, or process, the understanding that the children create is real to their experiential world.

Piaget and Vygotsky were early psychologists who helped shape current constructivist thought. Piaget defined age dependent stages of ability from thinking in a sensory motor mode through the ability to think abstractly. Movement through these stages is not automatic. Young children need many experiences so that they can create meaning and further develop their thinking abilities. Thus, it is very important that young children be exposed to an enriched environment that challenges their current thinking (Staver, 1986). Vygotsky was more concerned with social construction of knowledge. Children must learn to share, communicate, and thus work together. The Vygotskian tradition led to social constructivism that incorporates the same ideas as Piaget's individual constructivism and then adds the interaction of children. Children, plural, are the operational imperative in social constructivism. Children interact, and then children create meaning. The teacher's role is to determine the meaning the children have created to explain various concepts, processes, or skills.

Teachers whose teaching is consistent with constructivist ideas encourage children to think aloud, and give verbal or pictorial descriptions of their current thoughts. After constructivist teachers discern the children's meaning, the teachers deliberately challenge the children's thinking. Teachers direct questions to the children in a fashion that causes the children to rethink, discuss, and negotiate new meaning(s) (Kasten & Clarke, 1991). Another tactic teachers might choose would be to provide discrepant events that the children encounter as a group, and view the same phenomenon.

Constructivism emphasizes the importance and interrelatedness of concepts, skills, and attitudes in children's learning and development. Katz and Chard (1989) identify these same aspects as knowledge, skills, and dispositions. These early childhood educators also emphasize the development and enhancement of the whole child in order to promote learning and conceptual development. In teaching the young child, sensory input and movement is a critical aspect of learning, as these have been the major modes of learning for the first two years of life. Language and interaction with other perspectives also move into primary modes as children become three and four years of age. During the early childhood years, children begin to understand that written symbols are used to represent objects and ideas. Children expand their thinking and modify their logic on (a) sensory input, (b) interaction with manipulatives and thoughts about their actions, and (c) their experiences and encounters with different perspectives. Young children begin to see relationships among concepts only if they are able to interact and think about objects and things that they can manipulate (Clements & Battista, 1990; Williams & Kamii, 1986). Through interaction with others, experiences over time, and learning more about their world, children begin to move into logical thinking.

Building on Interests and Life Experiences

Teachers whose teaching is consistent with constructivist ideas are aware of the importance of building on and making connections to the child's knowledge and experiences, or scaffolding. By knowing the range of new experiences and knowledge that each child can grasp and understand, the teacher can assist the child to make connections (Berk & Winsler, 1995). Each child is unique in her or his abilities, experiences, and perspectives of the world. The effective teacher understands each child, and facilitates his or her development by providing experiences that broaden and alter the conceptual understandings.

The constructivist educator must continually assess the children's intellectual development, select tasks and experiences which are appropriate for the children, analyze children's responses in terms of developmental criteria and understanding (along with content), and promote cognitive development through interaction with materials, experiences, investigations, and other children. The teacher presents experiences, learning activities, and investigations that are relevant to the developmental stage and interests of the children, thereby nurturing children's natural curiosity. Raw data and primary sources, along with manipulative, interactive, and physical materials are used for learning activities with the children. Child autonomy and initiative are encouraged and accepted.

5 Es Paradigm

We have built on past research and work in the field of science education (Science Curriculum Improvement Study, 1976; Thier et al., 1986; Trowbridge & Bybee, 1996) and developed a paradigm that can be used to promote conceptual understandings and "scientific literacy." We have modified Trowbridge and Bybee's (1996) model into both a planning (unit planning) and an instructional (learning activity sequence) paradigm. The presented paradigm is based on both individual and social constructivist views of learning. A constructivist paradigm, like this one, is inconsistent with many examples in the literature which present completed, detailed, lesson plans. A truly constructivist model must be dynamic and fluid, since it is dependent on the constructs children form during interactions with materials, environment, and peers.

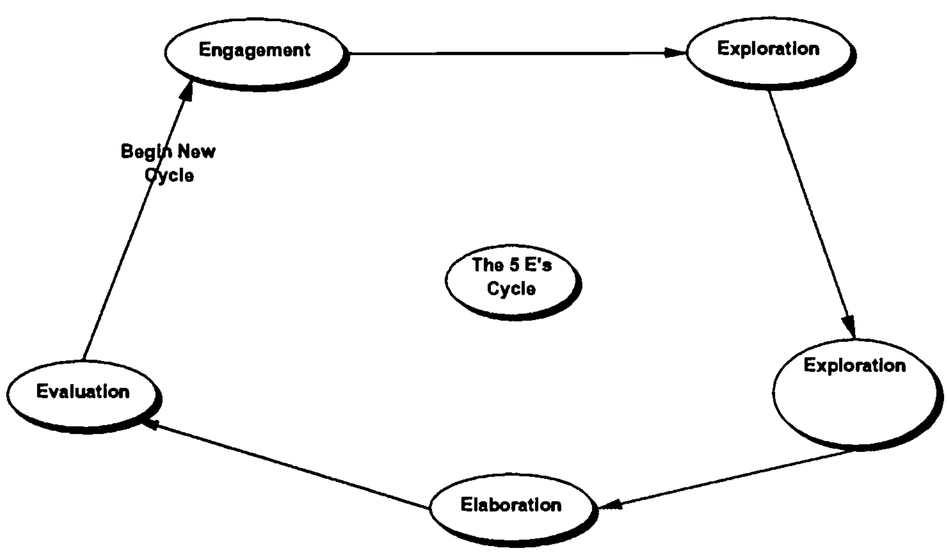
The five phases of the presented paradigm are: engagement, exploration, explication, elaboration, and evaluation (5 Es) (See Figure 1). The first phase is that of *engagement.* This initiates the learning process when interest and curiosity in the topic are generated. This phase makes connections to the past and future activities. Questions are raised about the topic and activities. These initial activities should be concrete and engaging.

The second phase is *exploration.* Exploration provides experiences that include the concepts, processes, and skills important to the topic. The topic is explored through investigations, manipulations and open-ended problem solving. Children are allowed some freedom to explore and manipulate problems presented by the teacher. This phase emphasizes active, open-ended investigations by the children, not demonstrations by the teacher.

The third phase, that of *explication,* is when vocabulary, terminology, labels, definitions, and explanations are initially brought into this cycle. Children focus on specific experiences, discuss them, and are formally introduced to concepts and labels. Discussion of the topic includes justifications and clarifications of the varying perspectives and findings that arose during the exploration phase. Children are the main contributors to the discussion.

The fourth phase, *elaboration,* includes active use of the newly learned concepts, skills, and vocabulary and applying the knowledge to new situations or extending it to other, appropriate

Figure 1. The 5 Es cycle.



situations. Interrelated experiences that extend the children's understandings and applications of concepts, processes, and skills are presented. New and different experiences develop deeper and broader understandings. Elaboration includes both application of knowledge, skills, concepts, and vocabulary, along with extension, transfer, and generalization of these knowledge and skills.

The final phase, *evaluation,* focuses on assessment. Authentic activities are used to assess the children's understandings and abilities. Children are also encouraged to assess their own progress. The extent to which the topic has been learned and new directions for further investigation are determined. General attitudes and behaviors towards working with others and investigating problems are also assessed. Figure 2 provides guidelines for assessing children's general science skills and attitudes.

Figure 2. Criteria for assessing children's performance (from National Research Council, 1996).

Performance Indicator	Evidence/Criteria
Following directions	Child follows the directions
Measuring and recording data	Measurements are reasonably accurate and include correct units.
Planning	Child organizes the work appropriately.
Elegance of approach	Child invents a sophisticated way of collecting, recording, or reporting observations
Evidence of reflection	Child comments on observations in ways that indicate the he/she is attempting to find patterns and causal relationships.
Quality of observations	Observations are appropriate to the task, accurate, and have some basis in experience or scientific understanding
Behavior in the face of adversity	The child seeks help and does not panic if sand, water, or other materials are spilled, but proceeds to clean up, get replacements, and continue the task.

This 5 Es paradigm emphasizes physical interaction with materials and interpersonal interactions with teacher and peers. The 5 Es also includes vocabulary and language development, which enhances young children's conceptual advancement. The basic science processes of observation, classification, communication, and measurement, are stressed throughout the paradigm. The authors view the 5 Es paradigm as a guide, for teacher planning and implementation to enhance conceptual development through appropriate learning experiences for children.

Science process skills provide a basis in the logical disciplines for children to understand their world and the natural phenomena in it (National Research Council, 1996). For young children, emphases on the basic process skills of observation, classification, communication, and measurement are of critical importance. These processes are essential for children to describe and think about objects and events, to communicate with one another, and to explain and understand different perspectives. Expanding children's communication and language skills significantly augments their thinking and conceptual development (National Council of Teachers of Mathematics, 1986; Perlmutter, Bloom, & Burrell, 1993). Providing meaningful experiences with concept and language enhancement, also allows children to connect vocabulary terms with activities, processes, and attitudes (Flick, 1993; Kilmer & Hofman, 1995).

Therefore, in setting up and establishing the classroom environment and learning activity sequences, there are several issues to be considered:

1. Children learn through hands-on, minds-on activity.
2. Children need to be able to make choices.
3. Children focus and attend best if the learning is related to their interests.
4. Children learn in an integrated fashion. The curriculum areas are not separated in life or in the minds of young children.
5. Children need interaction with others to confront differing ideas and to realize that there are other opinions and perspectives.
6. Children need interaction with others to determine common understandings and transmission of culture.
7. Children need broad and extended bases of experiences.

Developing Learning Activity Sequences

The 5 Es provide a template for planning learning activity sequences within a unit of study. The emphasis is on children actively learning and the teacher facilitating. In an activity sequence, the first phase, engagement, is used to focus children's interest and attention on the topic. In the exploration phase, children actively explore the topic and manipulate materials relating to the topic. In the explication phase, the children learn about the concepts and a formal vocabulary is provided by the teacher and attached to these concepts. During elaboration, the children apply and extend the newly developed concepts. In the final phase of evaluation, children reflect on the concept and vocabulary and their understandings are assessed by the teacher. The definition of the five phases reflects this transfiguration as follows.

Engagement

This phase initiates the learning task. This phase should make connections between past and present learning experiences, and anticipated activities and focus children's thinking on learning outcomes. The children should become mentally engaged in the concepts, processes, or skills to be explored. This portion of the lesson plan focuses on the learner and learning. Thus, focusing on what the child is experiencing and learning is imperative for conceptual development.

Exploration

This phase provides children with a common base of experiences within which they identify and develop current concepts, processes, and skills. During this phase, children actively explore their environment and/or manipulate materials. The children also discuss the different extents of their findings within small groups.

The teacher inquires about children's understandings of concepts in order to ascertain in which direction and on which levels to proceed with learning activities. The teacher probes into children's levels of reasoning, asking for justification and then exposes the children to differing points of view through experiences, tasks, learning activities, and investigations. Children are encouraged to record their data in notes, on charts, or in picture form. The teacher engages the children in experiences that might engender contradictions to their initial responses and then encourages discussion.

Explication

This phase of the sequence focuses children's attention on a particular aspect of their engagement and exploration experiences and provides opportunities for them to verbalize their conceptual understanding, or demonstrate their skills.

This phase also provides opportunities for teachers to introduce vocabulary, formal labels, or definitions for the concepts, processes, or skills explored in the previous phase. The teacher asks questions and translates children's words to science terms or formal labels. The teacher may encourage children to talk with one another and develop further explanations. (This is not an appropriate place or paradigm for lectures.)

During discussion, the teacher introduces content vocabulary and specialized terms. At this point, cognitive and science terminology such as "observe" and "classify" are used when framing additional tasks and investigations. The teacher encourages children to engage in dialogue with one another. The teacher also encourages critical thinking by asking thoughtful, open-ended questions, and encouraging children to ask questions of each other. Sufficient wait time is allowed after posing questions to allow for thoughtful answers, and to provide time for students to construct relationships and create metaphors.

Elaboration

Children's responses are used to drive lessons, shift instructional strategies, and alter content. Subsequently, the teacher sets up experiences, tasks, and activities that require the children to apply and transfer this newly grasped understanding. The children work predominately in small, heterogeneous groups, so that they encounter other opinions and points of view. The experiences and tasks are related to the children's lives, and are meaningful and of interest to them.

This phase challenges and extends children's conceptual understanding and allows further opportunity for children to apply concepts, processes, or skills to a novel application. Through new experiences, the children develop deeper and broader understanding, gain more information, and strengthen skills.

Evaluation

Lastly, the teacher assesses children's understandings through meaningful tasks (Brooks & Brooks, 1994). Assessment is intertwined with instruction, and includes assessment of children's: problem-solving, record-keeping, work with materials and peers, and analyses of thinking processes. Assessment results also provide information useful for further planning (Hein & Price, 1994).

This phase of the sequence encourages children to assess their understandings and abilities. The teacher evaluates concept, skill, and process development by assessing what the child has understood and accomplished. This will guide further explorations to meet educational objectives or curricular goals. It is important to note, that if some children have not adjusted or revised their thinking, this concept may be beyond their "zone of proximal development." Teachers need to allow children's "logical" thinking and responses, even if they are incorrect. Later investigations, interactions, experiences, and developmental learnings may alter the thinking of these children. To coerce them into mouthing the generally accepted reality may force their true beliefs underground where they are not available to transformations or modifications through explorations.

When implementing the 5 Es, it is helpful to keep in mind the role of the teacher and the role of the children. For example, do not force a "correct" response. If children are "told" an answer or explanation, they mimic this in their responses without modifying or adapting their thinking (schemas). We have found that separating what the child is to do from what the teacher is to do ensures that the child is involved in active experiencing. Other clarifications are listed in Figure 3. One way to assess the overall activity sequence is to develop a checklist that includes the following points:

- Is the topic interesting to children?
- Is the topic interesting to me (the teacher)?
- Is the activity sound in terms of curriculum and content?
- Are there adequate resources for this activity sequence?
- Will the activity sequence engage children at different levels of abilities?
- Are there strong cross-curricular connections?
- Are there sufficient opportunities for children's input to guide or determine direction?
- Is there an emphasis on oral and written language development and communication?

The 5 Es learning activity sequence planning template facilitates conceptual development through interactions with materials, teachers, and peers. (Note: If you are unable to determine an activity for a concept, some possible resources are: another teacher (middle and secondary teachers are also useful as content consultants), activity books in the library, a National Science Teachers Association journal, Science and Children, other journals for teachers of young children, and ERIC documents.) When working with young children, most learning activity sequences should be exploratory in nature.

To illustrate application of the learning activity sequences, we have developed a unit on weather. The aspects of weather that we have chosen for the children to explore are wind, temperature, the water cycle, and weather trends. Within each of these major categories, we identified several topics (utilizing national science and mathematics standards, and state science and mathematics standards) as important for children to understand. The aspects of weather we have chosen for the children to explore

Figure 3. Implementing the 5 Es learning activity sequence

Engagement create interest in topic raise questions	**Engagement** show interest in topic ask questions
Exploration encourage children to work together observe and listen to children asks questions to redirect children	**Exploration** think freely about topic suspend judgment and try alternatives record observations and ideas discuss ideas and experiences
Explication have children explain in own words have children define in own words ask for justification from children use children's previous experiences and understandings to explain concepts provide definitions, explanations, clarifications, and formal labels	**Explication** explain possible solutions to others use observations and data in explanations listen critically to others' ideas
Elaboration encourage children to apply and extend learnings to new situations remind children of alternatives expect children to use formal labels remind children of existing data and	**Elaboration** apply new learning in new but similar situations use newly learned terminology ask questions, propose solutions, design investigations make reasonable conclusions from

evidence
ask "What do you think?" "Why?"
ask questions to redirect children

evidence
record observations and explanations
with peers

Evaluation
observe and record as children apply new
learnings
look for evidence that children have changed
encourage children to work together
their thinking
guide children to also assess own learning
ask open-ended questions to assess children's
reasoning

Evaluation
evaluate own progress and learning
demonstrate reasonable understanding of
new learnings
discuss investigations and conclusions
apply observations and evidence to answer
open-ended questions

are wind, temperature, water cycle and weather trends. Within each of these topics, we identified

several

subtopics (utilizing national science and mathematics standards and state science and mathematics

standards) as important for children to understand. The first topic is wind with subtopics of

directionality, moving things, and speed. The second topic is types of weather with subtopics of sunny,

rainy, cloudy, thunderstorm, hurricane, foggy, and tornado. The third topic is temperature which

includes feeling on skin, cold, warm, chilly, thermometer, degrees, and "reading" thermometers. The last

topic is the water cycle which includes evaporation, clouds, humidity, condensation, dew, fog, frost, and

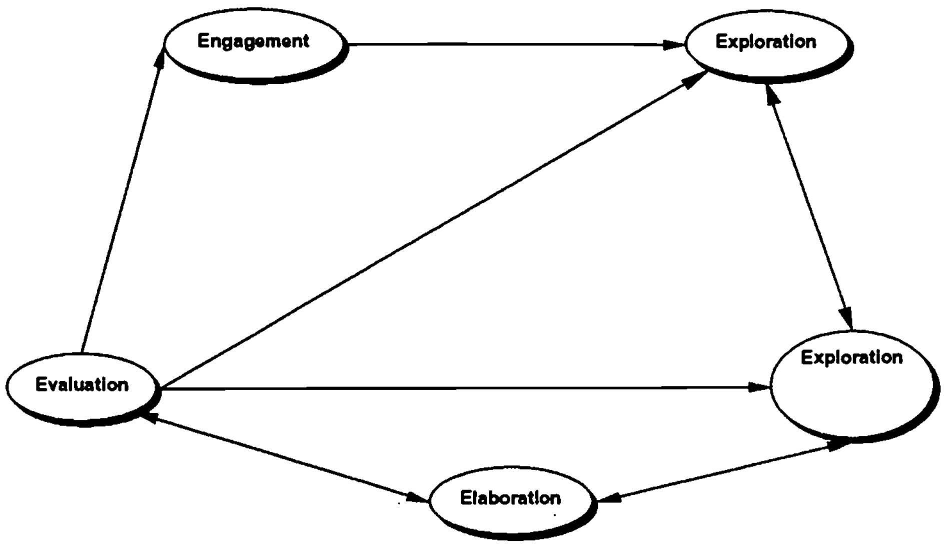
precipitation types.

The four learning activity sequences on the following pages illustrate how the teacher could use the 5 Es to plan and teach particular concepts for a unit on weather. The following activity sequences are presented: Wind Activity Sequence which includes blowing winds, wind directions, and speedy winds; Temperature Activity Sequence which includes feeling hot and cold, and measuring air temperature; Water Cycle Activity Sequences which includes condensation and water cycle; and Weather Trends Activity Sequence including foggy days. These sequences can be found in Appendices A – D.

Because the phases are extremely flexible, the 5 Es paradigm is particularly good *for* affecting adaptations for various ability levels. During exploration, activities can be individualized easily to suit special needs. In addition, during the phase of elaboration, extension activities for individual abilities are easily developed. Another possibility that utilizes the inherent flexibility of the 5 Es paradigm is the ability to cycle from explication back to exploration when a child is not yet ready to apply the concept in the elaboration phase. Many children will remain in the exploration phase for an extended period. Figure 4 illustrates how a teacher may recycle among the phases in order to meet the needs and abilities of the children. This can only be determined through observations of children's abilities and thinking processes.

Remember, this is a cyclical learning and instructional strategy. Teachers may choose to cycle between two or three phases before continuing. Some children may not progress beyond the exploration phase in understanding certain concepts based on their experiences and developmental level. The 5 Es is not a linear paradigm. The teacher can remain in one phase or can cycle between two or three phases. If in the evaluation phase, the child or teacher sees a need for further development or application, they can easily recycle back to the phase that can be utilized to meet this perceived need. Sometimes a teacher cycles between exploration and explication, or among explication, elaboration, and evaluation, using different activity sequences each cycle. This flexibility allows the teacher to meet the individual child's needs and to develop specially tailored activity sequences.

Figure 4. Cycling within the 5 Es.



Conclusion

Educators need to remember that children share many behaviors with scientists as they are exploring and learning about their world. Through their experiences, they are developing concepts, skills, processes, and positive dispositions toward learning about their world. This 5 Es paradigm for planning units of study and instruction of learning activity sequences will assist teachers to guide children in discovering and correcting their naive theories. Through implementation of the 5 Es cycle-engagement, exploration, explication, elaboration, and evaluation-teachers can augment children's intellectual development based on understanding the underlying concepts and relationships among materials, the environment, and society. This paradigm takes into account the nature of the young child as a learner, the philosophy of constructivism building on both science education and early childhood education), and the cyclical and spiral learning that occurs through learning activity sequences. When implementing the 5 Es paradigm, teachers will find that it is continuously evolving. Each phase is dependent on the one in front of it. Often, teachers will continuously recycle through the beginning phases, as the children need more experiences and explorations before they are ready to move on. The

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Appendix A

Wind Activity Sequence: Blowing Winds

What the children do

Engagement

Watch a fan that is blowing streamers.

Exploration

Watch the fan blow the streamers at slow, medium, and fast speeds.

Hold streamers on different sides of the fan (at a distance). Determine which streamers blow, and in which direction. Draw pictures of the fan, wind, and streamers.

Explication

Children explain the direction and the speed the streamers are blowing based on the direction and speed the wind from the fan is blowing.

Elaboration

Examine the wind blowing objects outdoors (streamers, leaves, grasses, dust,

Evaluation

Children move like an object being blown by the wind.

What the teacher does

Engagement

Set up a fan to blow streamers tied to the grill indoors.

Exploration

Have the children *watch* the fan blow the streamers at slow, medium, and fast speeds. Have children hold streamers on different sides of the fan (at a distance).

Ask: which streamers blow, and in which direction? Which direction is the wind blowing?

Which direction are the streamers blowing? Have the children draw pictures of the fan, wind, and streamers.

Explication

Have the children explain the direction and the speed the streamers are blowing and how they relate to the direction and speed the wind from the fan is blowing.

Elaboration

Take the children outdoors to examine the wind blowing objects (streamers, leaves, grasses, dust, etc.).

Ask: which direction is the wind blowing? How do you know the wind is blowing in that direction? What other objects are blowing in the wind? Are they blowing in the same direction?

Evaluation

Have the fan blowing without the streamers. Ask the children to stand in the wind and to use their arms as if they were limbs on a tree. They should be able to show the direction and type of movement that tree limbs would make when blowing in the wind. The teacher may move the direction the wind is blowing to corroborate directionality and may change the speed of the "wind" to see if children make their arm wave more in stronger "wind."

Wind Directions

What the children do

Engagement

Children take compasses and go outside with them. They experiment with the compasses.

Exploration

Children point their compass north and set it on the ground in front of them.

Children *turn* to face the wind so that it blows straight into their face. They will notice the direction that they are facing (they will read the compass).

Explication

Children explain the direction the wind is blowing based on the direction they are facing and their reading of the compass.

Elaboration

Repeat the investigation and determine the direction the wind blows for several days. In pairs, the children can list or chart the days and wind direction for the week.

Evaluation

Draw the direction of the wind.

What the teacher does

Engagement

Explain to children that compasses help us to determine direction. Explain how the compass works and N, S, E, W. Have enough compasses for each child or pair of children. Take the children outside on a windy day.

Exploration

Help the children line up their compasses with North and set them on the ground. Have the children turn their faces into the wind.

Ask: Which direction is the wind blowing from? Which direction (compass letter) is the wind blowing from? What else is the wind blowing that helps you determine where is it blowing from (trees, etc.)?

Explication

Have the children explain the direction the wind is blowing from and how they determined the direction.

Elaboration

Take the children outdoors to determine the direction the wind blows for several days. List or chart the days and wind direction for the week.

Evaluation

Have the children draw the direction of the wind. One sample can be used each day for class weather charts. Other papers can go in a book that the children are making about weather.

Speedy Winds

What the children do

Engagement

Children look at anemometers (official or homemade). They experiment with the anemometers by blowing against the front and back of the cups.

Exploration

Children take the anemometers outside and determine if the wind makes the anemometers move.

Explication

Children describe how fast the wind is blowing. At slow speeds, the children can count the number of turns the anemometer makes in a minute.

Elaboration

Children further investigate the wind speed by observing how the wind is affecting blades of grass, leaves, and branches of trees.

Evaluation

Illustrate the effects of wind on blades of grass, leaves, and branches of trees at the different wind speeds.

What the teacher does

Engagement

Provide several anemometers (purchased or homemade) for the children to look at and experiment with by blowing against the front and back of the cups.

Exploration

Have the children take the anemometers outside and determine if the wind makes the anemometers move.

Explication

Ask the children to describe how fast the wind is blowing. Can they count the number of turns the anemometer makes in a minute? Can the children blow as fast as the wind is blowing? Is the anemometer turning fast, medium or slow? How can they tell? Tell the children that they are using an anemometer, and that this is a tool that measures wind speed. Have the children describe how it works.

Elaboration

Take the children outside with the anemometers on still days, on slightly windy days, and on very windy days. Have the children explain how fast the wind speed is on each of these days. How does the anemometer react?

Have the children further investigate the wind speed each day by observing how the wind is affecting blades of grass, leaves, and branches of trees. Have the children examine the wind speed using the Native American tradition:

No wind =no leaves or branches moving

Slight wind =leaves and grass blades gently waving in the wind

Medium wind = small branches and bushes gently bending in the wind

Strong wind = medium branches bending in the wind and grass blades bent over in the wind

Evaluation

Have the children illustrate the effects of wind on blades of grass, leaves, and tree branches at the different wind speeds.

Appendix B

Temperature Activity Sequences

Feeling Hot and Cold

What the children do

Engagement

Using warm, room temperature, and cold liquids, children order the liquids by warmest to coldest (serial classification).

Exploration

Children use thermometers. Children note where the red line on the thermometer is for room temperature.

Children record if the red line inside the thermometer is higher or lower as they place it in different containers.

Children observe the red lines in thermometers to see if their earlier serial classification by touch show that the height of the red line changes accordingly if temperature is cold or warm.

Explication

Children explain what the red line indicates about warmth or coldness of the liquid. Teacher explains that the instrument they are using is a thermometer.

Children explain what the thermometer measures.

Elaboration

Children can measure the temperature of other objects, liquids, and gases. Children select the objects to take the temperature of and then draw a red line on the paper that matches the red line on the thermometer. Children then serial order the temperatures of solids, liquids, and gases in the room.

Evaluation

Children "measure" the temperature of novel objects such as an ice cube,. and a container of orange juice that has just been removed from the refrigerator. Children serial classify the order of the temperature of the objects from hottest to coldest.

What the teacher does

Engagement

Provide a minimum of three containers of water for each pair of children (one cold container, one warm or room temperature container, and one hot (not too hot) container of water).

Ask: Which liquid is coldest? Hottest? What sense are you using to decide how hot or cold the water is? Tell children to arrange containers from hot to cold.

Exploration

Provide each pair of children thermometers. (Make sure to use large, safe, and easy to read thermometers.) Have children note where the red line on the thermometer is for room temperature.

Have the children set thermometers in the liquids. Children record if the red line inside the thermometer is higher or lower as they place it in each container.

Children observe the red lines in thermometers to see if their earlier serial classification by touch show that the height of the red line changes accordingly if temperature is cold or warm.

Explication

Ask: How long is the red line when the liquid was cold? How long is the red line when the liquid is warm? Do you think the length of the red line stays the same all the time? Explain that the instrument they are using is a thermometer. Have the children explain what the thermometer measures.

Elaboration

Make sure that other solids, liquids, and gases are available so that children can take the temperature.

Have children draw a red line on the paper that matches the red line on the thermometer. Ask the "explain" questions again.

Have children serial order the temperatures of solids, liquids, and gases in the room.

Evaluation

Select novel objects that the children haven't yet measured the temperature of and that they have not previously serially classified according to temperature. Have children indicate serial order based on touch and then by adding the technology of a thermometer.

<u>Measuring Air Temperature</u>

What the children do

Engagement

Children explain how they know if it is hot or cold outside.

Exploration

Children experience thermometers and measure the temperature of their hands and of the air.

Children measure the temperature outside the classroom and compare to earlier temperatures.

Explication

Children tell what hot, warm, and cold feels like. Children tell what hot, warm and cold looks like on the thermometer.

Elaboration

Children keep a chart of daily room temperature and outdoor temperature.

Children graph the weekly and monthly indoor and outdoor temperature.

Eventually children can graph the temperature for the seasons during the school year.

Evaluation

Towards the end of the school year, children tell the temperature patterns of the seasons.

What the teacher does

Engagement

Distribute thermometers to children. Tell children that they get to use these tools today.

Exploration

Show children where to hold the thermometer, and how to read the red line. Have children hold the bulb between their hands and observe what happens to the red line. Have children hold the bulb in the air to determine room temperature. Take the children outdoors. Have children hold the bulb in the air to read the outside temperature. Have children (if able) write the inside and outside temperature on a previously prepared chart.

Explication

Ask, "Is the temperature the same or different inside and outside?" Tell the children that these tools are called "thermometers." This tool is used to measure temperature, or how hot or cold something is. (Write thermometer on board.)

Elaboration

Continue taking indoor and outdoor temperatures daily

Ask: which season is coldest outside? Hottest outside? What kind of weather is outside when it *is* hottest? Coldest?

Evaluation

Have children draw a picture of a cold, warm, and hot day outside.

Appendix C

Water Cycle Activity Sequences

Condensation

What the children do

Engagement

Early in the morning at the start of school, children examine the wet grass.

Children examine the exterior wetness of their snack or lunch time cold drinks.

Exploration

Children investigate several containers with warm liquids, room temperature liquids, and cold liquids. Both clear and colored liquids are provided both warm and cold. Children write or draw their observations using the five senses. If children are unable to write or draw, a list of the children's spoken words can be created. (Children can taste the water on the outside of the container and the contents to determine if it is the same liquid that is inside the container.)

Explanation

Children explain how the water, condensation, was formed on the container.

Children will learn vocabulary of "condensation," "dew," etc.

Elaboration

Children decide how they might further investigate condensation. They conduct many other investigations and record (with teacher assistance) their findings.

Evaluation

Children determine what they learned. Children will present their findings, or brainstorm what they learned, and the teacher writes it down. Children draw pictures of condensation. If some children's conceptions remain naive, allow them further experience with condensation across the school year.

Say, "Touch the grass, and tell me, what do you feel?" Later in the morning, the teacher directs students to observe again, and asks, "What do you feel on the outside of your drink box?"

Exploration

Provide a variety of warm and cold liquids in clear glass and plastic containers (water, cola, milk, tomato juice, etc.) Make sure the drinks are visible and the products (e.g., cold, milk, etc.) are known. One container of each liquid will be at room temperature while the other will contain very cold liquid. Both clear and colored liquids are required, so children can further explore if they assume that the container leaks. Then ask, "What do you feel on the outside of the container?"

Encourage the containers to be touched and compared. Ensure that all five senses are used. Encourage written, drawn, and spoken responses. (Young children may not be able to record their observations, but the teacher may break the investigation into steps, and the children can voice their observations at each step and the teacher can record these.)

Ask guiding questions such as, What does the outside of the container feel like? Which containers are wet? Are only the cold containers wet on the outside? Are the warm/room temperature containers also wet on the outside? What does the liquid taste like? Is it the same liquid that is in the container? (This helps dispel the notion that the container is leaking.) Accept all answers and ask further questions to help clarify observations. Children's answers should be collected in some format.

Explication

Ask questions such as, What is on the outside of the container? What temperatures allowed the water to form on the outside of the container? Where did the water come from? What does it mean when we say there is water is in the air? Ask the children to explain their thinking, and provide children with the appropriate vocabulary and labels for the concept being explored (e.g., dew, condensation, and humidity).

Elaboration

Assist children in deciding how they might want to further investigate condensation. Perhaps the children want to see if cold solids also cause condensation (e.g., flour, and cold rocks). Perhaps other liquids should be investigated. Perhaps children want to determine if light or darkness affects condensation. These investigations are then set up. Have the children observe and record their findings, and compare these findings to those during the exploration phase.

Evaluation

Have the children determine what they learned. Perhaps the children will present their findings, or brainstorm what they learned and the teacher writes it down. If some children's conceptions remain naive, then allow them further experience with condensation across the school year.

Water Cycle

Water Cycle Chorus:

Rain falling down,
Back to the ground,
Streams going by,
Back to the sky,

Water cycle, water cycle, water cycle.

What the children do

Exploration

Children begin making motions to fit the words. Children draw pictures of a circle, cycle. Children draw a stream, clouds, and rain. Children draw a circle that attaches these things together.

Explication

Children show motions or draw pictures to illustrate a cycle. Children tell in their own words, what a cycle is.

Elaboration

Children tell stories about being caught in a rainstorm, or how humid it is today. Children tell stories about steam rising from pots of boiling water, or fog on the lakes and rivers in the morning.

Evaluation

Children tell or draw a water cycle story.

Engagement

The chorus of the song, "Water Cycle" is playing. Children are listening and learning the words.

What the teacher does

Engagement

Play the chorus of the song "Water Cycle" repeatedly. Teach the children the words to the chorus.

Exploration

Encourage the children to create movements to match the words of the song. Supply paper and crayons so that the children can draw a cycle or a circle. Ask the children about water in the air, from the previous activities on condensation. Ask what a lot of water looks like and feels like. Ask about rain, what is rain, how does rain happen.

Explication

Ask, "What is a cycle? Rain falls down to...? The streams and creeks run to ...? The water goes to...?" Ask a circle to be drawn so that these items are attached.

Elaboration

Show a teakettle boiling, with steam coming out of the spout. The teacher holds a cookie sheet over the steam. The teacher asks for observations about water in the sky, about water condensing on the cookie sheet, about water falling off the cookie sheet.

Evaluation

Have the children create a drawing to illustrate the miniature water cycle created by the teakettle.

Appendix D

Weather Trends Activity Sequences

Foggy Days

What the children do

Engagement

Children stand in the fog and observe with all their senses.

Exploration

Children write or draw their observations. Other days children look at clouds in the sky and observe.

Explication

Children speculate what fog is made up of, how it formed, and why it is on the ground instead of up in the sky.

Elaboration

Children share information about driving through fog, fog on the mountains, over the rivers, and over the lakes. Children share information about airplane trips that they have taken through the clouds.

Evaluation

Children draw or explain similarities and differences between fog and clouds.

What the teacher does

Engagement

Have the children stand in the fog and make observations. Go inside and record the observations for the children.

Exploration

Have the children write or draw their observations.

Explication

Tell children that fog is a cloud on the ground instead of up in the sky. Ask children what fog is made up of, how it formed, and why it is on the ground instead of up in the sky.

Elaboration

Have children share information about driving through fog, fog on a mountains, fog over rivers, and fog over lakes. Have children share information about airplane trips that they have taken through the clouds.

Evaluation

Have children explain similarities and differences between fog and clouds.

Daily Weather

What the children do

Engagement

Each day the children go outside or look out of the widow and draw the weather.

Exploration

Children measure the temperature outdoors each day at the same time. They graph the temperature, and draw a picture of the weather.

Explication

Children describe the weather each day. Children explain the water cycle and what is happening outside that relates to the water cycle.

Elaboration

Children examine weather patterns by looking at the temperature and precipitation charts that they have made. Children will describe weather patterns by the seasons.

Evaluation

Children name and draw the type of weather and temperature on several school days.

What the teacher does

Engagement

Each day, have the children go outside or look out of the window and draw a picture of the weather.

Exploration

Have the children measure the temperature outdoors each day at the same time.

Have the children graph the temperature and draw a picture of the weather.

Explication

Have the children explain the weather each day. Children explain the water cycle and what is happening outside that relates to the water cycle. Ask: What part of the water cycle are you seeing when the water is falling from the clouds? What do we call water falling from the clouds? What do we call frozen water that falls from the clouds? What part of the water cycle is happening on a clear day?

Elaboration

Have the children examine weather patterns by looking at the temperature and precipitation charts that they have made. Have the children describe weather patterns by the seasons. Draw the season lines on the charts or the children can state where they believe the season lines should go. (Repeat this lesson throughout the year.)

Evaluation

Have the children name and draw the type of weather and temperature on several school days. One sample can be used for class charts. Other papers can go into a book that the children make about the weather.

HYBRID SCHEDULING EFFECTS ON SCIENCE TEACHING AND LEARNING

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Introduction

As forms of school restructuring sweep the nation, teachers are interested in how block scheduling will influence their models of professional practice. This report examines one of the most common trends to restructure secondary schools; block scheduling. Proponents often view block scheduling as a way to extend the traditional periods of uninterrupted class time and improve student achievement. Yet, like other methods of school restructuring, these changes are significant largely in the degree to which they influence the outcomes or day-to-day practice of teaching. As the trend continues to grow throughout the United States, teachers, parents, administrators, and university professors are seeking evidence for the impact of block scheduling on teaching.

Teachers and parents at South Springfield High School (SSHS) studied a proposal to switch the school year from a traditional six period day to a 4x4-block schedule. The change to a 4x4 alternative schedule was proposed after five years of study and consideration. After an experimental six-week block in the fall of 1995, the faculty at SSHS voted in the spring of 1996 to implement the 4x4 for the 1997-1998 school year. Due to pressure from some community members, a tri-schedule was instituted as a compromise for the 1997-1998 school year. A tri-schedule includes three schedules types (traditional, 4x4-block, and hybrid) running at the same time during the school day. It was determined that the tri-schedule would serve during a trial period to determine if the 4x4-block schedule could be implemented. The traditional schedule consists of six 55-minute classes that are taught for the entire year. The 4x4-block schedule consists of four 87-minute classes each being taught in one semester during which time a year's curriculum is taught. The hybrid schedule consists of three traditional and two block classes each day. Utilizing the unique circumstances present at SSHS (three approaches to scheduling present in one school), this study sought to document the ways that traditional, hybrid, and block schedules differently influenced the possibilities for teaching and learning.[1]

Unlike many university-affiliated research projects, the SSHS administration and teachers initiated this study (Sirotnik, 1988). The school-based initiation of this research was emblematic of the importance of the study to its primary stakeholders (Tanner, 1998). The action research study was important because it informed SSHS as to whether the switch to a block schedule enabled them to achieve important goals (Stringer, 1996; Veal & Tippins, 1996). For example, does the switch to a block schedule alter the teachers' instructional methods; does it change the modes and increase the efficacy of teaching and learning; and does student achievement increase due to block scheduling?

This study fulfilled the important task of being the first to systematically examine and report the effects of the transition from a traditional to a hybrid schedule. The collaborative, two-year study analyzed a relatively comprehensive set of data on the school's first year of implementing a tri-schedule format. The faculty and administration from SSHS initiated this study precisely because they wanted to use its findings to intelligently guide their school practice. They were committed to the idea of block scheduling only to the degree that it, in fact, proved beneficial to their learning community (e.g., Canady & Rettig, 1995; Edwards, 1993). As a result, the hybrid schedule became the focus of the study; specifically, how did the schedule change influence science teaching and learning.

[1] The study was funded by the Research Institute on Teacher Education at Indiana University and by The Spencer Foundation.

Previous Research on Block Scheduling

A few empirical research studies on block scheduling in science do exist (Bateson, 1990; Hess, Wronkovich, & Robinson, 1998; Lockwood, 1995; Raphael, Wahlstrom, & McLean, 1986; The College Board, 1998; Wild, (1998); Wronkovich, Hess, & Robinson, 1997). Even though these studies presented "hard data," the conclusions were tenuous. For example, Bateson (1990) investigated the effects of full-credit semester and all-year timetables on science attitudes and science achievement of grade-10 students. The students were tested on cognitive and affective domain tests. Students in the all-year courses consistently outperformed first- and second-semester students in the cognitive domains. There were no significant differences in the affective domains. Analysis was done using ANOVA statistical techniques. One significant problem with this report was the fact that the content used on the test covered grades eight to ten. Also, no mention was given as to the schedule of the students before their tenth grade year.

The College Board (1998) published an article comparing student achievement on four Advanced Placement (AP) Examinations among schedule types. An analysis of covariance using the PSAT/NMSQT as a covariate was performed. Students who were taught AP biology under an extended traditional class time (meeting everyday for more than 60 minutes) scored higher than students in a traditional schedule and both fall and spring 4x4 schedules. These results might be expected if more time was spent on a daily basis learning any subject. These results reported the effects of the extended traditional schedule and the 4x4, but did not mention other types of block scheduling; such as block 8, trimester or hybrid.

Although there have been some studies that have presented tenuous conclusions, a few have reported usable conclusions. For example, Hess, Wronkovich, & Robinson, (1998) studied the effect of 4x4 block scheduling on student achievement in four areas using "retired" copies of

SAT II Achievement Tests and the Otis-Lennon Scholastic Aptitude Test as a covariate. Regression analysis on pre- and post-tests on biology indicated a significant difference between the block and traditional students' achievement. Students in the intense block class out-performed their traditional counterparts.

Even though researchers have reported the benefits of block scheduling on student achievement, these studies have not mentioned or addressed the type of teaching or the change in teaching methods used in the block classes or schedules. Papers and research that have addressed the issue of teaching in the block schedule format have only reported on the attitudinal effects the schedule has had on the teachers through surveys. In fact most surveys were administered once the teachers had already changed to the block schedule. The subjective nature of survey data and the lack of a direct comparison to teaching under both schedules have led to criticism of these reports.

The majority of research conducted over the past decade has focused on student outcomes as a dependent variable. In particular, studies have examined the relationship between block scheduling and student grade point averages (Buckman, King & Ryan, 1995; Edwards 1993; Schoenstein, 1995), state standardized test scores (North Carolina Department of Public Instruction, 1996), college entrance exams (Hess, Wronkovich & Robinson, 1998) and graduation rates (Carroll, 1995; Munroe, 1989). The findings of these studies have been inconsistent, sometimes reporting gains for students on block scheduling, sometimes reporting no difference, and sometimes reporting losses compared with students on traditional scheduling. For example, Averett (1994) compared mathematics achievement at twenty-one North Carolina schools, and found an increase in scores at the schools that had recently changed to a semester block schedule. However, Marshall et al. (1995) report a study of mathematics achievement conducted in British Columbia schools that found block students scoring lower than students on a traditional schedule. At one level, these findings are not difficult to explain. In reviewing seven studies of mathematics achievement, including the two cited above, Kramer (1996) concludes: "It is likely that the contrasting results . . . are owing to important differences in the way block scheduling was implemented" (p.766).

This conclusion is an important reminder that the effects of block scheduling on achievement are mediated by its effects on classroom practice. Advocates of block scheduling argue that this strategy increases student achievement by providing an impetus for professional development and opportunities for improved methods of teaching (Canady & Rettig, 1996; Holtenstein, 1998). Yet, effects on practice have been studied less often than effects on achievement. At best, researchers have only begun to tentatively identify the types of changes in practice that may be associated with block scheduling. These possible changes include greater variety in the use of teaching methods (Canady & Rettig, 1996), more frequent use of individualized instruction (Eineder & Bishop, 1997) and small-group activities (Boarman & Kirkpatrick, 1995), together with adjustments in content coverage (Kramer, 1997). The National Science Teachers Association (NSTA) published a compendium of articles on teaching science in the block schedule. Moreover, none of these articles mentioned data to support the practices suggested by the authors.

Purpose

The relationships among science teaching practice and student achievement are notably complex because they involve a constellation of factors beyond block scheduling per se. For this reason, this study draws on a somewhat broader body of scholarship that examines change within the context of classroom science teaching. Eisner (1990) and others (e.g., Cuban, 1993) point to the stability of this context, arguing that: 1) large class size usually favors conventional forms of whole-group instruction, 2) school and state-wide testing practices mitigate against curriculum changes, 3) textbooks tend to standardize course content, and 4) self-contained classrooms often isolated teachers from school reform.

While this study examined the effects of block scheduling on teacher practice and student achievement, it also sought to recognize the professional lives of teachers as a context for both change and stability. The research question, therefore, is twofold: How does block scheduling change science classroom practice within specific subjects, and how does block scheduling effect student science achievement?

Methodology

The research methodology used in this study included quantitative and qualitative strategies. The multiple strategies provided a basis for validating and contextualizing the research (Miles & Huberman, 1984). This type of approach was employed because previous studies were limited in their analyses and focus (e.g., Guskey & Kifer, 1995; Hackman, 1995). Previous studies only included percentages, descriptive statistics, and listings of comments in their reports (e.g., Angola High School, 1997). The current data were generated from two teacher surveys, a parent survey, a student survey, the student records computer database, and semester exam item analyses.

Context

South Springfield High School is a large, four-year school located in a medium-sized college town in the Midwest. The student population of 1800 is mostly white, combining children from the city and rural areas of the county. In the fall of 1997, SSHS began the scheduling format described earlier. Under this format, both traditional and block courses are offered in all subject areas except the performing arts and advanced placement classes. The total contact time in block courses is approximately 37 hours less than for yearlong traditional courses (Table 1). This equates to 40 fewer class meetings for block classes than traditional classes. Initially, students were randomly assigned either a traditional or block schedule. Due to parental requests, class scheduling, and class sizes, some students were placed in a hybrid schedule. Teachers were asked to choose either a traditional, block, or hybrid schedule to accommodate the course selections of the students.

Table 1
Descriptive information for classes under block and traditional schedules.

Schedule Descriptors	Traditional	Hybrid	4X4 Block
Class Time (mins./day)	55	55 and 87	87
Number of Days of Instruction	180	180 and 90	90
Class Time (mins./school year)	9900	9900 and 7830	7830
Classes/Day	6	5	4
Classes/Year	6	7	8
Hours/Day	6.5	6.5	6.5
Credits	12	14	16
Teacher Utilization Rate[a,b]	83%	83%[b]	75%
Teacher Preparation (mins.)[c]	55	55	55

a. Defined as the total teaching contact hours divided by the total class time during a day.
b. Teacher utilization rate was the same for all teachers due to contract and union regulations.
c. Teachers in the hybrid and block classes had additional duty time" to compensate for the extra time during the preparation period.

Instruments

Surveys

Four surveys (two teacher, one parent, and one student) were administered, and measured the level of agreement (Likert scale ranging from –2 = strongly disagree to 2 = strongly agree) of the respondent to a series of statements concerning the new scheduling scenario. The first teacher survey was administered to all teachers just before the semester break in January and then again half way through the second semester. This was done to monitor for changes in attitudes over time. Two additional questions on the teacher survey focused on the loss of instructional time in the block classes and the possible addition of course offerings as a result of block scheduling. The parent survey was mailed in January and returned by postage paid mail during the following three months. The student survey was administered at the end of the school year. Even though the surveys were administered to all teachers, parents, and students, general results were ascertained as guidelines for further inquiry in the area of science. Survey data results are given for all stakeholders, but the focus of the paper is on just the science teachers and subjects. Statistically relevant results could not be ascertained only for science due to the small number of science teachers. Comments and general themes from the larger teacher population were used to guide the results and discussion of the science teachers.

Semester Exams

An item analysis of exam questions within subject areas was one aspect of the project initiated by the faculty and administration at SSHS. The science department at SSHS came together to determine curriculum goals for each subject area. The teachers in each subject area created common questions that assessed the content covered during each semester for each course in block and traditional classes based upon those curriculum goals. Subject teachers had the flexibility to create types and quantity of questions for each semester exam. The majority of the questions developed for the semester exams were multiple choice due to the time frame for evaluation. Exams given by teachers had only some common questions from which comparison could be made. Each teacher for their own classes selected the rest of the questions on the exam.

Comparable pairs of traditional and block classes were identified before analyzing the data with the t-test. The measure of comparability was the average 1996-1997 grade point average (GPA) of all students enrolled in each fall semester class. To determine comparability, the difference between last-year GPA for traditional and last-year GPA for block for each course was derived. This difference was then divided by the lower last-year GPA value. If the quotient was within 5 percent, the classes were considered comparable.

There were some limitations to the data analyses of semester exams. First, all questions were multiple choice. Second, although some questions were generated mutually by block and traditional teachers, block teachers due to the early occurrence of their exams chose questions based upon completed content and not on anticipated content completion by which traditional teachers made their decisions.

Data Analysis

Teachers, parents, and students answered questions on surveys based upon a five point Likert scale, and provided additional comments as appropriate. One-way ANOVA analyses were performed on the Likert responses, and qualitative data analysis was completed on the written responses. One-way ANOVA tests were also performed on data retrieved from the student databases. Teachers also compiled item analyses from semester tests in each major subject area in science. The qualitative methodology used in the study involved four tools; semi-structured interviews, classroom observations, teachers' written responses on the surveys, and teacher journals and various school-related materials. The written texts were coded for a priori and emergent themes, and then compared with results from the surveys.

Results

Surveys

All four surveys were administered to all teachers, parents, and students. The response rates were 91 percent and 88 percent for the two teacher surveys, 19 percent for the parent survey, and 64 percent for the student survey. The results are not specific for science. The significance of various questions provided themes to guide classroom observations, interviews, and qualitative analyses. Qualitative responses on the surveys did provide discipline and content specific data for analysis. Table 2 shows some themes from questions on the three surveys. The numbers in the table represent F values and their corresponding levels of significance with two degrees of freedom. The alpha level was set at a 95 percent confidence.

Table 2
Common themes and one-way ANOVA with Tukey post hoc significance among teacher, parent, and student surveys.

Survey Question	Teacher Survey 1[a]	Teacher Survey 2	Parent Survey	Student Survey
Teachers' instructional methods have changed.	**8.065** **.001**	**7.165** **.002**		**29.148** **.000**
	TB, TH[b]	TB, TH		TB, TH
Anxiety level has decreased.	0.838 .437	**3.159** **.050**	**5.985** **.003**	**3.317** **.037**
		TH	TB, BH	TB
Grades have improved.			**5.268** **.006**	**17.996** **.000**
			TB	TB, BH
Assessment has changed.	**5.630** **.006**	0.794 .457		**10.079** **.000**
	TB, BH			TB, TH
Relationship between teacher and student has not changed.	**5.676** **.009**	**3.462** **.038**		**22.658** **.000**
	TB,TH	TH		TB, BH

a. Numbers reported are the F and p values at a 95% alpha level.
b. TB represents significance between the traditional and block schedules.
TH represents significance between the traditional and hybrid schedules.
BH represents significance between the block and hybrid schedules.

Instructional Methods

According to responses from surveys, interviews, and observational data, instructional methods for most of the teachers with block classes changed. Two general themes emerged from the data. First, the amount of time influenced the type of teaching strategy employed. Second, the specific teaching methodologies used were varied and differed from previous years.

The time in block classes was longer during each period, but for the duration of the year, block classes had 22 percent less time to cover the same amount of content. Both aspects of time effected learning and teaching. Students, parents, and teachers were split on the effectiveness of science teaching and learning in the block schedule. The negative responses focused on the pace of instruction and content coverage. For example, a junior student on the hybrid schedule commented, "Teachers seem to be rushed to get the material covered that is 'suppose' to be covered. It is hard to keep up sometimes especially in math or science." Parents were also cognizant of the impact the loss of instructional time had on teaching and learning. "Biology in block format was awful. The teacher stressed to complete the chapters. I felt my daughter was not comprehending the material." One parent aptly stated that "one [teacher] would have to give up (in block) either content or thoroughness." Teachers agreed with the students and parents on both negative aspects of time. "Much more has to be covered in what seems like fewer hours – but the students are still 14 & 15 years old and the concepts are just as difficult." The main reason for the negative aspects of block teaching in science was due to the loss of instructional time overall, and not on the length of time for a class each day.

On the other hand, the positive aspects of time while teaching on the block schedule focused on diversity, reflection, and content coverage. One student on the block schedule mentioned "We've been able to do more things in a class period like take a test and do a lab in one period." Most of the parents responded in a similar manner. In particular, the parents who responded positively to the block schedule for a specific course being in the block format supported the longer block class time for science. "Block is ideal for science with necessary labs and projects that need the longer time frame." Half the teachers agreed with the positive aspects of time in the block schedule for science teaching and learning. One teacher commented on the decreased amount of time as an impetus for restructuring or thinking about the curriculum. "It has required me to analyze the curriculum in terms of the specific lessons and activities I do, and decide what is mot important in order to meet our objectives." A hybrid teacher who had previously taught in a hybrid type schedule commented that "blocking does change teaching – 2 day labs can be done in one." Most of the science teachers believed that labs were taught and understood better in block classes as long as teaching methods changed with the amount of time. In terms of content coverage, one science teacher did mention in the second survey that "less material was covered, more depth (completion)." More specifically, teachers in physics viewed the shortened block classes as problematic for content coverage (interview, 3/6/98). Biology teachers also felt the pinch for content coverage, whereas the chemistry teachers had few problems covering the content. One hybrid chemistry teacher stated, "I actually covered more material in my block classes than in my traditional classes, because of my increased focus and different teaching methods" (interview, 4/2/98).

In term of instructional strategies, students noticed group work and lab work as most predominant teaching methods used by teachers. A senior in the block schedule commented on her teacher's use of group work and it's specificity to science; "It depends on what subject. Chemistry, yes." Teachers' responses were mostly general. For example, a hybrid science teacher stated, "Block classes have more variety during a class period." Another hybrid teacher commented, "Less notes/ more students doing more thinking (higher level) [actual quotation marks of teacher]." Some responses did focus on specific teaching methods or changes. For example, one science teacher stated, "I go to more discussion and less lecture." A hybrid teacher stated that she/he tried "to do more in-class activities and less note-taking and lecturing." Block classes did effect the types of instructional activities and methods used by science teachers.

Anxiety Level

In the first survey, teachers indicated increased levels of anxiety across all three schedule types. In the second survey, hybrid teachers indicated increased levels of anxiety significantly more often than traditional or block teachers. Hybrid teachers (as well as traditional and block teachers) most frequently attributed anxiety to change in general. "I had both block and traditional, in block finding a combination of activities that work is stressful." Another hybrid teacher wrote, "Much higher stress level!" One hybrid science teacher mentioned that the increased number of preparations on the hybrid schedule was what caused greater stress. "there is a big difference between having 2 and 3 preps on a block or hybrid schedule." Increased anxiety among teachers was in relation to the increased number of students per class, more preparations, and increased content presentation regardless of the schedule format.

Teachers who were more specific in their written responses reported that their increased anxiety was a function of having more students in each class and increased pace of instruction. A traditional teacher wrote, "More students and extra grading period equals high anxiety." In addition to teachers' concerns, parents also worried about the effect the pace of instruction had on content coverage. Even though some parents favored moving to block because certain concepts "fit the longer classes better," they also complained about which "content items were eliminated." Parents and teachers felt the combination of increased pace of instruction and decisions about what content to eliminate increased the anxiety levels of students and teachers.

Students' Grades

Students and parents felt that the students' grades increased in block classes as compared to comparable traditional classes. The significant difference was between parents of traditional and block students. Block students also significantly felt their grades improved more so than traditional or hybrid students. This assertion was supported with interview responses from parents and students. Many factors were attributed to this general feeling. For example, students could focus on fewer classes in block or hybrid schedule. Second, students could see the "light at the end of the tunnel" in the shorter semester classes. Third, "daily and intense contact with a subject matter" (chemistry teacher interview) was one reason for the grade increase in block classes.

Assessment

Assessment was another area of change for some science teachers due to the block classes. Few of the answers were specific, and their comments ranged from "not really" to "I still use tests." For example, a block teacher mentioned that she/he used "similar methods in blocked and traditional classes." For one hybrid teacher, the mixture of classes provided an opportunity to alter his assessment practices. "Less tests/ more comprehensive assessment and checking if the students understand connections of the material." The same teacher in the second survey also stated that he accomplished "quality goals." Some teachers did broaden their conceptualization of assessment to include the development of alternate means of grading. A biology teacher stated, "Recently we just did rubrics in both of the classes about the same time which was kind of hard. One of the projects was for the DNA model, making DNA models and then the other one was on habitat and niche."

Relationships with Students

In the first teacher survey, the question of whether relationships with students had changed due to schedule type elicited responses across all three groups. In the second survey, most teachers gave largely neutral or positive responses. The statistically significant difference using ANOVA statistical test was determined between block and traditional teachers, and also between hybrid and traditional teachers (see Table 2). Statistical significance was also determined using Pearson chi-square test between schedule types. Significance using chi-square analysis was found only in the second teachers' survey ($X^2 = 11.539$, $df = 2$, $p = 0.021$). Among the hybrid teachers who reported change, both positive and negative effects were mentioned in their written comments.

Positive changes were attributed to increased daily contact as well as to seeing fewer students per day. A hybrid teacher attributed the difference to extended class periods, reporting that, "In 87 minutes, I have greater opportunity to interact with students, and that helps in learning how to deal with individual problems." Another hybrid teacher stated, "I see less students in one day and stronger relationships have formed." A traditional teacher mentioned, "I have 5-7 more students per class period. I feel this affects my interactions with students." Personal relationship with students was an indirect benefit of block scheduling. The block or hybrid schedule only positively effected the relationship if it caused the number of students in a class or in a day to decrease.

Science Teacher Data

Course GPA data were collected from four hybrid science teachers. Table 3 shows the teacher, course, and GPA for general biology, chemistry, and physics. In all cases the teacher did modify his/her instructional methods due to the class type – block or traditional. It was determined that this comparison was better than a list of all traditional verse all block classes due to the direct comparisons made within classes.

In most cases, the instructional methods were changed for the block classes, while the assessment methods were maintained. The hybrid teachers were able to reflect and compare their

Table 3
Course GPA data for four hybrid science teachers.

Hybrid Teacher	Course	Schedule Type and Course Number	Course GPA
Redox	General Chemistry	Traditional – 6101	2.68
		Block – B6101	2.77
Ballistic	General Physics	Traditional – 6111	2.80
		Block – B6111	3.06
Kelvin	General Physics	Traditional – 6111	3.03
		Block – B6111	3.00
Kreb	General Biology	Traditional – 6003	2.26
		Block – B6003	2.41

teaching methods in block and traditional classes. "I feel that I have achieved more in my block classes than in my traditional classes because I have the opportunity to devise new methods of presentation" (chemistry interview). A hybrid physics teacher felt that the direct comparison brought about a rushed feeling which was due to the lack of content presentation. "I can't cover as much as I can in traditional. Because of this, I have to lecture more than I want." The block classes had a higher GPA compared to the traditional classes, because the students learned less content in a more intense or accelerated manner. Sometimes the accelerated manner was due to "streamlining" the curriculum content.

Science Student Data

Several data were recorded for science students. The first set of data gives background information on the type of student that enrolled in classes within a particular schedule. The data in Table 4 represent descriptions of students in the year prior to implementation of the tri-schedule and the first year of implementation. The data represent the entire student body and are not limited to science.

Table 4

Descriptive Statistics of GPA by gender and schedule for academic years 1996-97 and 1997-98.

	Traditional	Block	Hybrid	
Year 1996-97 GPA				Total
Male (N = 469)	2.84	2.54	2.68	2.75
Female (N = 415)	3.15	2.99	3.40	3.14
Total	2.98	2.79	2.99	
Year 1997-98 GPA				
Male (N = 469)	2.71	2.75	2.92	2.76
Female (N = 415)	2.96	3.02	3.24	3.02
Total	2.82	2.88	3.07	

Females performed significantly better than males in 1996-7 and 1997-98, regardless of schedule type. ($p=0.000$, $F=22.908$, $df=2$, $\alpha=0.05$ for 197-98) Students who elected or were placed in the block schedule had a significantly lower GPA in the year prior to implementation than students in the traditional and hybrid schedules. ($p=0.005$, $F=5.299$, $df=2$, $\alpha=0.05$) During the year of implementation, students who were in the block and hybrid schedules out-performed their traditional counterparts. Hybrid students performed significantly better than the traditional students. ($p=0.003$, $F=5.299$, $df=2$, $\alpha=0.05$) Males did perform better in the hybrid and block schedules than in the previous year. The male students performed the worst in the block schedule. Males entering the 1997-98 school year improved their GPA in both the block and hybrid schedules.

The second set of grade data is the breakdown of grades by science course. The perceptions of the students and parents that students' grades in block classes had improved were validated by the comparison of grades for traditional and block classes. In three out of the four courses, block classes had a higher percentage of A's. Biology and chemistry had a higher percentage of B's in block classes. All block classes in all of the courses had fewer failing grades. The higher achieving students did well in the block classes, while the weaker students had fewer failures. The average student did better in biology classes, while the physics and chemistry students performed equally well. Grade inflation was ruled out as a basis for an increase in block schedule results due to the number of hybrid teachers who did not differentiate their assessment between bock and traditional classes.

Table 5
Number and percentage of students and their grade breakdown for science courses.

Grade	A		B		C		D		F		Total
Applied Biology											
6000	5	18%	9	32%	4	14%	7	25%	3	11%	**28**
B6000	9	33%	4	15%	9	33%	3	11%	2	7%	**27**
Total	14		13		13		10		5		
Biology											
6002	38	23%	37	22%	41	25%	25	15%	25	15%	**166**
B6002	24	15%	45	29%	52	34%	27	17%	7	4%	**155**
Total	62		82		93		52		32		
Chemistry											
6100	32	25%	47	36%	24	18%	17	13%	10	8%	**130**
B6100	31	35%	30	34%	15	17%	10	11%	3	3%	**89**
Total	63		77		39		27		13		
Physics											
6110	43	27%	50	31%	34	21%	21	13%	12	8%	**160**
B6110	57	41%	43	31%	30	22%	6	4%	3	2%	**139**
Total	100		93		64		27		15		

Semester Exams

Semester exams were used instead of standardized tests because there were no pre-existing state, district, or department wide subject tests, and faculty did not want their entire test to be based upon a common set of questions with a specific format. Many block classes did not cover as much content as traditional classes, thus fewer questions were asked than originally desired. In essence, these semester exams acted as standardized tests since all subject teachers decided on the content to be included and the questions to be asked. Comparable class pairs were biology, chemistry, and physics. The last year's GPA for block and traditional students in applied biology was not close enough to make a direct comparison. Students in the block classes had a higher percentage of correct answers on semester exams than their traditional counterparts in all of the comparable class pairs. In all block classes the students outperformed their traditional counterparts based upon common content topics and concepts that were jointly covered by both class types. It should be noted that some block classes did not cover as much content as the traditional classes. It can be implied that students learn science better in an intense environment with fewer classes to take and learning less content than in a traditional course.

Table 6
Semester exams in science courses with number and percent of correct responses.

Subject	Last Year's GPA for Students in Course	No. of Students	No. of Questions	Average Number of Correct Responses	Percent of Correct Answers
Applied Biology Trad.	2.27	59	45	26.5	58.9
Applied Biology Block	1.89	59	45	27.8	61.7
Biology Trad.	2.91	184	30	20.6	68.7
Biology Block	2.93	179	30	21.6	72.0
Chemistry Trad.	3.28	135	24	17.0	70.8
Chemistry Block	3.26	102	24	17.6	73.3
Physics Trad.	3.25	170	40	30.1	75.3
Physics Block	3.28	146	40	31.9	79.8

Discussion

The results reported above offer qualified support for the argument that block scheduling can serve as an impetus for change. In the teacher survey results, where significant differences were found, and student achievement data the differences were aligned with what this argument would predict; that is, traditional teachers reported less change than block or hybrid teachers. However, when reported changes were examined within the broader context of teaching, the results of this study are more difficult to interpret. In particular, while teachers reported some of the benefits addressed in the research literature on block scheduling, they also reported challenges, tradeoffs, and obstacles to improving their classroom practices. Not only were there positive changes, but there were also negative changes as a result of block implementation.

Content Coverage

In addressing the issue of content coverage, parents, students, and teachers repeatedly commented on the pace of their instruction, demands on teaching in general, and demands on class time in particular. Thus, while change in general was associated with the teachers' overall workload, increased pace of instruction was explained specifically by the need to cover a set amount of course content. Content decision making, especially content exclusion, has not been widely addressed in the literature on block scheduling. Yet, content was the paramount issue for those teachers in our study who reported the hazards rather than the benefits of block classes. In particular, all the physics teachers felt a need to cover more content than they were able to in the shortened block schedule. The teachers who identified criteria for eliminating course content may shed some additional light on this issue. On the one hand, criteria related to school and state testing and perceptions of what students will need for other courses suggest that content beliefs are connected with the basic structures of schooling. Teachers, in short, did not work in a vacuum. On the other hand, teachers also suggested that their reluctance to eliminate content was rooted in their conceptions of teaching and what it meant to be a teacher. On this point, content seemed connected to both the structural context of schooling and the professional beliefs of teachers.

It's the teacher, not the schedule

The teachers in this study reported at least two changes that are often considered to be among the potential benefits of block scheduling. Teachers noted the first benefit in the context of increased variety of instruction. Specifically, teachers offered examples that represented a move toward more student-centered instruction. These reported changes included a more frequent use of projects, cooperative group learning, and individualized forms of instruction. The second benefit focused on improved student-teacher relationships. Some teachers also connected this benefit with an overall improvement in classroom climate. Positive changes in both interpersonal and group dynamics were largely attributed to working with fewer students, longer class periods in which to get to know students, and more opportunities for individual attention.

Of course not all teachers reported these benefits. On the contrary, some teachers indicated that block scheduling had opposite effects on their day-to-day work. Teacher- and subject-centered methods of instruction were noted in some classes by the more frequent use of lectures and handouts. These results produce a seeming contradiction between the benefits and hazards of block scheduling. A partial explanation for such conflicting reports was found in the multiple, and sometimes competing effects of block scheduling on practice. One effect in particular, the increased pace of instruction, stood out because teachers mentioned this effect in all four areas of the teacher surveys that showed significant differences; teaching methods, anxiety level, assessment, and relationship between teacher and student (see Table 2).

The change in schedule did effect some of the pedagogical methods employed by the teachers, but it was the idea and opportunity for change that allowed certain teachers to explore new instructional methods on their own. The schedule change did initiate discussions about content coverage, pace of instruction, and instructional methods, but change did not occur unless the individual teacher initiated it themselves to make the transition and accommodate the new parameters. The transition included developing alternative assessment methods, re-formulating the textbook based content, and altering instructional methods; especially with small class sizes and in some cases increasing lecturing.

There was a ripple effect from the block and hybrid teachers to the traditional teachers. Many of the traditional teachers mentioned that they had started to apply many pedagogical concepts that were discussed with or used by the block class teachers. The need to limit the content and develop common test questions caused the science department and science discipline teachers to communicate more often and efficiently. The traditional teachers often had "lab envy" because the block teachers could complete an entire lab in a day. This effectively produced discussions about appropriate methods of teaching labs, and how labs could be re-written to enhance learning of specific concepts.

Reflection-on-Action

The hybrid teachers had a unique opportunity to compare what they taught in one course to the same course only in a different format and pace. The hybrid science teachers did mention that they were able to develop and integrate more advanced ideas into their traditional classes at an earlier time in the semester. As long as teachers communicated with their colleagues and did not isolate themselves in their classrooms, teachers implemented new teaching methods. The teachers increased their use of explicit and connecting analogies, examples, and problems to teach new concepts. For example, a chemistry hybrid teacher defined compounds as strong or weak acids rather than just sulfuric or acetic acid when instruction focused on naming compounds. In essence, he knew from teaching acids and bases to block students that they did not have a good level of prior knowledge on acids and bases. Specifically, naming the compounds early in the year as strong and weak gave the students this prior knowledge.

With respect to methods, the more frequent use of lectures was explained as "a quicker way to cover materials." Teachers reported that reflection was less manageable with "little time to pause." Hybrid teachers reflected on their teaching methods and content more efficiently and quickly than if they were only teaching in a year-long traditional schedule. What was learned in the accelerated block class was applied to the traditional class and the second block class more readily. This method effectively eliminated the year long waiting period that many teachers have when implementing a new idea discovered through reflection on their actions. Schon (1983) stated that teachers learn better and implement new teaching strategies when they reflect-on-action. The hybrid schedule decreased the amount of time between reflection-on-action and implementation.

Implications for Teacher Education

The final section focuses on the implications of this research for pre-service teacher education. Although models of teacher education differ in substantial ways, they typically share two goals. The first goal is to prepare future teachers to perform the tasks that schools expect them to perform. The second goal is to prepare future teachers to improve schools by actively participating in educational reforms. What teacher education programs can do to help future block teachers successfully meet these goals is the question to be answered.

The first goal of teacher education is guided by the practical demands of teaching. Given the changes in classroom practice reported by the teachers in this study, block teachers face greater demands to use a variety of instructional methods within and across class periods. This finding suggests new opportunities for teacher educators to address teaching methods (especially methods that involve hands-on learning and simulations) that may have once been considered impractical due to the time restrictions imposed by traditional, 50-minute class periods. Expanding the repertoire of teaching and assessment methods that teachers bring to their work is an important task because different methods require different skills as well as a conceptual understanding of how these skills fit together in practice. Moreover, the very notion of a repertoire implies the critical knowledge of not simply how to use methods, but also when to use them and to what ends they are best suited. Situational and content specific methods of teaching imply a development of these characteristics in the preservice program. The how and when aspects become the focal points for pedagogical content knowledge as a theme for preservice education.

One potential learning situation which might enhance greater understanding of methodology faster is to place a student teacher in a hybrid schedule. This schedule would encourage the student teacher to directly compare content and pedagogy used in longer class periods and shorter year-long classes to traditional classes. The longer classes would provide the opportunity to experiment with different teaching styles while examining the content for applicability and compatibility.

Increasing the teachers' repertoire of instructional methods is one of the primary findings of this study. Interpretation of the data of the study also suggests that this ability alone will not ensure that block scheduling works to the advantage of students. As in the case examined here, the most common forms of block scheduling reduce the total contact time between teachers and students for any given course. The evidence suggests that increasing the pace of instruction in response to this aspect of block scheduling will undermine its benefits. For this reason, content decisions take on renewed importance. It was not surprising to learn that these decisions were often left in the hands of individual teachers. Yet, a related finding was unexpected. Specifically, teachers reported using criteria for content exclusion that rest largely outside their own judgments of what knowledge is most relevant and most worth learning. In essence, district and state standards guided their decision making. The implication for teacher education is that preservice teachers should be knowledgeable about state and national standards, and their implications for classroom practice.

On the issue of content, the questions for teachers and teacher education are twofold. First, how can future teachers be prepared to make the difficult decisions that shape their own curriculum? Should teachers rely entirely on state and national proficiency guidelines, college entrance exams, and the like? If not, what alternative criteria should inform these decisions? What guidance do curriculum theory, educational philosophy, and debates within specific subject areas offer in this context? Second, when are traditional, subject-specific conceptions of secondary teaching inadequate to inform practice? In other words, when is content an obstacle to good teaching? To avoid this danger, can future teachers be prepared to productively challenge views of content coverage that others often take for granted? Ultimately, how well do teacher education programs model school reform that effects classroom science teaching and learning?

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CONVERTING PRESERVICE SCIENCE TEACHERS TO CONSTRUCTIVISM

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Building A Model

Many teachers are aware of constructivism but have not experienced many science activities that are overtly designed to teach science concepts using constructivist methodologies. In this workshop activity participants conducted a novel, motivating and hands-on activity that develops an understanding of population growth rate under different assumptions while modeling an effective and constructivist teacher role. This activity, titled "My Family in 100 Years," is an inquiry investigation in a recently developed, standards-based high school biology curriculum, *Biology: A Community Context* (Leonard and Penick, South-Western Educational Publishing, 1998). This activity is shown in Figure 1. Cooperative groups will each role-play the growth of a family for one hundred years beginning with two parents. Each group (family) will have different growth variables, which apply to that family: number of children allowed per couple, the age at which the couple begins to have children, and the time increments between children.

Data Collection

Data will be collected for each generation for a total of one hundred years and placed on both family and class graphs so that the curves of each family can be compared. Participants typically have to make many decisions in this activity and then consider the consequences of their decisions.

Discussion

Much discussion usually ensues. This discussion models a constructivist method to learn effectively both biology concepts and science processes. We discuss the effects of different variables as well as the instructional approach taken during the activity. Participants soon decide that female's age of initial childbearing is the most important variable in population growth patterns although other variables, such as number of children per mother, are also tightly linked to the final outcomes. To arrive at these conclusions, though, requires a lot of discussion and consideration of many aspects of the situation.

Implementation

After making some decisions about the science concepts learned, we next turn to implementation strategies for this activity. Participants receive a complete kit of student and teacher instructions for implementation in their classrooms and, since they have actually participated in the activity and discussion, they quickly see how they could use it in their own teaching. Since this activity teaches both science and instructional strategies, it makes a fine addition to a methods or inservice course. As participants discuss what makes this a constructivist activity, they also begin to see why this activity may lead science teachers to see this as a productive methodology (Shymansky, 1992).

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Figure 1
Constructivist Activity for Preservice Science Teachers
From *Biology: A Community Context* (1998)

Guided Inquiry 3.3 My Family in 100 Years

Question

How quickly will families grow if there are different number of children born each generation and different times at which the females begin having children?

Materials

Large graph paper or poster paper; marker pens; *World Population Data Sheet*

Procedure

Compute the number of children each generation for your assigned family for the generation interval nearest to 100 years. Assume, for this model, that all children born are females. Graph your data for a presentation to the class. Elect a member of your group to present the data.

Assumptions for Various Families

Asano	The Asano family lives in the suburbs and averages two children per generation. The women have their first child at age 25.
Brown	The Brown family lives in a metropolis and averages one child per generation. The women have their first and only child at age 35.
Norako	The Norako family lives in a large city and averages three children per generation. The women have their first child at age 15.
Ruppert	The Ruppert family lives in a rural area and averages three children per generation. The women have their first child at age 20.
Ortiz	The Ortiz family lives in a college town and averages two children per generation. The women have their first child at age 20.

Interpretations and Applications

1. How does the number of descendants in your assigned family compare to those of the other families after 100 years.

2. Which appears to have a greater impact on the final population size of a family: the number of children in each generation or the time between generations. Support your answer with data.

3. Use the *World Population Data Sheet* to find possible reasons why populations in various countries appear to be growing quickly. What appear to be other variables contributing to potential overpopulation?

GLOBE ENHANCES INTERDISCIPLINARY SCIENTIFIC RESEARCH

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Students in grades K-12 have an exciting network to join if their teacher is a GLOBE certified teacher. GLOBE (Global Learning and Observations to Benefit the Environment) is an international environmental education program that greatly accentuates student learning by equipping teachers with training that allows their students hands-on experiences with their environment.

GLOBE trainers attend training sessions to ensure that lessons called protocols are delivered to the students in the appropriate manner. The main office of GLOBE is housed in Washington, D.C. and it provides training for those who desire to become a GLOBE trainer. It also provides free classroom materials to trained teachers.

While universities are striving to adequately train preservice teachers, Mississippi State University is the first university in Mississippi to provide GLOBE training to preservice teachers as part of the secondary science methods' class. Additionally, preservice teachers are given the free materials during the training sessions and are GLOBE certified teachers when they graduate from Mississippi State University. The school system in which they will eventually work can then become a GLOBE school.

GLOBE training allows additional technology training for the preservice science teachers because of the computer component of the data input. Students join a network of scientists, students, and teachers who are able to communicate through the Internet. Because data is recorded through the Internet, a new world of communication opportunities opens to the students. Because the protocols or activities are being conducted all over the world in the same manner, students find communicating with other countries much easier.

The GLOBE activities give the students the opportunity to see themselves as research scientists collecting data and recording their findings. This recording of data acquaints the students with computer usage. Among the activities for which data are recorded are air temperature, precipitation, cloud cover, water temperature, dissolved oxygen, conductivity, pH, and alkalinity. Images taken by the Landsat satellite allow the comparison of biological aspects and land cover characteristics of different areas. All students have the opportunity to participate in the K-12 activities because of the variety offered with the free materials furnished by GLOBE.

Allowing the students the chance to participate in actual research provides teachers with meaningful ways to incorporate science into all discipline areas. Through the Internet, communication with other countries becomes easy as students may discuss the weather with students in other parts of the world. Locating other countries on a map is more meaningful to the students if they are comparing data collected according to the same protocol. Language barriers melt away when the "student scientists" look at comparing their actual data. Writing can be integrated with foreign language and social studies as students have the possibility of studying about other cultures and talking with those respective students through the use of the Internet.

These types of activities fulfill requirements of the Mississippi Department of Education by creating an environment for student involvement and by incorporating technology into the various disciplines. Through the GLOBE hands-on problem-solving activities, student achievement is enhanced by the essential incorporation of computer technology into the classroom.

Assessment of student achievement is broadened to include performance-based evaluation which is highlighted in many content-based standards. The National Education Goals Report (1994) reported that about 50% of the professional development participation of teachers dealt with technology and assessment. GLOBE offers the opportunity for teachers and students to actively participate in research that teams technology and assessment in an enjoyable atmosphere of learning.

Problem-based learning integrated throughout the various disciplines allows students to improve their problem-solving skills along with their research and environmental awareness through the GLOBE Program. Training preservice teachers in the use of the GLOBE protocols prepares them in advance to enter the classroom with exciting research related protocols.

Another important aspect of the GLOBE Program is that it allows students from all academic backgrounds to get involved with the research associated with GLOBE. Main-streamed special education students, gifted students, and regular classroom students are all comfortable with the activities designed for each particular grade level. Specific goals to meet the needs of all students are outlined in the *GLOBE Teachers' Manual* (1997).

GLOBE (Global Learning and Observations to Benefit the Environment) offers a great collection of activities in association with a worldwide network of teachers, students, and scientists who are literally "mapping the globe." As researchers, participants in GLOBE training are actively involved in exploring local day to day changes in conditions of the earth. Adding to the worldwide data base helps the participants (teachers, students, and parents) to understand how the earth and its integrated systems work.

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TEACHING STRATEGIES DESIGNED TO ASSIST COMMUNITY COLLEGE SCIENCE STUDENTS' CRITICAL THINKING

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A need to increase career opportunities has resulted in an increase in the demand for higher education and has brought a flood of students to community colleges. Preference for community colleges has been prompted by the economy, flexibility, and open access policies of these institutions. Although the practice of open enrollment is conducive to increasing the numbers of "at-risk" students in community colleges, the expectation of many of the students is to achieve success in a career following minimal preparation, or to transfer to a senior institution to pursue a higher degree. The challenge for instructors is to help students learn both content knowledge and the skills needed to utilize the knowledge in pursuit of their goals in the abbreviated period of time the students spend enrolled in the two year institution.

Problem

The expectations set forth for professional programs impact preprofessional educational programs. For example, many of the students enrolled in Human Anatomy and Physiology courses at community colleges are pursuing a career in an Allied Health field, with the exception of a few individuals who are taking the course as a prerequisite for work in Sociology or Social Work. Once they have completed their preliminary course work at the community college, application will be made to professional schools for degree completion. As they enter into institutions of higher education, it is expected that students will arrive not only with basic content knowledge, but also with critical thinking skills that are appropriate for their career choices.

While methods for teaching and assessment have long been directed toward mastery of content knowledge, determination of effective ways to increase students' critical thinking skills has not been "ritualized" into a simple task. Ideally, one might suggest that it would be beneficial to introduce general pre-requisite courses that are non-subject specific and are focused on critical thinking. Since many community college students are economically driven to complete academic requirements, however, they cannot necessarily afford to spend additional time taking preparatory courses that are not absolute requirements for their major. Whether thinking skills can be taught in the course of one semester so that students incorporate them into their own learning strategies for application in their study and career is seen as an important question (Weinstein, 1994). We are cautioned, however, that the relationship between critical thinking and success in college is complex and multi-faceted. More research is required in order to investigate other factors such as maturation, drop out rates of less capable students, and motivation that may have a bearing on student success (Spaulding & Kleiner, 1992).

Teaching learning skills or strategies cannot substitute for teaching domain-specific content, since one factor frequently relies on the other (Weinstein & Mayer, 1986). The strategies are taught in order to be used during learning. They consist of behaviors as well as thoughts that are expected to influence the manner in which all information is encoded or processed by a learner. However, if the academic community embeds approaches to thinking within the instruction of content, we may be able to teach the approaches implicitly to students (Marzano, 1992). Resnick (1987) has found that this can be done by asking students to perform tasks that model specific types of thinking processes. Studies by Brown, Bransford, Ferrara, and Campione (as cited in Wittrock, 1986) suggested that when students become aware of the cognitive processes they are using, they are able to transfer them more readily to other areas of their learning.

Exploring ways to improve students' ability to think critically is in step with the current reform movement in education. Directing the attention of students to deliberate questioning activities may result in forcing them to confront misconceptions with which they have grown comfortable so that in resolving their discrepancies, more meaningful learning may result. Questioning the "fit" between the world outside and inside their own minds could contribute to resolving a problem Yager discussed in science education, which is the fact that students do not see the relationship between science and their daily lives or potential careers (Yager & Lutz, 1994). In addition to individual processing, Driver, Asoko, Leach, Mortimer, and Scott (1994) stress the value of discourse in learning about science concepts. As a learner meets new experiences and tries to make them meaningful, construction or reconstruction of ideas becomes important. And, because learning science is sometimes viewed as equivalent to embracing a new culture (Driver, et al., 1994; Aikenhead, 1996), encouraging students to critically view the concepts through social interaction may serve to make the transition into the culture easier, more personally rewarding, and durable.

While critical thinking can make one a more capable consumer, worker, manager, or citizen, Halpern (1989) also comments on the need to be able to deal effectively with the volume of information that electronic technology can place so quickly within one's reach. Additionally, Davis (1993) discusses the ability of a critical thinker to enjoy a more satisfying and interesting life and contribute to the maintenance of a democratic society. This aspect of liberation is recognized by King (1994) who states that the ability to think critically enables individuals to be empowered in order to stay in control of their own lives. Achieving control is most critical in students who may be academically or socially disadvantaged and who are considered to be at risk as they enter postsecondary educational institutions (Wehlage & Ruter, 1986).

A review of 27 studies that were completed from 1950 through 1985 and investigated the effect of instruction directed toward critical thinking showed that specific instruction failed to enhance critical thinking (McMillan, 1987). However, it was the opinion of the reviewer that this may have been due to a lack of clarity in defining what was being measured, the use of inappropriate assessment instruments, and a lack of precision in describing the measures that were to be applied. It was suggested that there was a need to develop assessment materials that would follow the changing lead of cognitive research. The direction indicated was toward descriptions of critical thinking with emphasis on everyday problems, the use of metacognitive skills, and the development of thinking skills in the domain of specific content (McMillan, 1987).

Many of these research directions have been pursued in the classroom. For example, Novak and Dettloff (1989) found that they were able to help students learn "task analysis." This was accomplished by modeling study guides for Biology students and successfully encouraging the students to independently develop their own guides. Other studies with nursing students preparing for clinical work indicated that skills applied to nursing-related content were very effective in developing critical thinking processes (Girot, 1994). And, in a study by Hanley (1995), students in a critical thinking course who were purposely directed toward a metacognitive analysis of their individual approach to solving a problem showed a significant gain in thinking skills and personal satisfaction. There is increasing evidence, therefore, that research on methods to improve critical thinking is being directed more effectively toward cognitive processes occurring within the learner and between the learner and the learning environment.

With this in mind, it is important to look at students attending community colleges who may require more intense instructional support. Increased enrollments have prompted several studies that focus on identifying students in community colleges who are potentially at-risk with regard to their being able to successfully negotiate the demands of a college level curriculum. Some characteristics that were identified for students potentially at risk were: being out of school five or more years; fulfilling five or more social roles that are conflicting; returning to school due to unemployment; and not having English as the primary spoken language (Tyler, 1993). Other studies found that additional factors affecting students' success were increased age, the need to work full-time and attend college on a part-time basis, and participation in college preparatory or remedial classes during the first semester of enrollment (Windham, 1995).

In research done on first generation college students, it was found that their parents' educational level and the degree of familial support significantly influenced their expectations and college choices (Stage & Hosler, 1989). Many students have also experienced confusion or isolation resulting from their academic as well as cultural and social backgrounds. Due to deficiencies in integration at academic and social levels (Billson & Terry, 1982), the students appear to have lacked persistence and failed to attain degrees. In further research, Terenzini identified other familial characteristics of at-risk students (Terenzini, Springer, Yaeger, Pascarella, & Nora, 1996). A study was conducted which included 2685 students, of whom 825 were first-generation, and 1,860 were more traditional students attending 23 different institutions. Twenty-three of these schools were four-year universities and five were community colleges. The focus of the study was to ascertain differences between the two groups of students with regard to their precollege characteristics, first year experiences, and any effects these factors would have on cognitive development. The first-generation students were typically found to have a lower income, minority designation, weaker cognitive skills, lower aspirations, less involvement with students and teachers, a greater number of dependent children, and a lack of parental encouragement with regard to their decision to attend college.

With regard to effective instruction of at-risk students, some suggestions have arisen from successful research with students of various age groups. Earlier efforts discussed by Levine (1988) that have produced some degree of success are individual enrichment programs, metacognitive approaches, techniques such as concept mapping and advanced organizers, and computer aided instruction. Other techniques that have been utilized are supplementary reading, brainstorming, and writing assignments (Franse, 1991). Tom Drummond (1998) has compiled some of the best overall practices that may be used in college teaching. Included are methods dealing with delivery of lecture material, cooperative group learning, and helping students develop self-responsibility.

Research by Brophy (1986) indicates that better explanations on the part of teachers would be helpful, while engagement in cooperative learning has been suggested as an effective strategy to enhance learning as this allows interaction with students and teachers and increases opportunities for academic integration (Tyler, 1993). Cooperative learning in a college level computer lab course, for example, increased both the performance and retention of students engaged in cooperative learning versus those students receiving traditional instruction (Keeler & Anson, 1995).

Finding appropriate ways to teach students critical skills is challenging. Curriculum must be kept simple, friendly and understandable. Students come with complex house plans and want to be able to run power tools so that they can quickly build their "dream home" and be finished with the educational experience. However, educators are also interested in helping them learn the art of fine craftsmanship. We study the quality of the "wood" to be used, try to cut it into the best shape for the purpose under consideration, and use "sandpaper" techniques to remove the rough edges so that it will be sound fitting as well as comfortable. Skills acquired by students should be long lasting and durable for a pleasant and productive future.

The purpose of the study was to determine whether learning thinking strategies within the context of a community college course would result in students' increased academic performance and incidence of critical thinking skills. If successful, benefits gained by students would not be limited to science instruction, but may provide a relatively trouble-free way to increase their ability to think critically within the context of any subject area, or well beyond that context.

Method

Students in a Human Anatomy and Physiology class were taught to apply a technique that required them to generate questions (Arburn, 1998). The technique used a set of generic question stems employed by students as a format to fill in with specific content covered in the lecture class. The question stems had been identified as to the level of cognition each demonstrated. Students who had been taught to use the question stems have demonstrated significant improvement in their learning (King, 1990, 1991, 1994). While the technique had been used successfully at senior institutions, it had not been employed at the community college level of instruction.

The technique was introduced during a regular class meeting where participants were told of the success effected by use of the technique to learn more complex methods of thinking. Following distribution of a reference sheet containing the question stems, sample questions were generated with the help of the instructor. The question stems were intended to work as scaffolds in that they supported students as they learned to ask questions and also reduced the complexity of the technique as it was being learned. However, the question stems did not specify each step a student needed to complete for the purpose of actually generating a question. The choice of the stem and its completion were left to the student (Schrag, 1992).

The questioning technique was used for a period of eight weeks. The time period of treatment was based on early studies using guided questions in which six successive lectures within a three month semester produced significant results with regard to improvement in students' achievement (King, 1989). Following lecture presentation of new material, students were required to use the question stems to write a question based on the material that had been presented. The questions were then exchanged with a peer who was given a few more minutes to provide a written answer to the question. Emphasis was not directed toward grammatical accuracy or factual correctness of the response. The use of student-generated questioning techniques has resulted in improved lecture comprehension on the part of university students (King, 1989). In fact, in the studies by King, these techniques proved more effective than independent review and peer questioning in small cooperative groups. These and additional studies were included in a review of 26 studies in which students were taught to generate questions. A comparative analysis of all methods employed in the studies showed that signal words and generic questions or question stems resulted in the greatest improvement in comprehension (Rosenshine, Meister, & Chapman 1996).

Students were pretested at the beginning of the semester using the Learning and Study

Strategies Inventory (LASSI) and California Critical Thinking Skills Test (CCTST) to profile their personal learning strategies and ability to engage in critical thinking. At the end of the semester, posttesting was carried out using the same instruments. Students in a control group were similarly tested but did not engage in the use of question stems. The final course content examination scores of all students were also analyzed, using their entry Grade Point Average as a covariate.

The LASSI includes individual scales that measure attitude, motivation, time management, anxiety, concentration, information processing, selecting main ideas, study aids, self testing, and test strategies. Of these items, information processing has been suggested to be an indicator of critical thinking (Weinstein, 1987). The CCTST also includes individual scores that can be used to show changes in inductive reasoning, deductive reasoning, analysis, inference, and evaluation (Facione, 1992).

Results

In the current study, application of student-generated question stems following lecture did not result in improving the achievement scores of students as significant results were not found when comparing the control and treatment groups. It should be noted that the same exam was administered to all group. And, the application of Cronbach's Alpha showed that the internal consistency of the exam had a value of 0.89.

Characteristics of length of intervention, mode of application, and evaluative methods that were used fit the general profile of previous studies using the question stems. What differed, however, were the population of students and the nature of the content material. It is possible that an interface between students who may not be academically prepared and content material that is technically complex and challenging may be a chasm that requires a longer period of intervention in order to be effectively traversed. Further manipulation of the length or type of intervention may provide viable options to assist in clarifying the issue.

In light of the results obtained, however, it would be constructive to illustrate a benefit elucidated as a result of the study. What can be concluded is that the use of the questioning technique did not serve to diminish the performance of students on the final examination. This should provide encouragement to many teachers in content intensive disciplines who are hesitant to relinquish the podium to methods of instruction that are less didactic in nature. Frequently, there is a concern that material will not be thoroughly or appropriately addressed during the course of the class if it is not addressed by way of a lecture. To cling to this attitude may not only prove fallacious but may deprive students of an opportunity to gain higher cognitive skills that are needed in order to appropriately assimilate and apply the content that has been addressed.

In seeking an explanation for these results, it is also relevant to consider the nature of the material being learned and the disposition of the learner. At-risk students with an academic and social background that may be limited in a new arena are confronting a subject area replete with new vocabulary and extensive, interrelated concepts. Their mastery of appropriate reading and writing skills is sometimes deficient, and some are further challenged by the need to both think and express themselves in a second language. Under these circumstances, relating new material to that which is already known may not present itself as a feasible, urgent, or prime strategy choice. The immediate demand for simply organizing and consuming a massive amount of new material may have a tendency to overshadow or supersede the need for more appropriate assimilation of the material. If this is the case, the instructor must more actively assume the responsibility of assisting students in this task by providing opportunities to help them relate the subject matter to their own, though possibly limited, realm of experience. A study by Collins and Smith (as cited in Wong, 1985) has shown that a lack of prior knowledge may make it difficult to understand information that has been presented. However, unsuccessful activation of prior knowledge may be an even more important problem to examine and seek to change (Bransford, Stein, Vye, Franks, Auble, Mezynski, & Perfetto, 1982).

Analysis of performance on LASSI showed no significant change in the use of an information processing strategy by students in the study. However, further analysis of other scales measured by LASSI showed a significant change in the students' ability to select main ideas. Learning to select main ideas may be result from the necessity for seeking ways to effectively master new material. As students progress through a course that is very content intensive, this would be an important strategy to learn. And, having to generate questions based on the material appears to have contributed to the development of this strategy in the experimental group of students. Improving one's ability to focus on material that is more important maximizes the efficiency of studying efforts (Weinstein, 1987). Development of the strategy could, therefore, have been enhanced by the use of the questioning technique due to the fact that students had to identify important points within the lecture material on which to base their questions.

While overall CCTST scores were not significantly changed by the intervention, examination of the respective indices showed that the use of question stems did significantly increase the students' use of deductive reasoning and inference. Typically, deduction connotes the ability to reach a conclusion by reasoning from a general premise to a more specific conclusion. While syllogisms or mathematical proofs provide examples of deduction (Facione, 1990), its usefulness is not limited to these applications. In fact, one could look at another clinical example to illustrate deduction. If your patient had diabetes, what complications might be anticipated? It is not unreasonable to expect circulatory complications that could become manifest as problems with vision, the kidneys, or ulceration on the feet and legs that could even become gangrenous if left untreated.

Application

In summary, the absence of improvement in achievement failed to confirm results of earlier studies where intervention based on generating questions was successful (King, 1989; Redfield & Rousseau, 1981; Rosenshine, Meister, & Chapman, 1996; Wong, 1985). And, significant improvement was not effected in information processing or an overall measure of critical thinking. Positive results were obtained, however, in the ability of students to select main ideas and engage in inference and deductive reasoning. The long-term effects of this improvement remain to be investigated.

While community college teachers have been recognized for their interest in students and the improvement of pedagogy, their ability to effectively reach and teach non-traditional and at-risk students promises to remain a challenge. The present study and the success that it demonstrates is offered as a valuable addition to a repertoire of easily applied, reliable, and productive techniques for the nature of cognitive activities in the classroom. Instructors can expect benefits if they will make a commitment to relinquish time from the podium in order to introduce students to the purpose and method of the technique to be used, allow time for its practice, and celebrate in the expectation that students may derive benefit from its use.

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INTEGRATING TECHNOLOGY INTO THE SCIENCE CLASSROOM

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Introduction

One of the biggest challenges facing teachers today is to find ways to use technology to enhance academic achievement. In the Washington State Essential Academic Learning Requirements Technical Manual for Science, Social Studies, Arts, and Health and Fitness, the Commission on Student Learning (1996) writes:

> Technology and other forces are rapidly transforming the ways we live and work. The forces of change are also re-shaping what it means to have the knowledge and skills necessary to lead a successful life now and in the 21st Century. (p. 2)

One technological force re-shaping life today is the Internet. This powerful technology is also a tool that teachers can bring into the classroom to enhance teaching and learning.

As a requirement of my Master In Teaching (MIT) Program at Washington State University Tri-Cities, I conducted an action research project that involved the integration of technology, primarily the Internet, into a middle school science classroom. Through this study I hoped to build student interest in science and technology and to understand how using technology impacts students. I also wanted to evaluate my success at integrating technologies such as the Internet into the science classroom.

Problem Statement

The Washington State Commission on Student Learning (1996) and the National Research Council (1996) have recognized the important role of technology in the area of science with specific requirements. For example, the Essential Academic Learning Requirements in Science state that the student will "understand the connections between science and technology" (Washington State Commission on Student Learning, 1996, p. 32). Similarly, the National Science Education Standards call for students in grades five to eight to develop "understandings about science and technology" (National Research Council, 1996, p. 161). In addition, the

Washington State Technology Plan (Office of Superintendent of Public Instruction, 1997) calls for funds to integrate technology into the curriculum and to train prospective teachers how to incorporate new technology-based instructional strategies into the curriculum.

To be prepared for the global world of the 21st century all students must become comfortable with using technology. In order to facilitate this, teachers must learn how to use the technologies available to them, including the Internet. They must learn how to utilize these technologies to the benefit of their students. In other words, all teachers must decide what to do with the Internet in their classrooms.

Theoretical Background

Technology has affected society for centuries. For example, in 1450 only about 30,000 books existed in all of continental Europe (Gates, 1996). That year Johan Gutenberg introduced the first printing press to Europe. By 1500, there were more than 9 million books, on many topics, not to mention other types of printed matter such as handbills, available in continental Europe. For the first time, the common person had access to written information. Now there was a reason to learn to read and write. People became interested in learning what was going on in other parts of the continent and in recording what was happening in their part of the world. As Bill Gates (1996) writes in *The Road Ahead*, "Books gave literacy critical mass, so you can almost say that the printing press taught us to read. The information highway will transform our culture as dramatically as Gutenberg's press did the Middle Ages" (p. 27).

Already it is difficult to interact in the world today without seeing some reference to the Internet. Web addresses are everywhere, in magazines, on books, and even on commercials. And, as Ray Schneider (1997) wrote, "Incredible as the Internet already is, it is only a shadow of things to come" (p. 14). In the October 27, 1997 *U.S. News & World Report,* 11 of the careers listed in "20 Hot Job Tracks" required science and/or technology backgrounds. Collins and Collins (1996) pointed out that in order for "our students to compete in the current global community, it is imperative that . . . educators embrace and use [the Internet] in our teaching" (p.101).

Besides the reform requirements at state and national levels there is increasing pressure from the business community and federal agencies to teach our students to learn how to use technology. According to the Tri-City Herald ("Going High-Tech," 1997) the Information Technology industry has now emerged as the country's largest manufacturer and accounts for $866 billion in revenue per year. In addition, last year the high-tech sector accounted for 6.2% of our nation's output of goods and services and employed almost 4.3 million people. This sector grew by 7.2% in the 1990's. Furthermore, high-technology workers earn wages 73% above the general private sector rate. "The role of education in providing the skilled workers that 'high-tech' requires is central to any community strategy involving the industry" (Going High-Tech, 1997, p. A6). Today most communities are doing everything possible to attract high revenue industries like Information Technology, including examining how they educate future workers.

In response to the Improving America's Schools Act of 1994 the U.S. Department of Education wrote a national long range technology plan, *Getting America's Students Ready for the 21st Century: Meeting the Technology Literacy Challenge. A Report to the Nation on Technology and Education* (1996). At the heart of the plan is the President's Technology Literacy Challenge, which urges that the nation's students be technologically literate by early in the 21st century. In a letter to Congress opening this plan, Richard Riley, Secretary of Education, (U.S. Department of Education, 1996) wrote:

> Computers are the 'new basic' of American education, and the Internet is the blackboard of the future. . . .I strongly believe that if we help all of our children to become technologically literate, we will give a generation of young people the skills they need to enter this new knowledge- and information-driven economy. (p. 3)

These sources provide evidence that there is a reason for students to learn how to use technology, but does it have any benefits or pitfalls for them? Can the use of the Internet help students develop other skills needed in the workplace, not just make them technologically literate? Results of a project on the Internet and literacy (Wright, 1997) suggest that Internet use has a positive affect on students in regard to literacy, but do these effects extend to the areas of science and technology?

Through coursework at Washington State University I know that the work of L. S. Vygotsky and others (Biehler & Snowman, 1993) demonstrated that a constructivist approach was more beneficial to students. My own experiences as a student suggest that it also makes learning more interesting and thus increases the desire to learn and improves student performance. In writing about the potential of using technology in a constructivist classroom Strommen (1995) points out that students raised in a technology-driven world with video games, remote controls, and the like are used to an environment where they control the flow and access of information. He believes that these students are naturally more interested and involved in a classroom with technology.

A previous study of equity issues showed a potential for technology use to introduce another gender-related bias to the classroom. Do boys and girls both experience a positive influence when technology is included in the curriculum? And finally, how do teachers feel about their experiences using technology in the classroom? To find answers to some of these questions I turned to past research on the impact of technology use in the classroom.

In two related research projects Goodwin (1996) and Rogan (1996) collected data from rural teachers with no prior Internet experience who integrated it into their curriculum. Their data sources included questionnaires, interviews, discussions and teacher journals. All teachers involved in the study had an interest in the teaching of math and science. The teachers in Goodwin's study were also trained in changing the way they teach science based on theories and strategies of reform in science education. Both Goodwin and Rogan found that teachers' were frustrated while learning to use the Internet, but that they also experienced an end to feelings of isolation. Both teachers' and students' enthusiasm increased and classroom practices changed to a more student-centered approach. Goodwin also found that teachers reported improvement in students' overall performance.

Jane Hollis, in a 1995 action research project, had her students do multimedia presentations for an Oceanography project. The students shared their final presentations with the class. Based on data collected by surveys and observations, Hollis reported an increase in student interest. For example, in the month before the project there were 14 tardies while during the project there were no tardies. Students also asked to stay and work on their presentations after school several times, a rare event before the study. Hollis also reported that she felt the excitement return to her teaching.

While Wilcox and Jensen (1997) expressed concern that girls' (and minority groups') interest and achievement has been shown to decrease with increased computer use in the classroom, Walker and Rodger's 1996 research study showed the opposite. Walker and Rodger implemented the PipeLINK program to attract and retain women and girls in computer science careers. Subjects either were assigned mentors or acted as mentors, participated in labs on using the Internet, and used e-mail, bulletin boards and chat rooms. Data collected by questionnaires found that girls' interest in computers increased with more exposure. Walker and Rodger concluded that one key factor in girls' increased interest may have been the communication aspect of the Internet.

The United States Department of Education in its 1996 publication *Teaching and Learning with Educational Technology: Myths and Facts* reported that:

> [S]tudents with more extensive access to technology are more likely to learn how to organize complex information, recognize patterns, draw inferences and communicate findings . . . it is these students who exhibit superior organization and problem-solving skills, compared to students in more traditional school programs. (p. 1)

Finally, the Department of Education also reported a dramatic example of how technology can impact students' achievement in their national long-range technology plan (1996). In the late 1980's students at Christopher Columbus Middle School in Union City, New Jersey had state tests scores that were very low, and a high absentee and dropout rate. In 1992 Bell Atlantic offered to work with the school district to demonstrate that technology could improve students' performance. Computers were installed all over the school and in students' homes. Two years after the initial installation of the computers, dropouts and absentees were near zero and students were scoring 30 points higher than the New Jersey inner city school average on standardized tests. On New Jersey's Early Warning Test students' scores were more than 10 points above the statewide average. In addition, Columbus now held the district's best attendance record for both students and faculty and the transfer rate had dropped significantly. Students were proud of their work and eager to learn. They even lined up to get in before the formal school day began.

Overall, my review of the research and literature on using technology suggested that:

1. Technology fosters interactive, self-directed learning (Goodwin, 1996; Swain, Bridges & Hresko, 1996; Wellburn, 1996) and higher order thinking skills (Goodwin, 1996; Rogan, 1996; Wellburn, 1996).
2. Technology increases student-centered learning (Goodwin, 1996; Rogan, 1996).
3. Technology improves overall student performance (Goodwin, 1996; U.S. Department of Education, 1996) and increases student interest (Hollis, 1995; Goodwin, 1996; Rogan, 1996; Strommen, 1995).
4. Technology may influence girls either by increasing their interest (Walker & Rodger, 1996), or inhibiting their interest (Wilcox & Jensen, 1997).
5. Technology decreases teachers' feelings of isolation (Rogan, 1996; Swain, Bridges & Hresko, 1996) and increases their interest in teaching (Hollis, 1995).

Research Questions

The research questions that guided my study were:

1. How does using the Internet influence student performance in science?
2. How does using the Internet influence student interest in and understanding of science and technology?
3. How does using the Internet influence girls' interest in science and technology?

As a corollary to these questions I wanted to determine how using the Internet influenced my teaching.

Context and Participants

I integrated technology in the classroom for the first time during my internship experience in an eighth grade physical science class at a Southeast Washington suburban middle school. Research occurred primarily during the seven weeks (out of 13) that I had full responsibility for classroom activities. Class periods were 47 minutes long four days per week and 37 minutes long on Wednesday. Although this project was actually implemented during all six class periods, data were collected primarily from the students in the third and fourth hour class periods, referred to as the focus study classes. The third hour class was chosen because they had the lowest scores prior to beginning the project so any potential effects might be observed more easily. Fourth hour was included to bring the number of male and female subjects to a more equal number as third hour had significantly more females than males. Fourth hour also provided somewhat of a balance through a more even distribution of scores. However, students in all six class hours were studied during observations and post data from students (surveys, essays and opinions) were taken from all six classes. Evidence from these other classes was included to provide additional support in the data analysis.

The students and I were the subjects of my study. There was a total of 137 students in the six classes (69 boys and 68 girls) and 43 students in the two focus study classes (20 boys and 23 girls). There were approximately six Hispanic students, six special needs students (including Learning Disabled, Attention Deficit Disorder, Behavior Disorder, etc.) and eight chronic absentees in the focus study classes (medical and other reasons), which was representative of all six classes. All classes included a variety of achievement levels. Students who dropped or added the class in the middle of the study were excluded from the focus study data. Those with excessive absences or other incomplete data were excluded from some of the data analysis. In these cases the data group of 25 students is referred to as the selected focus group (11 boys and 14 girls). My supervisor, my field specialist, fellow members of my cohort, and my family members also participated in collection, evaluation and/or interpretation of the data.

Implementation/Methods

Most of the students had at least seen the Internet in use. In fact, on most days my field specialist displayed a science article from the abc.com website on the television display attached to the computer. Many of the students had also had at least one technology course at school and some were also currently enrolled in another technology course. However, these courses concentrated on software uses rather than the Internet. Furthermore, many of the students and even more parents seemed apprehensive of student use of the Internet. I received several warnings from colleagues and other staff about allowing students to use the Internet. Finally, student access to computers during school hours was limited. There were two computers available in the classroom and a computer lab; however, the lab was frequently in use and the Internet access was not as friendly or timely as I had hoped. These factors caused me to take a more conservative approach to integrating the Internet and technology into the classroom.

When we began the chemistry unit I used the Internet for classroom discussions, demonstrations and displays. For example, when discussing the periodic table I used an interactive site that not only showed the standard periodic table, but also provided more information on families and individual elements by clicking on them. Other demonstrations included pictures of molecules, atomic structure and sublimation.

Through an informal survey I determined that about 85% of students had access to the Internet either at home or at a friend's house. I included a project that allowed Internet research use at home, for those with access, and at school during designated work periods (and with the television display to monitor students activities). The project involved creating a game which taught information about elements in assigned families to those playing. Students researched the families and their elements in order to create an effective game. Class time was provided for research using traditional methods and the Internet. As a corollary to this project I included extra credit projects based on the elements. These projects included a variety of choices for students, including a search on the Internet and the creation of a computer presentation or website on the elements (see Appendix A).

Data Collection

Because of time constraints I relied on data sources that required a minimum of class time. Therefore, as data sources for my research I used the following:

1. Information on student projects and grades earned pre- and post-implementation (performance).

2. Written student surveys collected pre- and post-implementation (see Appendix B).

3. Student essays and entry tasks on the definitions of and roles of science and technology in daily life written pre-implementation and answers to guided questions collected post-implementation (see Appendix C).

4. Written student opinions/reflections taken post-implementation concerning Internet use in the classroom and at home (see Appendix B).

5. My records of observations by my field specialist, my supervisor, the school principal, and me.

6. A researcher reflection journal written throughout my internship experience.

Surveys assessed student interest in science and technology before and after the study (Hollis, 1995). The survey questions shown in Appendix B are adapted from action research studies by Hollis (1995) and Phyllis Green (1995). The first survey shown in Appendix B was piloted in class periods five and six. Minor modifications were made before use of the second version in Appendix B (modifications are shown in italics), in class periods three and four pre-implementation, and the final version in Appendix B (questions 13 to 22 were added), in all classes post-implementation. Students in all classes were asked to write essays defining science and technology, and describing the role of each in society today pre-implementation. Unfortunately, student cooperation in writing these essays was limited despite being a graded activity. However, in addition to essays, students wrote a brief entry task on a similar subject prior to implementation. This entry task was also used to assess student interest and understanding as a supplement to the essays.

Post-implementation I used a series of questions (see Appendix C) to assess understanding of the role of science and technology in daily life in place of the essay and received a better response. In order to answer the questions on the influence on girls' interest and understanding, data was separated by gender and a comparison was made. My observations and journal entries were guided by questions such as (Hollis, 1995):

1. What problems are students encountering on the Internet?

2. Are students having problems with content?

3. How much time is spent on various activities?

My field specialist, supervisor, and school principal verbally discussed their observations with me which I then recorded in my observation journal.

Data Analysis

I used the data collected from surveys, essays, guided questions, observations, journals and students' performance to compare students' attitudes and performance before, during and after the study and to draw conclusions for each research question. For clarity, data sources for each question are shown in Table 1 and are discussed below. In the table the data sources include my conclusions to the research questions as these are relevant to my conclusions about how using the Internet influenced my teaching. The table also indicates the time period during which the data was collected.

Table 1
Correlation of Data Sources to Research Questions and Time Collected

	Week Collected			
Data Source	Question 1	Question 2	Question 3	Corollary
1. Student projects and grades	Focus only-Weeks 5, 13			
2. Student surveys		Pilot-week 2 Focus-week 4 All-week 13	Pilot-week 2 Focus-week 4 All-week 13	
3. Essays, entry task, and guided questions		All-Week 6		
4. Student opinions, reflections, Internet use	All-Week 13	All-Week 13	All-Week 13	
5. Observations recorded by researcher	Weeks 1 to 13	Weeks 1 to 13	Weeks 1 to 13	Weeks 1 to 13
6. Researcher reflection journal	Weeks 1 to 13	Weeks 1 to 13	Weeks 1 to 13	Weeks 1 to 13
7. Conclusions to first three research questions				Week 13+

The first research question on the influence on student performance was assessed by comparing student projects and grades from before and after the study. Further evidence for this question was provided through student reports of understanding and my own and others' observations of students' performance. Questions such as numbers 8 and 10 in Appendix B were included in surveys to help rule out the influence of other factors such as the nature of, or interest in, the content on student performance (Hollis, 1996).

The surveys, essays, and student opinions/reflections provided direct reports from the students of their interest in and understanding of science and technology, which addressed the second research question. I analyzed student surveys, essays and opinions/reflections from before and after the study in order to understand if and how student interest and understanding had changed. By examining my own and others' observations and my reflection journal I had another measure of student interest and understanding. The third question about the influence on girls' interest and understanding in science and technology was addressed by comparing the changes in girls' and boys' interest and understanding as seen in surveys, essays, opinions/reflections, and observations. Finally, I was able to examine how using the Internet influenced my teaching by analyzing my observations and journal reflections, the observations of others, and my conclusions to the three research questions.

As I reviewed the collected data I coded evidence relating to each question using letters. "P" was used to indicate evidence related to student performance, "S" indicated evidence about student interest and understanding, "G" represented evidence for or against girls' interest, and "T" represented any data on the influence on teaching. Students were coded alphanumerically to protect their identity. Data on student grades was entered into an Excel spreadsheet and averaged in a variety of ways. Numerical answers to the first seven survey questions were also analyzed in this manner. Student understanding was given a numerical rating from zero to four based on essays and entry tasks written pre-implementation and guided questions answered post-implementation. These scores were assessed in the same manner. Additional evidence from the surveys was also entered onto the spreadsheet. By looking for patterns, similarities and correlations in the data and comparing student interest and performance before and after the study I was able to reach some conclusions about the influences of using the Internet. I was also able to draw some conclusions about my success in using the Internet as a teaching tool.

As a validity check I asked others to review my findings including geology professors at Washington State University and a vice-president of a research lab. I also discussed my findings with members of my MIT cohort, my field specialist, and my supervisor to further reduce the chance of bias. Collecting data related to each question from three or more sources allowed for triangulation of the findings and helped reduce the likelihood of error in my findings when similar results were observed in two or more sources (Hollis, 1995).

The data collection and analysis techniques I used are similar to those used by the Center for Applied Special Technology (1996), Francis (1997), Goodwin (1995), Hollis (1995), Rogan (1995), and Walker & Rodger (1996), all of whom were investigating the effect of using technology on students and/or teachers.

Results

Influence on Student Performance in Science

I expected to see an increase in both student performance and student interest and understanding of science and technology as has been noted in previous studies (Hollis, 1995; Goodwin , 1996; Rogan, 1996; Strommen, 1995). Analysis of the data from student projects and grades, essays, entry tasks and guided questions, and student surveys provided evidence of such increases. This evidence was further supported by data from student opinions and recorded observations.

Although student grades and performance on projects were acceptable prior to implementation, there was a noticeable decline in student scores from the first to the second quarter of the school year. As shown in Table 2, from the first to the second quarter 76% of all students in the focus group and 83% of the selected focus students saw a decrease in their grade average.

Furthermore, the average student score for all focus students decreased from 76% to 70% and for the selected focus students from 83% to 78% as seen in Table 3.

Post-implementation data on Tables 2 and 3 indicated that student scores showed some improvement. Although the average student score for both groups did continue to decline, it was less than the decline observed from the first to the second quarter. From second to third quarter the focus group average declined 70% to 68%, a drop of only 2% compared to the 6% drop from the first to the second quarter. The selected focus group exhibited nearly identical results with a drop of 2% from second to third quarter compared to the drop of 5% seen between the first two quarters.

Additional evidence was noted in the percentage of students whose scores declined versus those who scores rose in the third quarter (see Table 2). From the second to third quarter only 52%

Table 2
Comparison of Change in Student Scores for Focus and Selected Focus Students

Time Period of Change	% of Students		
	Improved	Declined	Unchanged
All Focus Students			
First to Second Quarter	19%	76%	5%
Second to Third Quarter	34%	52%	14%
Selected Focus Students			
First to Second Quarter	13%	83%	4%
Second to Third Quarter	48%	43%	9%

Table 3
Comparison of Average of Student Scores by Quarter

Time Period	Data Population	
	All Focus Students	Selected Focus Students
First Quarter	76%	83%
Second Quarter	70%	78%
Third Quarter	68%	76%

of all focus students and 43% of the selected focus students exhibited a drop in their grade average compared to 76% and 83%, respectively, for the same groups from the first to second quarter. These results occurred in spite of many factors distracting the students during the time of the study. These factors include the normal erratic performance of students at the middle school level compounded by the onset of spring, the realization that they would be moving onto high school the following year, and a temporary change in teachers. Furthermore, student scores improved even though observations indicated that my grading standards tended to be slightly higher than that of my field specialist.

The results of the data from student grades pre and post-implementation are supported by observational evidence from all six classes. Students took more pride in their work during study implementation and paid closer attention to materials that were presented from the Internet. Both of these facts contributed to a noticeable improvement in grades. For two students, the interest generated by using the Internet resulted in completion of extra credit projects and quality work on their game projects. This improvement in performance raised their letter grades by one to two letters at the end of the third quarter.

One student, SC2B, rarely turned work in and showed little pride in the work he did turn in. This same student rarely scored below a B average on tests. After completing quality work with his partners on the game project, SC2B demonstrated even greater pride in his extra credit work that included building a website on the elements. He remarked to my field specialist that he had originally thought that the website would take him a short time, but it had actually taken hours. This student benefited through increased time on the subject we were studying that will eventually improve his test scores as well as his overall grade.

All sources of data indicated at least some improvement in student performance from pre-implementation use of the Internet in the classroom to during and post-implementation. In general, the use of the Internet did help students perform better in their science class. Based on observational evidence it is possible that the increase in performance was due to increased understanding and interest, the focus of my second research question.

Influence on Student Interest and Understanding

In assessing student understanding and interest only data from the 25 selected focus group students was used. Data from the 18 excluded students was incomplete due to surveys that were not returned or completed. The students in the selected focus group showed improvement in their understanding of science and technology from the pre-implementation essays and entry tasks to the post-implementation guided questions. An unchanged score on the scale of 0 to 4 indicated no improvement. Slight improvement was indicated by an increase of one, definite improvement by an increase of two and marked improvement by an increase of three.

Only 24% of the selected focus students showed no improvement in their understanding of science and technology. These students did not view the importance of science and technology to daily life any differently post-implementation than they did pre-implementation. However, half of this group was initially assessed at the 3 level, which indicates a good understanding pre-implementation, and half were assessed at the 1 level indicating a slight understanding pre-implementation. Of the remaining students 36% demonstrated slight improvement in understanding (10% of these had a good understanding pre-implementation), 32% had definite improvement and 8% exhibited marked improvement.

To assess student interest I analyzed the answers to statements one, two and five from the student surveys (see Appendix B). The first two statements concerned the students' enjoyment of science and learning science this year. The fifth statement directly addressed students' interest in science. As indicated in Table 4, responses from the selected focus students showed a mixture of increased and decreased interest in and enjoyment of science. There was a slight trend toward increased interest and enjoyment post-implementation. Of particular note was the increase in those who responded neutrally to the fifth statement concerning their interest in science. Neutral responses increased from 12% to 36% while all levels of agreement and disagreement with the statement decreased. This may indicate that students tended to answer in a more neutral manner on the day of the post-implementation survey. Further analysis of the student responses did indicate that the changes in student answers were usually only one level in either direction. This supported the idea that the mixed results may be attributed more to students' overall attitudes on survey days rather than a true measure of interest and enjoyment. Another possible reason for the mixed results is that students lacked true understanding of the survey questions. However, the consistency demonstrated by many students in their pre- and post-implementation survey answers indicates that this was probably not the case. Furthermore, the results obtained in my study are similar to those obtained by Hollis (1995) in a study which concerned the effect of technology on enthusiasm for science. Hollis' results were also mixed, but showed a slight trend as well.

Student interest was also assessed by looking at responses to questions designed to determine the influence of the subject matter. Students' likes and dislikes concerned activities as well as subjects. For activities, students reported greater interest in those that had included some type of Internet use than those that did not. Students also reported greater interest in the chemistry topics than the physics topics. I believe this resulted in part from use of the Internet for these topics as well as to the change in subject matter. As I taught a portion of both physics and chemistry I do

Table 4
Comparison of Selected Focus Students' Survey Responses Pre- and Post-Implementation

Statement Summary	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(1) Enjoy science Pre	8%	32%	40%	8%	12%
Enjoy science Post	12%	36%	32%	12%	8%
(2) Enjoyed learning science Pre	12%	32%	40%	12%	4%
Enjoyed learning science Post	12%	40%	36%	0%	12%
(5) Science is interesting Pre	28%	40%	12%	16%	6%
Science is interesting Post	16%	36%	36%	8%	4%
(6) Technology is useful Pre	44%	16%	20%	16%	4%
Technology is useful Post	28%	40%	20%	4%	8%
(7) Science and Technology are important Pre	36%	24%	24%	8%	8%
Science and Technology are important Post	36%	28%	24%	0%	8%

not think my overall teaching style caused this difference. I base this belief in part on student responses to how they felt about the use of the Internet during class discussions.

Most students reported that they liked the use of the Internet during class discussions. Of the approximately 20% who reported that they did not like use of the Internet, most wrote that they did not pay attention or did not have time. A few responded with answers such as "did not have Internet at home" or "no time" which indicated that they did not read the question clearly. Only about 5% responded that they did not understand or that they felt it was not explained. From my observations this percentage is lower than students who reported confusion when only traditional methods were used during discussions. It is my belief that student interest in the Internet during class discussions translated to increased interest in the material being discussed.

The data discussed above indicates at least some increase in student interest and understanding of science and technology. This evidence was supported by observational and journal evidence. During the pre-implementation period I noted that my students lost interest frequently and only a few ever became really involved in the topics. For the most part students complained that they had too much work, they hated the type of work, and they did not understand the material. Furthermore, despite a lack of understanding, few students requested extra help even when the offer was made repeatedly.

Observations during and post-implementation showed that an increased number of students were coming in outside of class time to use the Internet for research on their projects or for help from a teacher. Students reported that they had learned the elements and families better than other subjects during the year and that the periodic table or information on the elements was the most important thing they had learned in science this year. Student reports of the importance of this topic also suggest greater understanding of the topic and the relevance of science to daily life.

In addition, I observed that students' attention to the topics improved when the Internet was used during discussions. Students asked additional and more in depth questions on the topic. Often students would ask to see an example again or to see another example. This interest extended to their other work on the topic. For example, more students turned in one periodic table assignment than usually turned in any assignments. This assignment was explained using an Internet example and the address was provided at the students' request. Student performance on this assignment also showed improvement over performance on assignments with no Internet use.

One student demonstrated a significant increased interest in topics on the Internet. MS5B usually did not pay attention and acted in ways that often disrupted other students. During times when the Internet was used in discussions he appeared focused and actually participated in the discussion and completed in-class assignments. On a day when the students had a few minutes to complete an assignment in class he requested to read additional information on the topic on the Internet. This was especially significant for a student who never even opened his book. While evidence from some of the data sources was mixed concerning interest and understanding, other data supports the conclusion that students' interest in and understanding of science and technology did increase. In responses to the student survey statements on the usefulness of technology (statement 6) and the importance of science and technology to daily life (statement 7) a slightly greater percentage did respond with greater agreement (see Table 4). More significant was the fact that students began to ask more questions about how topics were related to their lives and to provide more examples of these relationships on their own. The results of this study do provide evidence that student interest and understanding increases with Internet use.

Influence on Girls' Interest

Because of the communication aspect of the Internet, girls' interest was expected to increase rather than be inhibited (Walker & Rodger, 1996). According to Linda Groppe, president and CEO of Girls Games, Inc., girls also like the Internet because it gives them the opportunity to explore ("Software firms," 1997). Data from student surveys and opinions, observations and journaling did not provide the strong evidence I expected for this increase. However, the data did not indicate decreased interest by girls compared to boys either.

Tables 5 and 6 show the data for student survey statements 1, 2 and 5, concerning enjoyment of and interest in science, separated by gender. Once again the data indicated mixed results which can be attributed to students' overall attitudes on the day of the survey. Boys did show a significant increase in neutral responses to the statement concerning interest in science (#5), but they also showed a significant decrease in the number reporting any level of agreement with the statement. No other significant difference in gender trends was found in the survey data.

Student opinions concerning use of the Internet indicate a potential to decrease girls' interest due to their frustrations with Internet use. Although girls were more likely to have used the Internet outside of class and to have done so on a regular basis, they also reported slightly more frustration. In addition, the only student in the focus group who reported that s/he would not like to use the Internet for more assignments was a girl. All of the boys and all other girls in this group responded enthusiastically to the idea of using the Internet more. Out of all students responding to

Table 5
Selected Focus Male Students' Survey Responses Pre- and Post-Implementation

Statement Summary	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(1) Enjoy science Pre	9%	36%	36%	9%	9%
Enjoy science Post	0%	45%	45%	9%	0%
(2) Enjoyed learning science Pre	9%	27%	45%	18%	0%
Enjoyed learning science Post	18%	36%	36%	0%	9%
(5) Science is interesting Pre	27%	45%	9%	18%	0%
Science is interesting Post	9%	36%	45%	9%	0%

Table 6
Selected Focus Female Students' Survey Responses Pre- and Post-Implementation

Statement Summary	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(1) Enjoy science Pre	7%	29%	43%	7%	14%
Enjoy science Post	21%	29%	21%	14%	14%
(2) Enjoyed learning science Pre	14%	36%	36%	7%	7%
Enjoyed learning science Post	7%	43%	36%	0%	14%
(5) Science is interesting Pre	29%	36%	14%	14%	7%
Science is interesting Post	21%	36%	29%	7%	7%

the post-implementation survey a total of four girls and one boy reported that they would not like to use the Internet for more assignments. All of the girls cited frustration and difficulty in using the Internet as the main factor. This frustration on the part of primarily female students could eventually translate to a loss of interest in the subject matter due to difficulty in using resources.

I also observed that girls were more likely to allow boys to monopolize the Internet during class time and to report that their parents restricted their Internet access at home. Girls did, however, engage in discussions using the Internet as enthusiastically as boys did. The interest level of girls was not observed to decrease due to Internet use and appeared to increase by the same amount that boys' interest increased when the Internet was used. Boys and girls were equally likely to offer to look something up on the Internet at home for a friend or project partner.

The evidence suggests that there is a potential for girls' interest in science and technology to either increase or decrease with Internet use. This could be due to changing attitudes among both genders concerning overall computer usage or to gender roles that persist in our society despite efforts to end them. Further studies are required to determine if any significant gender effects are seen when the Internet is integrated into the science classroom.

Influence on Teaching

Many of the studies I reviewed (Hollis, 1995; Goodwin, 1996; Rogan, 1996; Strommen, 1995) found that teachers reported an increased proficiency with technology as a result of using it; therefore, I expected to see an increase in my ability to use technology as a teaching tool. Results of the first two questions indicate that my proficiency is currently adequate to justify continued use of the Internet in the classroom, but also point to room for improvement. The results of the third question concerning girls' interest indicate a need to exercise caution in using the Internet so girls are not discouraged and do not lose interest. Since student interest and performance increased, as is consistent with the literature, my techniques are acceptable; however, I do need to reassess how I involve girls in the use of the Internet as a teaching tool.

In my attempts to use the Internet in the classroom I was often frustrated. Material that related to the curriculum, especially at an appropriate grade level was difficult to find. Part of my frustration was attributable to teaching a small portion of the curriculum in the middle of the year rather than planning for my own classroom for the entire year. When I did find material that I could use I was more excited and enthusiastic about the material. I know that this helped increase student interest in the material as well.

Use of the Internet helped me in other ways as well. On several occasions I found additional information that I was able to include in my lesson. This inclusion increased my confidence in the material that I was teaching and the way that I was presenting it. I also found activities for some lessons that I was able to adapt for use in my classroom. This resource was a powerful tool in my planning. Based on my observations and journal reflections I believe that using the Internet enhanced my teaching abilities and made it possible for me to reach more of my students.

Discussion

I believe that the results of this study have several implications for teaching. First, it provides some additional evidence of the positive influence of using the Internet and technology on student interest, achievement and understanding. This is important because as teachers we need to use whatever tools we have available to maximize student performance. We also need to prepare students for the challenges of the 21st century and there is no better way to do so than by having them use the tools of the future. Furthermore, students must be comfortable with science and technology as so much of the work of the future will be based on these areas. It is our duty as educators to prepare them in any and every way possible. Perhaps the results of this study will convince at least one other teacher to try integrating technology into his or her classroom.

This study did not provide conclusive evidence on the effect that using technology has on girls in the classroom. It did suggest a need for additional studies and caution to insure that no one, male or female, is left behind when using technology. This need for caution must also extend to special needs students and students of other cultures, who were not specifically observed in this study. As educators we must remember that our duty is to all of our students, not just the ones who respond well to our favorite, or even best, style of teaching.

This study also provides further evidence that using technology increases interest in teaching and reduces teachers' feelings of isolation. When I found resources on the Internet, I knew that other teachers had searched for and found answers to the same problems I was encountering my first time out. And, more importantly, these teachers were sharing their gained wisdom with me through the Internet. This has encouraged me to take additional courses in this area and may encourage other teachers to learn how to integrate technology in the classroom as well.

Finally, the results of this study also provide evidence to teacher preparation programs of the importance of preparing teachers to use technology in their classrooms. For nearly every other situation I encountered I felt prepared by the experiences I had in my coursework. Even the issue of discipline and classroom management, one of the most difficult for new teachers, was not uncomfortable for me. However, despite my interest in using the Internet, at times I was lost for ideas on how to use it successfully. The practice that one receives in a course in this area would have been invaluable to me in my own integration of technology in the classroom. Just as our students must learn to use technology to succeed in the world of the future, so must we in order to prepare them for that world.

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Appendix A

Periodic Tables on the Internet - Student Handout

Web Elements http://www.shef.ac.uk/chemistry/web-elements/main/ index-nofr.html

Periodic Table Challenge http://www.chem.uky.edu/misc/periodicquiz. html

Graphical Periodic Table http://ghs.bcsd.k12.il.us/projects/class/periodic/ 1997/

Periodic Table http://www.chem4kids.com/elements/index.html

Chemicool Periodic Table http://wild-turkey.mit.edu/Chemicool/

City Night Periodic Table http://citynight.com/periodic/periodic.html

Comic Book Periodic Table http://www.uky.edu/~holler/periodic/periodic.html

Exploratory http://www.exploratory.org.uk/plores/per_tbl/per_tbl.htm

HyperChem on the Web - Periodic Table http://tqd.advanced.org/2690/ptable/ptable.html

Carlos's Periodic Table of the Elements

http://starbase.ingress.com/~dwight/students/carlos/pages/elements/pages/periodic.htm

Periodic Table of the Elements http://www.intercorr.com/periodic/

Elements http://members.iworld.net/joo/physics/curri-sub/periodic/periodic-table.html

Los Alamos National Lab http://mwanal.lanl.gov/CST/imagemap/periodic/periodic.html

Periodic Table of the Elements http://members.aol.com/jeff555555/table/ptable.html

Pictorial Periodic Table http://chemlab.pc.maricopa.edu/periodic/periodic.html

Periodic Table of Elements on Internet http://domains.twave.net/domain/yinon/default.htm/

Elementistory (Element History) http://smallfry.dmu.ac.uk/chem/periodic/elementi.html

List of Periodic Tableshttp://www.anachem.umu.se/cgi_bin/pointer.exe?PeriodicTables

Appendix B

Student Science Interest Surveys

Pilot

Please rate the following statements on a scale of 1 to 5. A rating of 1 indicates that you strongly agree with the statement. A rating of 5 indicates that you strongly disagree with the statement. A rating of 3 indicates that you do not agree or disagree with the statement.

	Strongly Agree				Strongly Disagree
1. I enjoy science.	1	2	3	4	5
2. I have enjoyed learning science so far this year.	1	2	3	4	5
3. I feel that I have learned a lot in science so far this year.	1	2	3	4	5
4. Science is too hard.	1	2	3	4	5
5. Science is interesting.	1	2	3	4	5
6. Technology is useful.	1	2	3	4	5
7. Science and technology are important in daily life.	1	2	3	4	5

Please complete the following statements:

8. My three favorite topics in science so far this year have been
9. My three least favorite topics in science so far this year have been
10. My three favorite activities in science so far this year have been
11. My three least favorite activities in science so far this year have been
12. The most important thing I learned in science this year was:

Actual Student Science Interest Survey

Please rate the following statements on a scale of 1 to 5. A rating of 1 indicates that you strongly agree with the statement. A rating of 5 indicates that you strongly disagree with the statement. A rating of 3 indicates that you do not agree or disagree with the statement.

	Strongly Agree				Strongly Disagree
1. I enjoy science.	1	2	3	4	5
2. I have enjoyed learning science *this school year*.	1	2	3	4	5
3. I feel that I have learned a lot in science *this school year*.	1	2	3	4	5
4. *Science is hard.*	1	2	3	4	5
5. Science is interesting.	1	2	3	4	5
6. Technology is useful.	1	2	3	4	5
7. Science and technology are important in daily life.	1	2	3	4	5

Please complete the following statements:

8. My three favorite topics in science *so far this school year* have been

9. My three least favorite topics in science *so far this school year* have been

10. My three favorite activities in science *so far this school year* have been

11. My three least favorite activities in science *so far this school year* have been

12. The most important thing I have learned in science *so far this school year* is:

Student Science Interest Survey - April 1998

Please rate the following statements on a scale of 1 to 5. A rating of 1 indicates that you strongly agree with the statement. A rating of 5 indicates that you strongly disagree with the statement. A rating of 3 indicates that you do not agree or disagree with the statement.

	Strongly Agree				Strongly Disagree
1. I enjoy science.	1	2	3	4	5
2. I have enjoyed learning science this school year.	1	2	3	4	5
3. I feel that I have learned a lot in science this school year.	1	2	3	4	5
4. Science is hard.	1	2	3	4	5
5. Science is interesting.	1	2	3	4	5
6. Technology is useful.	1	2	3	4	5
7. Science and technology are important in daily life.	1	2	3	4	5

Please complete the following statements:

8. My favorite topic/topics in science so far this school year was/were

9. My least favorite topic/topics in science so this school year was/were

10. My favorite activity/activities in science so far this school year was/were

11. My least favorite activity/activities in science so far this school year was/were

12. The most important thing I have learned in science so far this school year was:

13. Did you like having some examples displayed off of the Internet during class discussions?
Yes No
Why or why not?____

14. How often do you use a computer and/or the Internet outside of school?
   a. Never (skip to question #16)
   b. Only when I have to
   c. Once a month
   d. Once a week
   e. Almost every day

15. In what ways do you use the computer and/or Internet?
   a. Programs for information
   b. Programs for games
   c. Chat rooms
   d. E-mail
   e. Search for information on the Internet
   f. Typing/desk top publishing
   g. Other ____

16. Did you use the computer and/or the Internet for anything in science the school year? (circle one) Yes No

If yes, what? (Circle all that apply)

a. Information for report or project.
b. Communicate with classmates or teacher.
c. Help with homework or studying
d. To type a report or assignment
e. Other. Explain______________________________

17. Did you use the computer and/or the Internet for anything in classes other than science the school year?(circle one) Yes No

If yes, what? (Circle all that apply)

a. Information for report or project.
b. Communicate with classmates or teacher.
c. Help with homework or studying
d. To type a report or assignment
e. Other. Explain______________________________

18. When doing research and/or studying what sources (references) do you use?

a. Computer and/or Internet
b. Text
c. Reference books
d. Library
e. Parent, teacher or friend
f. Other. Explain ______________________________

If you used the Internet for any part of science this year please answer the following questions as completely as possible

19. What problems did you encounter while doing work on the Internet?

20. How did you feel about working on the Internet?

21. What did you learn about your topic while working on the Internet?

22. How would you feel about doing more work using the Internet?

Appendix C

Guided Student Questions on Science and Technology

1. Provide at least one example of how science is helpful in daily life that you have seen over the past week. (For example, knowing some science helps me understand why putting gas in the car makes it operate).

2. Provide at least one example of how technology is helpful in daily life that you have seen over the past week. (For example, technology helps me share various periodic tables and other information with students on the television screen).

3. Provide at least one example of a concept or idea you have learned since August 1997 that helped you understand something in your daily life. (For example learning about wheels and axles helped me understand how the steering wheel on a car works).

Appendix D

Extra Credit Possibilities

The following element projects are available for extra credit. However, no extra credit will be awarded if an individual's family project "The Family Game" is not completed or shows a lack of quality work. Extra credit must be done using one or more of the elements you were assigned.

1. Make a model of an element's structure.
2. Write a poem, story, or song about one or more of your elements.
3. Make a mobil for one or more of your elements with information from the periodic table and/or properties of the element(s).
4. Write a brief essay on the background of the discovery of one of your elements and/or the person who discovered one of your elements.
5. Make a poster for one or more of your elements, include information on the properties of the element(s). The poster must teach something about the element(s).
6. Create a comic strip about one or more elements. The comic strip must teach something about the element(s) and/or it's family.
7. Write a commercial, radio advertisement, or a print advertisement for your element(s). Include the advantages the element(s) bring to our lives.
8. Write and perform a skit about your element(s) and the family to which they belong.
9. Write a newspaper or magazine article discussing the positive and negative aspects of one of your elements in the world today.
10. Make a timeline of important events in the history of one or more of your elements.
11. Create a new product using one or more of your elements.
12. Create a computer presentation or a website about one or more of your element(s).
13. Make a map of Internet sites with information on one or more elements. Include all web addresses and printouts of the information from the websites.
14. Create a country, island, city, amusement park, or planet based on your elements (may include all elements in you family).
15. Design a research project to investigate some aspect of one or more of your elements. Include a hypothesis and the project design.
16. Make a chart of all of the elements in your family to show their differences and similarities.
17. Turn in a graphic organizer (web outline) of the information you collected for the background on your "Family Game."
18. An element/family mini-project of your choice with prior approval from Mrs. M or Mrs. A.

OKLAHOMA TEACHER EDUCATION COLLABORATIVE (O-TEC)

Christine A. Moseley, Oklahoma State University
Sarah Ramsey, Oklahoma State University

The lack of science literacy among policy makers and the public at large, the declining number of American-born students expressing an interest in science and engineering, and the low involvement of minorities and women in the technical disciplines are causes for national concern. The environmental, medical/ethical, and economic decisions which will affect the future of this nation and the quality of life that it can offer to its citizens are dependent upon a scientifically literate populace and a technologically-skilled work force. Not only have major federal research agencies such as the National Science Foundation and National Institute for the Humanities sounded a warning, but such prestigious bodies as the National Academies of Science and Engineering and the American Association for the Advancement of Science have also issued strongly worded challenges to the education community to rectify the problem. Most agree that the solution to the problem begins on the first rungs of the educational ladder.

National Needs

As the education reform movement has matured, its focus has shifted to the central role played by classroom teachers. Moore (1990) noted, "Excellent teachers will make even the most difficult topics understandable and exciting, regardless of the mandated curriculum imposed on them...The curriculum is important, but not nearly as important as the teachers" (p. 332). The central role to teacher training in educational reform has been long recognized; indeed a study undertaken by Thomas Jefferson in 1798 (Hurd, 1986) found that education would be greatly improved if teachers were more learned. Based on modern research (Huling-Austin, 1992) it is clear that to develop better teachers, who will serve the youth of tomorrow, teacher education programs must recruit well-qualified students to the profession, offer interdisciplinary and meaningful instruction in content and pedagogical techniques, and support new teachers during their crucial initial years in the classroom.

Oklahoma Situation

Many of the shortcomings in science and mathematics education in Oklahoma documented a decade ago (Grigsby, 1986) remain prevalent today. Elementary teachers remain concerned about their level of background in science and mathematics content and are uncomfortable with hands-on inquiry methods of teaching science and mathematics. Similarly in secondary biology, chemistry, physics, and mathematics instruction, many teachers lack the skills and content knowledge necessary to teach modern curricula or are not aware of new approaches to teaching.

Also, shortages of teachers of mathematics and science will be a problem over the next decade in Oklahoma. A study done by the Southern Regional Education Board (1993) projects a surplus of new elementary school teachers but continuing demand for elementary level teachers trained in science and mathematics. The study foresees teacher shortages in middle school mathematics and science, and in high school mathematics, biology, chemistry, physics, and physical science.

Teacher Education

The need for change in teacher education is central to educational reform and directly related to national economic concerns. The 1992 SCANS report (Secretary's Commission on Achieving Necessary Skills) noted that poor science and mathematics teaching reduce the technical skills of the general workforce and affects the economic capacity of society as a whole.

There is agreement that pre-service teachers should be taught by methods that model the ways they should use in presenting information to their students. Among many science educators there is consensus that a primary objective of science instruction is an adequate understanding of the experimental nature of science (AAAS, 1989; Hazen and Trefil, 1991; Rutherford and Ahlgren, 1990). Unfortunately, many of the traditional science courses offered at the university level neither result in an understanding of the nature of science by the students nor do they allow students the experiences needed to construct an understanding of science from hands-on inquiry experiences (Brooks and Brooks, 1993).

And lastly, the National Science Education Standards (1994) noted the importance of field experiences in professional education: "The most powerful connections between science teaching and learning are made in the classroom, often through field experiences, team teaching, collaborative research, or peer coaching. Field experience starts early in the pre-service program and continues throughout a teaching career. Whenever possible, the context of learning to teach science is actual students, classrooms, student work, and curriculum materials" (p. 67).

Addressing the Needs

To address the problem issues, the Oklahoma Teacher Education Collaborative (O-TEC), a state-wide network of higher education institutions, professional organizations, and public schools, has been created with a grant from the National Science Foundation. All of the O-TEC participants share a common perspective of the important elements of teacher education. This vision is systemic in nature: teacher education begins with recruitment, continues with education at the college level, and extends into early experiences as a certified teacher (Senge, 1990). O-TEC institutions believe that the process of preparing teachers in science and mathematics from pre-service through induction should be:

- *Field-Based:* Teachers learn to teach best in elementary or secondary classrooms under the guidance of a master teacher. Professional education courses should be taught in conjunction with or related to field-based instruction.
- *Inquiry-Based*: Teachers should learn that process skills and the techniques of investigation are the essential elements of science and mathematics.
- *Technology/Issue Oriented*: Teachers should be prepared for the increasing role modern technology will play in classroom activities and in linking activities to external sources of information.
- *Integrated:* Teachers should be trained in a way so that there are no sharp boundaries among the sciences, between science and mathematics, or between technical areas and other curriculum areas. Just as important, there should be curriculum articulation, so that the elementary, middle, and high school curricula flow smoothly into collegiate offerings.
- *Network Forming*: Teachers should be part of a supportive network. Professionalism should be fostered at all levels, from students interested in a teaching career through accomplished teachers, to university professors.
- *Reflective:* Teachers need to recognize that learning is a life-long process and learn how to be reflective analyzers of their own learning styles and teaching methodologies.

Design and Objectives

O-TEC seeks to prepare teachers to meet student needs in science and mathematics education more effectively. Each of the higher education partners is working with participating school districts to develop plans specific for their locale. The higher education partners involved in the collaborative, which include a private liberal arts institution, five regional state institutions, an historically black land grant university, a major junior college, and two large flagship state institutions, are: The University of Tulsa, Northeastern Oklahoma State University, Southwestern Oklahoma State University, Cameron University, University of Central Oklahoma, Langston University, Tulsa Community College, Oklahoma State University, and The University of Oklahoma.

The O-TEC design, a five-year, multi-million dollar project, is based on the strategy that addresses the entire teacher preparation system from recruitment, through pre-service preparation, into initial service. Thus, it is to develop innovative ways to promote careers in mathematics and science teaching, particularly among minority students, build on the experience of other collaborative projects and teacher input to provide a high-quality pre-service education, provide graduate courses in science and mathematics for currently practicing teachers, expand the support new teachers are provided, and supply timely in-service training for experienced teachers. To accomplish these goals, the objectives of the O-TEC coalition include:

- Recruit more potential teachers through opportunities to explore a career in science and mathematics teaching, with special emphasis on underserved groups in Oklahoma.
- Restructure the undergraduate pre-service curriculum to enhance field experiences; integrate content, pedagogy, and technology; introduce interactive methods of instruction; and stress process skills and critical thinking through an integrated curriculum.
- Enhance retention during the induction process by strengthening support systems for teachers of science and mathematics in their initial years in the classroom.
- Inculcate the use of technology into recruitment, training and retention activities to enhance learning opportunities and facilitate communication.

- Build linkages among higher education institutions, common education, community institutions, and the private sector involved in pre-service instruction.
- Build linkages among science, mathematics, engineering, and education departments with institutions.

Initiatives

Several major initiatives have been planned and implemented by the participating collaborative partners. These initiatives include:

- **Summer Academies that provide quality experiences in the teaching of science and mathematics for undergraduate preservice teachers, para-professional teachers, and for high school students**

During the summer of 1997, O-TEC partners conducted five science/mathematics academies to encourage high school and college students to consider careers in teaching. The programs allowed these students to teach model lessons to elementary and middle school students.

Southwestern Oklahoma State University teamed with the Weatherford and Clinton school districts to offer high school and college students the chance to teach hands-on science to elementary children. Northeastern Oklahoma State University worked with districts in the Tahlequah area to introduce new methods of inquiry-based physics teaching. Langston University and Oklahoma State University worked with schools in Oklahoma City, Guthrie, Perry, Coyle, Stillwater, and Red Rock to introduce science and mathematics teaching to high school and college students. Tulsa Community College stressed technology in an academy for non-traditional college students. The Pawhuska schools and the University of Tulsa developed a model program at Indian Camp School that introduced high school students to teaching.

- **Revision of general education math and science courses to reflect an inquiry based, integrated approach to science and math**

At OU, Northeastern Oklahoma State, and the University of Tulsa, mathematics professors have worked with their colleagues in the sciences and in education to rework the math courses taken by teacher education students. The new courses tie theory and application together.

At OSU, Southwestern Oklahoma State, and the University of Tulsa, new science courses help teachers learn the methods of experimental science along with scientific facts. OSU has developed a new, four course, 12 hour sequence of general education science for all education majors. These courses; Biology, Physics, Chemistry, and Earth Science; use open inquiry-based learning, being laboratory driven rather than lecture.

- **Revision of teaching methods courses to build upon the science content taught in the general education courses**

OSU has also revised the science methods courses for early childhood, elementary, and secondary science education majors. These revised courses are taught by a faculty team using inquiry-based pedagogy, and are integrated with the general education science content and field experiences. Elementary education majors teach a science unit in the public schools while secondary science education majors serve as lab assistants in a weekly Introductory Biology course.

- **Development of science and math graduate programs**

OSU is developing a Master of Science degree in Natural and Applied Science designed specifically for elementary, middle and junior high school teachers who need the added science background.

- **In-service training in inquiry based science and math for classroom teachers and university faculty**

O-TEC has sponsored two weekend workshops on inquiry-based instruction in math and science. OSU has also sponsored a week-long Success in Science Institute for teams of public school administrators and teachers. Also, at OSU, the education and arts and sciences faculty have begun monthly brown bag seminars to discuss math and science education reform issues.

- **Post entry-year workshops that bring together groups of teachers following their first year in the classroom**

Faculty members in mathematics at Cameron University developed a workshop for teachers who had just completed their first year of teaching.

- **Materials support for entry-year teachers and local classroom teachers**

The Center for Science Literacy (CSL) at Oklahoma State University was created to address the issues of student math and science illiteracy and inadequate teacher preparation across Oklahoma. The CSL conducts inquiry-centered teacher training for secondary and elementary teachers. It also has begun to develop an extensive resource and materials center, making available materials used during pre-service and in-service training for check-out by student teachers and teachers.

- **Training in the use of classroom technology for preservice, entry-year, and classroom teachers**

Each of the O-TEC partners received mini-grants for the addition of computer technology to be integrated within the teacher education programs. OSU has also completed renovation of an inquiry-based laboratory, complete with computer technology for the general science courses and a new computer laboratory for the science methods courses.

Conclusion

O-TEC represents a multi-layered, multi-faceted collaborative. Not only are nine diverse institutions working together, but also collaboration has occurred across campuses between arts and sciences faculty and education faculty; between university faculty and public school teachers; and, between university faculty and local and state agencies that support various aspects of math and science education improvement.

Success in systemic undertakings, like reform of teacher education in science and mathematics, and success in science depend alike upon the ability to view systems as a whole. As Richard Feynman (1995) noted: "If our small minds for some convenience divide the universe into parts – physics, biology, geology, astronomy, psychology, and so on – remember that nature does not know it! So let us put it all back together, not forgetting ultimately what it is for" (p. 115). The most significant contribution of O-TEC to the preparation of teachers of science and mathematics has been, and will continue to be, the joining of faculties and disciplines involved in science and mathematics education to "put it all back together" as it is found in nature.

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USING COLLABORATIONS AT THE UNIVERSITY LEVEL

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University Collaborations

As the directions and goals set forth for science education in elementary, middle, and secondary schools change, teacher education programs must restructure their programs to facilitate these changes. One program change now emphasized is the ability of preservice science teachers to infuse into their teaching both the concepts of science and scientific thinking with pedagogy that reflects current research (Hammrich, 1998). Inherent to this change is the need for collaboration between faculty in education and the sciences (National Research Council, 1996; Rutherford. & Ahlgren (1990).

One model of such a transformation may be found in Georgia Southern University's middle grades science program. This program has developed a the collaboration between science and education faculty. Here the emphasis has been placed on blending sound middle school pedagogy with the directions and goals for science education, while trying to strengthen science content. In general, the middle grade program stresses collaboration within the department to provide a foundation for interdisciplinary teaching and learning. For instance, the middle grades science methods is taught concurrently with mathematics methods to facilitate the integration of subject matter. This blocking of science and mathematics methods allows students to see the natural connections between mathematics as a tool for science and science as a means of showing the relevance of mathematics. However, within the middle grades science methods course several additional and somewhat unique collaborations have been developed.

During the five years of the Georgia Southern Collaborative, the science methods course has been team taught by faculty from the College of Education and from the College of Science and Technology. This teaming takes an unusual format in that both professors are in the classroom on a daily basis. This provides a true integration of content and pedagogy since both the faculty members are actively involved in presenting different teaching strategies and demonstrating how they can be used most effectively in the classroom. Furthermore, content is emphasized by both faculty with each utilizing areas of their own expertise.

Developing Collegiality

As is expected, this collaboration between faculty members began slowly. With very different teaching styles, both faculty members had to find a zone of comfort in the shared classroom. At the start teaching tasks were divided into segments within the class periods. The "scientist" was unfamiliar with pedagogical terms and still refers to this class as the only education course he has ever taken. Likewise, the "educator" found the scope and depth of some of the science content a learning experience. Both soon realized that utilizing their varied strategies and methodologies of teaching were complementary rather then contradictory and this proved to be the basis for the growth of this collaboration. Although both still feel more comfortable dealing with their own expertise, the boundaries in the classroom are slowly dissolving. Both faculty members now interject comments, defer questions to the other, and on occasion, alter the direction of the class on the spur of the moment. This type of interaction grew out of respect for what each could add to the class and the knowledge that each had a common focus on what was best for the students.

The collegiality fostered and modeled by this team is particularly important when related to two more components of the Middle Grades concept: teaming and cooperative learning. This model demonstrates teaming in its simplest form, while utilizing cooperative learning strategies both inside and outside the classroom.

Structuring Course Collaborations

This collaboration is continuously developing as other scientists and faculty have been drawn into the collaboration through field trips to outdoor settings where science teaching is demonstrated. An all day field trip to Cumberland Island National Seashore has become a focal point for the integrating of science content and pedagogy through the study of the Island's four distinct habitats.

Initially, the two instructor joined with the education coordinator for Cumberland Island in the development of the program on the Island for the middle level preservice teachers. This expanded to the development of materials and ideas for curriculum, by the preservice teachers, that were utilized within environmental education center that was being developed for training teachers on the island. Park service personnel, in turn, provided expertise on the historical development of the island and the background on the native plants and animals. University personnel then structured activities that emphasized an integrated content utilizing the island's four habitats: the beach, marsh, dunes and maritime forest.

This science methods course also encourages students to practice the techniques demonstrated by their instructors. Special emphasize is placed on the unique natural environments of Georgia through the use of cooperative learning strategies. For the Cumberland Island trip, the students are placed in groups which research, develop, and then share their own expertise on the habitats of the barrier island. Students are divided into groups which research one of the four habitats and then share their expertise in a general presentation to the entire class. In addition, during the field trip to the island, the students are re-organized into new groups composed of one expert from each of the habitat groups. They are then responsible for assisting others as they experience each habitat, providing background information, and answering question that arise as they participate in activities on the island. The activities on Cumberland Island focus on the integration of science and mathematics but also include the history of the island as it impacts the natural environment. Science content and skills are emphasized by students doing activities such as; a beach profile where students collect data in field notebooks and then on returning to the classroom, compare and interpret data. In addition, after returning from this experience, the students then work on teams to plan an interdisciplinary unit incorporating the four major subject areas.

The use of specific scientific techniques and methods for collecting data that have been added to the course are validated in the eyes of the students since they are now demonstrated by a "real" scientist. The course now incorporates topographic profiles, as well as random sampling techniques, changes in population and beach dynamics which are types of research studies currently being conducted by various universities along the coast. Thus students are exposed to 'real time research" not just a simulated activity. Data is collected and compiled by several groups within each class and shared from term to term to demonstrate the emphasis scientists place on the verification of data and the importance of viewing changes over time, as well as emphasizing the collaborative nature of science. In the field, the students make observations which relate the natural environment and the interaction of man. This emphasizes the integration of other disciplines with science by dealing with the issues of social studies and the interpretation of data through mathematics.

Key Features of the Collaboration

Each faculty member plays a key role in planning the course. The scientist identifies current concepts and issues that adapt well to the methods and strategies structured by the educator. Together they design inquiry activities that use scientific research techniques, are relevant to the middle grades content, and reflect the recent efforts in science education reform. By building these links students seem to place more relevance on both the content and the pedagogy being taught in the course.

The participation of science faculty in the daily activities of the course help students realize the importance of content in developing a good science lesson. It also provides an additional resource person for students throughout the course, but particularly when they are planning lessons for their field experience. The acceptance of the scientist as an integral part of the course is obvious as former students continue to rely on him for assistance in additional field experiences. Furthermore, by interacting with science faculty outside of the core courses and in more informal science settings, students have developed more positive attitude toward learning and teaching science.

The education faculty member helps to validate the applicability of these science concepts as they are adapted for use in a middle grades curriculum. Preservice teachers begin to see that there is a clear connection between the content they are learning and what they will be teaching in middle school science classes. In evaluations at the end of the course some students have expressed more confidence and interest in teaching science. Furthermore they comment on how important building a better science content base was to their success when they taught in their science classroom field experience.

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BRINGING THE REALITY OF SCIENCE TEACHING BY USING A FIELD-BASED METHODS COURSE

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Field Experience in Science Methods Courses

Science methods courses for the elementary and secondary teacher education programs require the application of science concepts that support the curriculum, provide clinical experiences that demonstrate skills in classroom management of inquiry lessons, and opportunities to model effective teaching strategies and techniques to motivate and involve students in building concepts about science. It is possible that preservice teachers enrolled in a science methods course may experience for the first time the complexity of the teaching-learning process and realize that learning how to teach is a continuous process of self-development, regulation, and transformation. Another important event that occurs in a science methods course with field experience is the application of pedagogical theories and principles into practice in the classroom.

George J. Posner (1992) said that the one indispensable part of any teacher preparation program is field experience. The purposes of field experience are to provide preservice teachers with the opportunity to observe the dynamics of student-teacher interaction during a teaching episode, help them formulate a model of good teaching, become aware of students' characteristics, experience teaching, develop methods of assessing students' learning formally and informally, and begin to reflect about the teaching-learning process. It is during the field experience that the integration of theory into practice becomes evident to the preservice teachers.

Preservice teachers are immersed in teaching situations during field experience. Mentors or cooperating teachers are generally involved to monitor the progress of students in acquiring sound teaching practices To achieve the objectives of the field experience the mentor or cooperating teacher and the university instructor/supervisor must work together as a team. They should agree on the field experience objectives, expectations, and the methods of monitoring students' progress.

This paper presents the field experience component of a methods course in the biology teacher licensure program at the University of Southern Mississippi (USM).

The Field Experience in USM's Biology Teacher Licensure Program

The degree program for the Biological Science Teacher Licensure is administered by the Department of Biological Sciences in the College of Science and Technology in collaboration with the College of Education and Psychology and the Center for Science and Mathematics Education. The program consists of three sections: (a) the General Education Core, (b) the Specialty Studies (e.g., biology, chemistry, physics), and (c) the Professional Studies.

The General Education core consists of 44 credit hours of introductory college courses in English composition, social sciences, speech and communications, mathematics, humanities, geology, and computer sciences. Specialty courses include 36-37 credit hours in the biological sciences which include a course on application of biology concepts to secondary school instruction. Twenty-nine hours of other required science courses (i.e., chemistry, physics, and geology) are counted as Specialty courses. The Professional studies refer to courses in foundations of education, education of students with special needs, educational psychology, tests and measurements, general methods course, and science methods course for secondary schools, amounting to 18 credit hours. Finally, 14 credit hours in one semester of student teaching experience complete the program.

The three courses in the Biology Teacher Licensure program with field experience component are: (a) a general methods course, CIS 313 (Principles of Teaching High School), (b) science methods course, SCE 460 (Methods in Teaching Science- Secondary), and (c) biology content and instructional methods, BSC 495 with laboratory (Application of Basic Concepts in Biology for Secondary School). The types of field experience vary according to the objectives of each course. For instance, in CIS 313, preservice teachers conduct 16 hours of observation in high school classrooms in their area of specialization. SCE 460 requires preservice teachers to observe the mentor teacher in a science teaching episode, and to spend most of the time in practicum, i.e., helping the mentor in preparing a class or laboratory activity, tutoring a group of students, and teaching a science lesson. The laboratory component of BSC 495 is field-based where students experience being a biology teacher in the classroom of a designated mentor for five weeks. BSC 495/495L is a five-hour course with three credit hours in the lecture and two credit hours in the laboratory. It was instituted in 1994 for students in the biology licensure program. The course was designed to provide preservice teachers the opportunity to apply the biology knowledge they have acquired for instruction in secondary schools. During the field experience they practiced effective teaching strategies to teach high school biology as a process of knowing about the natural world. This course satisfies the requirement of the National Council for the Accreditation of Teacher Education (NCATE) to include field experience in methods courses.

A Focus on the BSC 495 Field Experience

The field experience for this course is designed to apply previously learned knowledge in biology and teaching strategies and to learn and grow from the experience of working with a mentor and students in the school environment. As preservice teachers spend time in the classroom interacting with the mentor and the students, they will be guided to become "reflective teachers who review, reconstruct, reenact, and critically analyze their own and their students' performance, and who formulate explanations with evidence" (Shulman, 1987).

Preparation for the Field Experience

Several procedures were followed to insure that the objectives for the field experience will be achieved. First, the course instructor and the Director of the Office of Field Experience selected mentors from public schools within commuting distance from the university. These mentors are master biology teachers qualified to serve as models in teaching. After the selection, the Director of the Office of Field Experience formalized the collaboration with the district administrators and the school principal. Second, the course instructor matched the preservice biology teachers' schedule with the class schedule of the mentors. The third procedure, an orientation meeting, is critical in understanding the collaboration between the university and the local high schools. Two weeks before the field experience started, the instructor conducted a five-hour orientation meeting with the mentors to explain the goals and objectives of the field experience and the tasks and expectations from the preservice teachers. In addition, observation instruments based on the constructivist perspective were introduced and rating with them was practiced on videotaped teaching episodes. Evaluation protocols for mentors to assess the performance of preservice teachers on various tasks were also discussed.

The Tasks of Preservice Teachers

The reports on the tasks listed below were compiled and presented in a field experience portfolio. It was evaluated by the instructor based on completeness, organization, neat presentation, and evidence of reflection and transformation in their teaching practices.

The five tasks completed by the preservice biology teachers were:

TASK 1. Observation of the school campus, facilities and resources.

This task was initiated by a meeting of the preservice biology teachers with the principals to explain the tasks and to request permission to tour the campus. The observations included a description of the geographic location of the school, the community around the school, the layout of the buildings, the ambience of the main office, the athletic field and office, the academic areas of the campus, the cafeteria, and the auditorium or multi-purpose room. The library and its holdings were surveyed for up-to-date books, audiovisual resources, and multimedia instructional materials, with attention to science learning resources. The computer lab (if there is a separate room) was included in the survey. Greenhouse and nature trail used for instruction were also noted.

The classroom of the mentors was also observed with attention to the resources for science teaching. This was done during the mentors' planning period. Books, references, and magazines, posters, bulletin board displays, animals in cages, terraria, potted plants, and other instructional aides were noted. Safety facilities and equipment such as eyewash, shower, blanket, and fire extinguisher were described when present.

The report included photographs of some areas of the campus, a copy of the school handbook which describes the policy of the school, a copy of the curriculum guide in biology, a map of the school campus, and a floor plan of the biology classroom.

TASK 2. Observing a biology teaching event.

The date, period, and class to be observed were pre-arranged by the preservice biology teachers with their respective mentor. An observation form developed by the instructor was used. The observation focused on the administrative routines, instructional procedures such as motivational techniques, teaching methods and strategies, student activities, evaluation of student learning, closure of the lesson, and classroom management and discipline performed by the mentors. One complete period (55 minutes on a regular schedule or 90 minutes on block schedule) was used for this task.

TASK 3. Helping the mentor to prepare a laboratory or class activity.

This task illustrated the importance of planning a lesson. Preservice biology teachers worked closely with their respective mentor in preparing the laboratory or class activity, such as, gathering the materials and supplies for the number of groups of students per class, and preparing reagents and solutions. During this task, they realized the volume of materials needed for three to six classes daily. On the other hand, some mentors taught more than one course, therefore, the type and number of preparations were different. The preservice biology teachers' knowledge of laboratory techniques and safety practices, and their ability to organize materials and supplies for many groups were displayed in this task. Organizational skills of preservice biology teachers proved very useful Task 3 and Task 4 were done sequentially. Preservice teachers helped their mentors to teach the lesson for which they prepared the classroom and laboratory setups. In doing so, they realized the adequacy, shortcomings, or excesses of their preparations. They saw how the students used the materials and setups, and they developed ideas to improve the laboratory management. Besides preparing instructional materials, they also learned the seating plan and workstations of groups of students. They called the class roll to become acquainted with the students and to establish rapport.

The report for this task included the responses to questions that required preservice teachers to reflect on the practical importance of what they learned in their biology and chemistry laboratory courses, the various preparations required for the types of activities used to teach the lesson, the amount of time involved in the preparation of a laboratory or classroom activity.

TASK 4. Helping the mentor to teach a laboratory or class activity.

During this activity the preservice biology teachers called the class roll and prepared the attendance report of the class. They helped in various ways, such as, tutoring groups of students, supervising students during a laboratory activity, and guiding students in conducting an experiment or project. In some lessons, the mentors have the preservice biology teachers grade laboratory reports so they become aware of students' quality of work and to match these with their expectations.

The report for this task consisted of journal entries for at least three lessons where they prepared the materials and setups for the laboratory or class activities and helped teach them. They described their participation in teaching the lesson, the students' activity, and their perception of themselves as they helped students. Questions in the journal entry required them to reflect on their teaching ability, their perceptions about high school students, and ways to improve if they have to teach the lesson again.

TASK 5. Teaching two biology lessons.

Planning for this task was started early in the second week of the field experience when the mentors decided what lessons will be taught by their assigned preservice teacher. This sequential teaching allowed them to teach a concept completely. They also made revisions in their teaching plans based on the suggestions of the mentors and the instructor and on their reflection of their first teaching experience. As early as possible they submitted a draft of their lesson plans to their mentor and instructor. The mentors and instructor asked questions, evaluated the accuracy of the concept(s), and gave suggestions and management tips for the lessons. After several revisions the lesson plans were approved. The instructor observed and videotaped the first teaching episode. The mentors gave immediate feedback which preservice teachers considered in improving their second teaching experience. The instructor gave the preservice teachers their videotape to self-critique using the reflective questions such as, "What was your strength in teaching this lesson?", " What would you consider as your weakness?", and " Write a plan to improve two weaknesses in your next day of teaching." These improvement in teaching was observed and recorded by the mentors.

Task 5 included hours spent by preservice teachers during the conference with their mentor and instructor about the lesson plans, the preparation of instructional materials, the actual time used in teaching two lessons, conference with mentors and instructor, self-critique of videotape, and reflection on the quality of teaching based on mentors' and instructor's feedback and student assessment using the instrument, Student Outcome Assessment Rubric.

A Study on Preservice Teachers' Perceptions and Teaching Practices

The study was conducted over five years during the fall semesters when BSC 495 was offered. The course is required for students in the Biology Teacher Licensure program. The philosophy of teaching biology as inquiry and constructivism as the instructional model was adopted from the Biological Sciences Curriculum Study Developing Biological Literacy (Uno, 1993). Instructional methods such as guided discovery, learning cycle, model building, role playing, simulations, and the use of discrepant events were practiced in cooperative learning groups during the course. Therefore, the preservice biology teachers played the role of students and experienced the activities to help them build concepts.

Samples and Instruments Used

Thirty-three preservice biology teachers participated in the study. Two instruments from the Expert Science Teaching Educational Evaluation Model (ESTEEM) were used (Burry-Stock, 1995). The ESTEEM Classroom Observation Rubric was used to evaluate the teaching practices from actual teaching and the videotaped teaching. The ESTEEM Student Outcome Assessment Rubric was administered to the students after the lesson to measure the quality of teaching by preservice teachers such as in communicating the main idea, piquing students' curiosity, and explaining the relevance of the lesson. Three qualified evaluators rated the videotape of the preservice teachers on the Classroom Observation Rubric to assess their teaching practices and scored the students' responses on the Student Outcome Assessment Rubric.

Besides these instruments, other data sources provided by the preservice teachers include a 2 to 3-page statement of their philosophy of teaching, self-critique report on their teaching based on the videotape, and journal entries in the professional portfolio. The mentors' evaluation and anecdotal reports were also used. The professional portfolio and self-critique were examined to show the development of preservice biology teachers into becoming a reflective teacher.

The Research Questions

The following questions guided the study:

1. What are the perceptions of the preservice teachers about biology teaching?
2. What are the preconceptions of preservice teachers about high school students?
3. What constructivist teaching practices were used by preservice teachers?
4. What evidence of reflective thinking was explained in the journals and self-critique of the preservice teachers?

Results

The findings on this qualitative study were based on the data sources and instruments used during the field experience. Answers to the research questions are summarized as follows.

Perceptions about Biology Teaching and Adolescent Learners

Prior to the field experience the preservice teachers submitted a statement of their philosophy of teaching biology to the instructor. The statements revealed preconceptions about the nature of biology, the teaching process, and the characteristics of adolescent learners. As expected, most of the statements were theoretical and quite idealistic. The following statements summarized the preservice teachers' perceptions of biology teaching.

1. All students can learn biology by using different teaching strategies to match their learning styles. They also learn at varying rates---some learn certain concepts faster or slower than others.

2. Biology education should teach the concepts and processes that are relevant to living in the real world. Biology teaching should present ample examples from experiences of students in the natural world.

3. One important function of biology teaching is to teach students to think analytically.

4. Biology learning should involve active learning with fun and exciting activities appropriate for the cognitive level of students.

5. Finally, biology teachers should respect and make students feel that they sincerely care about them.

The preconceptions of preservice biology teachers about adolescents were generally positive. Most of them believed that Grade 10 students are already mature and they understand what and why they are doing something. In addition, preservice biology teachers assumed that high school students are motivated and enthusiastic to learn and possess the basic skills to read and understand their textbooks.

Teaching Practices of Preservice Teachers

The ESTEEM Classroom Observation Rubric was used to assess if the preservice biology teachers are using constructivist teaching methods learned in the course. BSC 495 emphasizes the constructivist teaching model through inquiry or investigative laboratory, problem-solving lessons, the use of the learning cycle, discrepant event, metaphors and analogies, simulations, role playing, and model building. In following the constructivist model of teaching, students redefine, reorganize, elaborate, and change their initial concepts through interaction with their environment, including other individuals (Uno, 1993). The instrument consists of four categories, namely:

Category 1: Facilitating the Learning Process. The teacher is a facilitator of the learning process. The responsibility for learning is on the student.

Category 2: Content Specific Pedagogy. The teacher is constantly making the content of the lesson relevant to student understanding.

Category 3: Contextual Knowledge. The teacher shows a high level of proficiency in using contextual knowledge during the lesson.

Category 4: Content Knowledge. The teacher displays excellent knowledge of the subject matter.

The mentors and three qualified evaluators, with an inter-rater reliability of 0.87, examined the teaching practices of preservice biology teachers. The average percent score of the preservice teachers on the four categories were: Category 1= 78, Category 2= 81, Category 3= 72, and Category 4= 84. The average total percent score on all categories based on the total percent scores of 33 preservice biology teachers was 80. These averages shown in Figure 1, suggests that preservice biology teachers when provided with adequate instruction and practice, can begin to teach using constructivist methods. Although the majority of the scores were only 70-80 percent, these results were encouraging for beginning teachers. The results indicate that preservice teachers need to improve their teaching skills are categories 1 and 3. Category 1 defines the teachers' role in a constructivist classroom. A high score in this category would show the students have control and responsibility for their own learning. Understandably, beginning teachers were not comfortable with this practice because they were afraid of losing control of the class. Category 3 requires preservice teachers to confront students with their misconception and guide them in resolving it. Few beginning teachers have developed the fluid control of digressing from the lesson plan and confronting students' misconceptions. Most beginning teachers have a tunnel view of their teaching, therefore, unexpected responses that need clarification generally went unnoticed or ignored. The average percent score on categories 2 and 4, both referring to content (biology) teaching showed that the preservice teachers have sound knowledge of biology and were able to explain the concepts accurately. Table 1 presents the average scores (expressed in %) of 33 preservice teachers at four levels of performance based on the scores at the 90 %, 80%, 70%, and 60% levels.

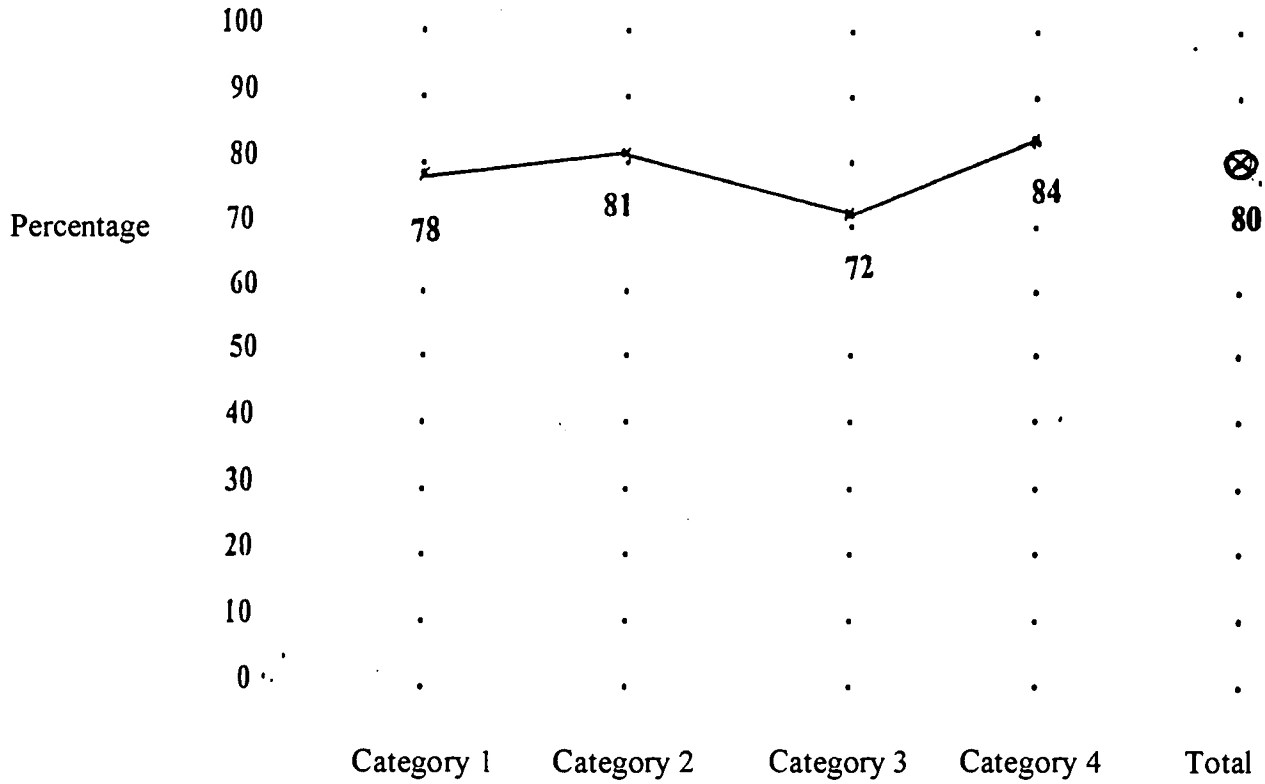
Table 1
Sum of Percent Scores of 33 Preservice Teachers at Four Levels of Performance

Sum of Percent Score at	Category 1	Category 2	Category 3	Category 4
90% level	364	362	341	370
80% level	1180	1207	1045	1215
70% level	800	849	745	890
60% level	236	264	260	315
Average Percent Score	78.18	81.27	72.45	84.54

Figure 1 shows the profile reflecting the constructivist teaching practices of thirty-three preservice biology teachers on the four categories of the ESTEEM Classroom Observation Rubric.

The frequency distribution of the total scores of preservice teachers is shown in Table 2. The highest total percent score was 91 and the lowest was 62. Preservice teachers who scored in the 90 percent level were students with high grades in biology and professional studies courses. They showed an easy predisposition to teaching and ability to weave and tailor the explanation to the students' language and comprehension. However, those who were in the 60 percent level

Figure 1
Constructivist Teaching Practices Displayed by Preservice Biology Teachers



need to improve in understanding the content and in communicating concepts accurately. The constructivist teaching practices most commonly used by the preservice teachers were inquiry laboratory investigations, the learning cycle, model building, and simulations.

Table 2
Frequency Distribution of Total Scores in the Science Classroom Observation Rubric

Total Score on Percentage Level	Number and % Total Sample (N=33)
100-90 (highest score=91)	4 (12%)
89-80	14 (42%)
79-70	11 (33%)
69-60	4 (12%)

Seven hundred twenty students expressed their perceptions of the teaching performance of the preservice teachers in their responses to three questions on the Student Outcome Assessment Rubric. On the question, "What was the main idea of the lesson?", 62 % of the responses stated the main idea of the lesson without elaboration. The statements given by the students were book-related or from notes copied during the lesson. Of 62%, approximately 25% gave responses that stated the main idea with details, descriptions, and accurate elaborations. These responses showed that the students understood the concept(s) and can express related ideas in their own words. The second question, " List some questions that today's lesson made you want to ask?", revealed that 55 % of the students asked questions related to the lesson. Of the 55% who asked questions, only 20% asked abstract questions that relate to the lesson. Some of these questions where complex and multifaceted. Several questions were of the "what if" or "how do we know" kind of questions. These types of questions are divergent and evaluative in contrast to the concrete and convergent questions asked by 35% of the students. Finally, the question on relevance revealed how students perceived the lessons' importance in their life. Only 22% of the students stated in detail that the lesson is important to some aspect of society. This was observed mostly in lessons on human genetics, pollution, and endangered species. Forty percent of the responses stated that the lesson was relevant to their life. These responses revealed that students have a narrow view of biological principles as it affects biodiversity, medical technology, and the future of the living world. Only a few of the students (2% of approximately 720) had no response on one or two of the questions. There was no observable pattern in the responses of students in the classes of preservice teachers who scored in the 90 percent and those who scored in the 60 percent level of the ESTEEM Classroom Observation Rubric.

Becoming a Reflective Teacher

During the field experience, preservice teachers have extensive contact with their mentors, the university instructor, and the students in the assigned classes. They received plenty of feedback, both formal and informal, throughout the field experience which helped develop their perceptions of themselves as a teacher. To document their reflection about these feedback the preservice teachers kept a journal. A summary of the reflections of preservice teachers after the field experience follows.

1. On Biology Teaching. The preservice biology teachers observed that students participated in cooperative group activities. They also found that lessons emphasizing relevance to themselves and to society proved interesting to high school students. Lectures laden with technical terms and scientific language turned off students' interest in biology.

2. About Adolescent Learners. Many preservice teachers confessed their disappointment about the lack of maturity and initiative of students to learn for the sake of knowledge. They also expressed the incongruity between their expectation of the students' ability and what most students' displayed in their work. All of the preservice teachers agreed that discipline and classroom management is an area of teaching where they need plenty of help.

3. On Mentors and Mentoring. The preservice biology teachers expressed gratitude for the time, guidance, and professional help that mentors extended to them. The unanimous description of the mentors by the preservice biology teachers was " they (mentors) were truly nurturing the beginning teachers like us." Through mentoring, preservice teachers were initiated to engage in discussing professional growth, to receive feedback and suggestions about their teaching and related behavior. The mentoring approach helped them build their self-concept as a teacher. On the other hand, the mentors appreciated the opportunity to help prepare future biology teachers. The experience provided them the opportunity to reflect on their early development as a teacher. All mentors agreed that mentoring was a rewarding experience.

4. On the Professional Portfolio. During the early part of the field experience, most of the preservice teachers were not convinced about the value of the portfolio. They questioned why they have to compile items for the portfolio (artifacts) then write perceptions about them. The portfolio, in their mind, was just another exercise on paper and busy work. However, they confessed that as they wrote their daily journal and described the artifacts they realized the wholeness and richness of the experience they were involved in. While reflecting on their experiences in the classroom, they expressed that they feel their passage from student to professional teacher. The reflections also helped them evaluate their decisions and actions related to instruction and interactions with students.

5. On the Field Experience. The preservice teachers unanimously agreed that the field experience is an effective method to understand the reality of the profession called teaching. No amount of classroom book learning would come close to the richness of the field experience.

Conclusions

For many years microteaching and peer teaching have been used in methods courses. More recently , field-based methods courses are becoming popular. It is apparent that field experience provides meaning to the complex interplay of coursework and practical classroom experience. Ebenezer and Connor (1998) pointed out that learning how to teach science is developmental-- aided by constant reflection of the preservice biology teachers' knowledge of science content, ability to deliver the content in the best method possible, and the concern about the impact of the teacher to the learner.

Mentoring by master biology teachers during the field experience provides professional support for preservice biology teachers while practicing their teaching skills to high school students during the field experience. Through the watchful eyes of the mentors, preservice biology teachers have the opportunity to change their own and their students' behavior. Through constant discussion and reflection about practical knowledge in teaching between mentors and preservice biology teachers, they developed professional collegiality. According to Mason (1989), the involvement of the science educator, science teachers, and the preservice science teacher is a cooperative and collaborative effort representing the university and the local schools in the preparation of science teachers.

The results of the study are encouraging especially the finding that constructivist teaching practices can be gradually included in the teaching repertory of beginning teachers through constant practice as they develop an understanding of the teaching-learning process. Future plans involve the logistical organization to link and integrate in a stepwise fashion the field experience in the general methods course, secondary science methods course, and the biology methods course on the application of biology concepts to secondary school instruction.

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"ONE HUNDRED PERCENT EFFICIENCY:" THE USE OF TECHNOLOGY IN SCIENCE EDUCATION SINCE 1900

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Introduction

> If there is a single word that is commonly associated with educational technology, it is "promise." .... Advocates of particular educational technologies such as educational radio, motion pictures, television, video cassettes, video discs, and computers have lauded the potential of their particular favorites as promising a revolution in education. (Levin and Meister 1985, p.1)

In the statement above, Levin and Meister began their examination of the disappointments associated with technologies over the decades. They found many areas in which to affix blame as to why technology had not accomplished its promised goals of revolutionizing teaching. Rather than focus on the sometimes giddy and often inflated promises of what technology was supposed to bring to teaching, this study focused on successful classroom practices using technology in science education. They were not promises; rather, they represented efforts by teachers to make use of new and innovative tools to help students learn.

The need for such a study is self-evident. The symbiotic nature of science education and technology have led to many individuals using technological tools to improve teaching and learning. Placing these tools into a broader historical context will help future educators look more objectively at the use of technology in the classroom, by offering perspective on its antecedents.

Interest in using technology to "improve" teaching is as great now as it has ever been. National initiatives supporting the infusion of technology in instruction include federal legislation such as Goals 2000 and Secretary of Education Richard Riley's (1997) goal that students should be entitled "to have their classroom connected to the Internet by the year 2000 and to be technologically literate." (Memorandum to Department of Education employees) To this end, school districts have sponsored "net days" and provided funds for technology and teacher training in its use.

Effective teachers use a variety of tools. Technology though the decades has represented a tool which provided teachers numerous opportunities. As defined by Reynolds and Barba (1997), technology is "electronic related devices and products of the production of these products such as the computer." (p. 262) With these tools, teachers were given the means to both automate and innovate their classroom practices. Whether seeking to achieve Thomas Edison's goal of one hundred percent efficiency in instruction or simply to develop a more sophisticated set of thinking skills, teachers found innovative uses for technology throughout the century.

Support for the use of technology emerged from all levels, including professional organizations such as the National Science Teacher's Association (NSTA). The NSTA in 1998 stated:

> NSTA recognizes and encourages the development of sustained links between the informal institutions and schools. Informal education generally refers to programs and experiences developed outside of the classroom by institutions and organizations that include...media [such as] film, broadcast, and electronic. (p. 54)

The use of technology ranged from the informal as described above--students watching television programs such as Bill Nye the Science Guy or NOVA, to highly structured approaches such as Optical Data's Windows on Science videodisc series. In between were software programs that allowed and encouraged exploration by students, using the World Wide Web as a source of information and as a means of communication, and using software to create a presentation of their experimental results.

Connecting the use of these tools with the past and current ideas of scientific literacy provided the overall structure for this study as to what science education was all about. Scientific literacy represented a concept that evolved over the decades. In essence, it represented the purpose to which science teaching was to be dedicated. Over the decades it moved from primarily a content focus to a broader set of ideas which included also the thinking skills and goals for learning science in a way that would positively impact society for all its members.

To the reader with an interest in some of the curriculum movements of the late 1980s, this study recognized the contributions of the science-technology-society (STS) structure for science education. However, it does not focus on STS except to place it in the broader context of some of the primary curriculum issues of the 1980s and 1990s. Many STS advocates regarded technology primarily as a philosophy and design process rather than as a set of tools.

Scientific literacy represented the "why" of this study. Representing the "how" are the technological tools used to achieve goals in scientific literacy. In particular, the focus was directed toward the use of three technologies and their roles in science education: the motion picture, the television, and the computer. While other technologies have been helpful in the process of science teaching, these three are, in one fashion or another, still available for purchase. Each of these technologies was lauded as "solutions" to the problems faced by education; each offered many of the same promises for improved teaching and learning; and each was subsequently criticized for not living up to its promises. Following their evolution to the current practices in the 1990s affords the opportunity to see how the same tools were used as differing conceptions of scientific literacy evolved.

What also emerged from this study were general findings with respect to the use of technology in science teaching; the trends associated with the use of technology in the science classroom, applications unique to each technology, and the broader trends present among all three of them. In addition, how these trends impacted teaching practice and advanced the purposes of science education were examined.

Finally, the last purpose of this study was to provide a broader historical perspective for the use of technology in science teaching during the twentieth century and to offer suggestions for additional study. Examining the technologies of the past and examining why their potential was not realized can provide insights into better use of technology in the future.

The need for this study is related to the purpose identified previously. With the ever-increasing clamor encouraging the use of technology in the nation's science classroom, the utility of a historical study is clear. By placing contemporary uses of technology into a broader context, the current and anticipated uses of technology may more clearly be ascertained. Technologies that may be "mature" in terms of their theoretical use may be suffering from the struggles related to the early stages of implementation for some individual teachers and schools. To this end, this study provided a comprehensive overview of how the motion picture, the television, and the computer have been used to support the goals of science teaching. If a future reader is able to perceive his or her use of technology as part of a broader canvas, then the goals of this investigation have been met.

Limitation of the study to three media was necessary due to the large array of possible technologies in current and past use in the science classroom. Each of the technologies examined during the course of this study remains in use in one form or another. Other technologies, such as the overhead, have limited applications unique to science teaching such as the motion picture, the television, and the computer provide. Lastly, a comprehensive body of literature describing their use from their inception is available. Some technologies such as the overhead projector and the slide projector were veritable ciphers within the science education literature. These technologies remain for future investigations.

Before examining the motion picture, the television, and the computer, an audit of the various incarnations of scientific literacy was appropriate. This offers the broader context for the remainder of this investigation.

Scientific Literacy

The view of scientific literacy underwent a number of transitions during the twentieth century. Though the term "scientific literacy" was first coined in 1958 and has come to represent a certain set of goals in the teaching of science, other science education goals have been present throughout the twentieth century. In the earlier part of the century, the primary consideration of what constituted scientific literacy related to the depth and scope of content knowledge by students. As the decades wore on, to the content knowledge was first added a set of thinking skills and then a recognition of the role of knowledge in a broader societal context. The acquisition of the thinking and content tools of science would allow the scientifically literate citizen to "engage intelligently in public discourse and debate about matters of scientific and technological concern." (National Research Council, 1996, p. 13)

As various technologies have been used in support of teaching practice, they also reflected their times and the best thinking as to what constituted scientific literacy. The use of the motion picture and television, for example, was lauded in terms of bringing the outside world to the classroom. Making a situation more authentic for a student and enhancing the student's level of understanding provided rationale for the use of a technology that was consistent with the existing concept of scientific literacy.

By the early 1990s, the concept of scientific literacy had expanded to make science learning more inclusive for all students. <u>Science for all Americans</u> (American Association for the Advancement of Science, 1989) was not only a title of a document promoting scientific literacy, but it also served as a signal that anything less than universal scientific literacy was not to be tolerated. For example, current uses of the computer as a classroom tool helped to develop this theme in classroom practice. The computer helped to provide all students with access to information, thus providing an avenue for all students to achieve the goals of scientific literacy.

Scientific literacy has come to represent the goal of science teaching. The complete acceptance of this goal can be seen as numerous states have adopted similar goals for their own state learning standards. Illinois, to take one example, identified a number of broad goals consistent with the pursuit of scientific literacy, as well as specific classroom-level objectives that are consistent with scientific literacy objectives.

With similar goals adopted by the states and two national initiatives promoting the same general view of what represents scientific literacy, the broad notion of scientific literacy should remain intact for the foreseeable future. Barring another Nation at Risk type of document, with an emphasis on returning science education's focus exclusively to content, or a movement promoting the needs of an educated elite over the masses, the current conception of scientific literacy should take science education well into the next century.

The likelihood of a national curriculum of some form--including some goals related to that of scientific literacy is strong. Both the Clinton administration and the American Federation of Teachers have endorsed such a proposal; the Clinton administration's goal of national testing could serve as a first step toward the adoption of national educational goals and an attending curriculum. Arguments in favor and against this approach exist. The perceived need for consistency in content and identifiable goals for learning lend support to the introduction of a national curriculum. Arguing against a national curriculum are advocates of local control of schools and supporters of allowing maximum freedom for teachers to teach to the needs of their students. This argument will likely continue whichever approach the future holds.

The evolving definition of scientific literacy has been evident through the practice of science education throughout the twentieth century. The notion that students should have a command of the content and processes of science has been in place for most of this century. What occurred as the century progressed was an expansion of the goal to include all students. In the 1950s, Hurd's essay captured the essence of the need for a scientifically educated populace; by the 1990s, the idea of scientific literacy had formed the core of what science education should comprise.

Related to the evolution of the concept of scientific literacy was an observation by Bybee (1997) that one of the critical differences between the science education movements of the Sputnik era compared to those conceived during other times was that Sputnik era reforms were not organized through the development of policy statements. Most of the reforms of the 1960s tended to be curriculum packages and curriculum reforms, without the overarching structures of being part of a reform movement.

The reform movements of the 1980s and 1990s provided several competing, yet compatible views of the scientifically literate student. Reformers recognized the need for a scientifically educated student body, wise in the ways of science, technology, and society. A precise means of implementing the goals and policy remained a critical need through the end of the 1990s.

With the context of one hundred years of science education providing the background, we may now turn to an examination of technology and its applications in science education during this century. A "how to" statement regarding the use of technology in the classroom was needed 100 years ago; it would still be of use today. How technology has been a means of enhancing scientific literacy provides the organizing principle for the remainder of this study. The assorted successes and failures using technology to achieve this end provide the narrative.

The Motion Picture

The use of the motion picture over the last nine decades underwent several transitions in classroom application. Commentary from 1922 by Thomas Edison made the following statement regarding the use of the motion picture in instruction:

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks. I should say that on the average, we get about two percent efficiency out of schoolbooks as they are written today. The education of the future, as I see it, will be conducted through the medium of the motion picture...where it should be possible to achieve one hundred percent efficiency. (Cuban, 1986, p. 9)[1]

The wizard of Menlo Park played a significant role in America's infatuation with technology, receiving several hundred patents over the course of his life. Many of his inventions and their direct technological descendants are still in use today. Also present is the attitude that technology can help us to achieve closer to "one hundred percent efficiency" in our daily tasks--including education. Looking back from the future Edison envisioned, the goal of "one hundred percent efficiency" has not been achieved, yet technology has impacted science education in ways that scarcely could have been conceived.

The film was one of the first electrical-mechanical technologies to enter the domain of education, with a long and storied history. In the early days of the motion picture in the science classroom, the focus was on two issues: efficiency and accuracy of content knowledge. Numerous studies attempted to teach students identical sets of content, with the experimental group experiencing film-based instruction and the control

[1] It is also worth considering that Edison's enthusiasm for the motion picture is likely related to his having invented this particular technology.

group exposed to more traditional methods of instruction. This, in principle, served to address both goals. Teaching larger groups of students and teaching with a minimum of teacher interaction served the purposes of efficiency. Teaching with film as a tool allowed for the content knowledge to be prepared by experts, increasing the accuracy of the content. This point connected strongly with the scientific literacy considerations of the early part of the century, when the increased quality of content knowledge among students was essentially the exclusive focus.

As the decades wore on, and use of the motion picture became more common, advances in hardware, such as videotape, allowed for some changes in practice to take place that helped teachers to achieve more sophisticated objectives.

In its current guise as videotape, the motion picture continues to serve as a helpful classroom tool. The convenience offered though the use of taping television broadcasts for classroom use has been popular with the current generation of teachers. As the availability of pre-recorded tapes continues to grow as it has over the last fifteen years, videotape technology will continue to find itself welcome in the classroom.

Film loops, to cite another example, allowed teachers to focus on single concepts during a 3-4 minute presentation. As they were available in a cartridge that could simply be plugged in to a player, ease of operation was very high indeed. Though soundless, they were helpful in focusing on relationship and changes such as helping students to comprehend the role of components in vector forces, or the depletion of oxygen caused by a burning candle in a closed system. Their use has been absorbed by the videodisc, allowing essentially the same flexibility but in a more substantial format.

The videodisc provided another example of how improvements in hardware could be used to achieve educational goals. The extreme flexibility of the videodisc allowed for a greater degree of interactivity in its use in the classroom. As an interactive frog dissection, it helped students to focus on relationships between systems as well as on the identification of individual organs. For teachers, the traditional ability to bring the world into the classroom was supplemented by the capability of arranging the sequence of video images in any order desired. Uses for review and assessment, such as those outlined with the Britannica Science Essentials series, were also helpful for achieving goals of science literacy.

A potential change in the distribution system of motion pictures may be made through the Internet. As connection speeds increase and allow greater amounts of information to be more rapidly accessed by teachers and students, the means of accessing video information will likely be from central distribution centers. This idea is already in practice with the Folkways and Twin\Tone record companies; music is available for consumer download rather than traditional over the counter purchase. This allows each company to keep their entire music catalog "in print."

For video, the process would be similar, with teachers able to access desired video images from a central distribution facility. This is similar in concept to the "Education Utility" endorsed by Gooler (1986). This approach will be addressed in more detail shortly.

Digital Video Disc (DVD) technology is another area of critical interest, offering improvements and refinements in other aspects of the software and delivery system. Possessing the information storage capabilities of a twelve-inch videodisc, and much more, with the physical size of a CD-ROM, it leads to a number of areas of interest, in particular the development of interactive multimedia applications.

DVD was available by the late 1990s as a medium for commercial motion pictures, but the area of particular interest is its potential as an interactive learning tool. The DVD offers the ability to include as much as eight hours of video content on a disc only five inches in diameter, along with eight audio tracks, and interactive hypertext capabilities (without the use of a separate computer). DVD will offer creative educators an excellent tool to share video images with students--and a challenge for the creators and developers of educational media to make use of DVD's potential.

Instructional Television

The use of the television as an instructional tool may best be described in Fischbeck's words: television wasn't replacing the teacher--but rather just "helping out." Though television did not revolutionize the teaching of science as early advocates such as Poole (1950) had hoped, it did provide a useful tool for bringing the world to the classroom as had the motion picture in previous generations.

As with the use of the motion picture, literature surrounding the instructional use of television presented three distinct phases:

1. Development of interest and focus on the hardware.
2. Development of appropriate pedagogy, and
3. Dissemination of software as the use of technology enters a mature state.

Examples to support this view were evident throughout this study. Examples of the first phase included Poole's Science Via Television, Planning for Schools with Television, and This is Educational Television. Planning for Schools with Television, in particular, highlighted the technical issues associated with the hardware and classroom arrangements needed to optimize television teaching.

The second phase of television infusion, development of the appropriate pedagogy, was exemplified by works such as Diamond's (1964) A Guide to Instructional Television, which detailed many of the important instructional issues related to the use of the television in the classroom. Many of the examples he used were designed to demonstrate the effective teaching of scientific principles via television. Many efforts during the 1950s and 1960s (see, for example, Rock, Duva, and Murray, 1952; Rock, Duva, and Murray, 1954; and Levenson, and Stasheff, 1952; Midwest Program on Airborne Television Instruction, 1961) helped to develop and disseminate effective pedagogy for television instruction.

The final phase in the evolution of the television as a tool for science teaching--the dissemination of software--was more problematic than with the motion picture. The availability of useful science television programming was through either a locally produced set of materials [see TV Schooltime (Caristi, 1997; Iowa State University, 1998), Fischbeck's General Science (Eddy, 1971), or the Hagerstown (David, 1963) application] or through programs which were more educational than instructional (NOVA, 1-2-3: Contact, or the Scientific American Frontiers series). Instructional applications were adapted on a case-by-case basis for science instruction by classroom teachers.

Though videotaping relieved the teacher from being held captive to the broadcast time slot, the limited availability of useful classroom materials has been the greatest deterrent to more liberal use of television in the classroom. Some children's educational programming, despite the attention given to scientific accuracy of content, tended to support unfortunate stereotypes.

A final area for reflection had to do with the challenge of balancing entertainment versus instruction, especially when applied to the commercial television and cable ventures that were not related to a particular curriculum. The advantages of showing a diverse group of young people engaging positively in science would be considered a virtue; the entertainment value of placing television scientists in lab coats and fright wigs sent a different message.

The development of instructional television for the science classroom has undergone a transition from capturing live broadcasts to making use of videotape to use broadcasts at the convenience of the instructor. This practice will likely continue. Also the transition from locally produced programming to programs produced at a regional or national level should also continue.

Instructional television, at the outset, offered a few key differences between itself and motion pictures. In particular, the ease of use for the technology and the ability to experience live broadcasts of some interest gave it immediacy not offered by the motion picture. As the decades have passed, the increasing use of prerecorded broadcasts has allowed the differences between the motion picture and the use of a television as a teaching tool to become minimal.

Likely to change will be the means of receiving information via television. As in the home, the shift to cable and satellite-distributed broadcasts will likely become more common in schools. This will allow for a greater variety of educational programming to be used in the classroom, and videotaping will allow the broadcasts--whatever the source--to be used at a time deemed appropriate by the instructor.

The Internet may also find service as a means of bringing television broadcasts into the classroom. With greater sophistication in technology and greater delivery speeds occurring on a regular basis, the use of telecommunications technology to serve as a means of distributing television broadcasts would seem to be a logical progression in the classroom use of the television. As the video feed technology and content of the Internet continue to improve, it is quite possible that within a few years, the Internet will resemble a television set with thousands of channels available.

The Internet as a potential television receiver led to a consideration of what the future holds for the computer, and what new practices may be anticipated.

Computer

By examining the purposes served by the computer (as presented by Tinker, 1987)--as an instrument to acquire information, to analyze data, to offer creative expression, and to communicate with others--an appropriate organizational pattern was available.

The most common applications of the computer in science teaching were its use for simulation and information retrieval applications. Simulation software, available in both commercial and teacher-created varieties, provided an excellent means of developing science process skills and higher order thinking skills as a part of the student's interaction with the software.

Microcomputer Based Laboratories, though well-represented in the science teaching literature, were challenging endeavors during their early incarnation. While it is certain that students would benefit from their use of the MBL, the requirements for the teacher's knowledge base were extreme; few teachers would be likely to use them, due to the large amount of programming and hardware knowledge required.

The Internet and Interactive Video were among the most recent technology infusions into science teaching. Interactive Multimedia provided a number of simulation and investigation experiences for students in the sciences, with the level of interactivity much higher than in previous types of simulations. The Internet, both as a source of information and as a communications medium, found its way into larger and larger numbers of classrooms during the 1990s. Several initiatives engaged students in interactive learning with other students located across states, nations, and continents.

Scientific literacy issues were clearly supported by the use of the computer in the classroom. In particular, software that allowed students the chance to analyze and interpret data as well as empowering ever-larger groups of students to engage in scientific investigations, promoted the best ideas of contemporary scientific literacy (Thompson and King, 1997; King and Thompson, 1998).

Lastly, the pattern of hardware-pedagogy-software presented itself though any number of articles supporting the use of computer technology in the science classroom. As the development of hardware and software accelerated and the availability of computers in the home and school expanded during the 1980s and 1990s, so too did the number of articles assisting teachers with the infusion of technology in the classroom. Nonetheless, the pattern of hardware-pedagogy-software dissemination remained intact.

Reflecting on the place of the computer in science teaching, one was struck first by the similarity in the pattern of adoption seen with the motion picture and the television. The initial fixation on the hardware followed by the development of teaching strategies to be used with the computer represented the first two steps in the infusion of the computer in science instruction. Lastly, the application of software supporting instruction dominated much of the discussion pertaining to current computer use in the classroom.

A challenge facing future curriculum developers may relate to the flexibility inherent in some of the new technologies. It may be that the pattern of hardware-pedagogy-software may become a relic of a simpler, pre-digital age. Scripting DVD for learning situations has essentially no precedents. When used in conjunction with the computer, approaches to learning involving the interaction between the learner and software may place the creation of the software before the development of the most effective pedagogy. At the very least, a more iterative process in which the movement ahead depends on the interaction among the pedagogy, software, and even the hardware would seem to be a conservative speculation.

An additional reflection on this continuum of how technology's use evolved in classroom practice related to individual differences within schools and within teachers. Though the theory and practices were well advanced, individual schools and teachers are located farther down on the continuum of the technology-related experience. How to accelerate this process and engage more teachers in the use of technology in their teaching remains a challenge.

Tinker (1987) described a number of conceptual uses for the computer. The categories he suggested--information acquisition, data analysis, creativity, and communications--all represent areas for growth in the use of the computer in the science classroom.

The area of information acquisition offers some exciting possibilities. As mentioned previously, the ability to transmit video images via the Internet is showing great improvements in both quality and download speed. Enormous amounts of data and text are already available via telecommunications; adding improved video and audio to the database are the next logical steps.

From this point of view, entire curricula could be accessed electronically. The Education Utility, mentioned previously, provided a framework for this approach:

> The Education Utility is an electronic delivery and management system that will provide instantly, to the desks of educators and students located anywhere in the world, massive quantities of continually updated instructionally interactive information (software programs, databases, sophisticated graphics capabilities, news services, electronic journals, electronic mail, and other instructional and administrative materials). All of these materials will be stored or accessed through a main "host" computer. Individual educational sites...will be connected via a state network. (Gooler, 1986, pp. 11-12)

Through this Utility, individualized instruction, group work, and large group instruction could be organized electronically. This sort of approach would be well-served by a national curriculum, as the Education Utility would be ideally situated to operate as a delivery and management system. The philosophical issue as to how this would impact student and teacher autonomy remains to be decided. It is worth considering also that the Education Utility described by Gooler was more than simply a theoretical construct: it described an actual working program. That it was developed a decade before the common use of the Internet suggests that it was a sound approach, but the lack of supporting technology and software caused it to become a historical curiosity as well as a model for delivering instruction.

Anticipation of Future Trends

Having examined science education and technology through the course of the century, it is appropriate to place the use of technology in science teaching into a broader context and to consider other avenues for research into what the use of technology could bring to science education.

Technology has not necessarily produced radical innovations to the level of the teacherless classroom; rather, it has allowed some innovative activities to take place in individual science classrooms. Reports from science teachers have offered numerous practices that automated and innovated science instruction. Technology has been a tool for more effective instruction as teachers sought to achieve the evolving goals of scientific literacy.

Trends for the use of technology are difficult to predict. From the vantage point of a generation ago, some predicted that all teaching would have been taken over by machines in the name of both efficiency and effectiveness. What has transpired has been the use of technology to help students and teacher manage, present, and communicate information. The machine as teacher has appeared in some small ways, but the teacher using a machine is quite commonplace.

The greatest concern that can be expressed for science teaching is that the hands-on/minds-on experience should remain preeminent. Technology represents an important tool for effective teaching, but the heart of the science program should be developed around student inquiry with materials. Technology is best suited for extending and deepening the level of investigation and understanding, but not as a substitute for the activity.

Anticipated changes will take place in two areas. The first includes the issues discussed in this study--the hardware, pedagogy, and software associated with using technology in the teaching of science. This will allow students and teachers to gain more information, to manage their information more effectively, and to communicate between and among students and classrooms beyond a single room. Hurd (1997) summarized the advantages of technology in science education:

> The transformation of our powers of observation and the technology for the management of data emphasizes that the practice of science comprises both theory and craft....We can expect more changes in the practice of science as the "information superhighway" develops and makes it possible to locate and access all the knowledge ever produced in the sciences. (Hurd, 1997, p. 55)

The other area of anticipated change relates to educational policy. The Education Utility represents a vision that would require a serious realignment of the organization of the classroom, school, and school district. The Goals 2000 initiatives represent another policy issue that may potentially impact the way science teaching is carried out. Technology can ideally serve as a tool of democracy and empowerment, so long as all students have access to its resources. A worst case scenario would allow the current disparity in educational funding to continue in its present manner. This in effect would deprive students from impoverished school districts of access to technology.

This problem of disparity could be exacerbated if commercial publishers offer high quality--and expensive--curricula via the Internet. Technology-rich districts could access the finest curricula available, ultimately leaving other districts poorer in both their technology and knowledge available.

Other changes in technology hardware are worth noting: among them are the further development of DVD, and improvements associated with the information delivering potential of the Internet.

Current difficulties accessing information are related to slow download times or overloaded servers. As these difficulties are addressed and more useful information is made available electronically, the use of the Internet should continue unabated. Further, as the ease with which students may publish on the Internet increases, the potential to raise the use of the computer to a communications medium rather than an information retrieval medium is enhanced. Higher levels of interaction among students are generally associated with higher levels of engagement and higher levels of learning.

A consequence of the computer serving as a means of accessing information encoded on a DVD is the further blurring of the boundaries between the technologies examined in this study. As the computer itself becomes a single device that can deliver motion picture, broadcast television programs, and operate a wide variety of software, the various technologies examined here become separate but related applications in a single device. When the additional communications and information acquisition potential of the Internet are included as well, the computer has even greater potential to serve as a highly sophisticated educational tool--the Education Utility, indeed.

Suggestions for Future Research

A general statement regarding the use of technology in the classroom may be derived from Salomon and Gardner (1986). The focus of their article was to provide a caveat for those technology enthusiasts who would recklessly infuse the computer into classroom practice before sufficiently informed pedagogy was developed. Learning from the struggles of advocates of instructional television, they made the point that educators must

> realize that learners bring many assumptions, proclivities, and active learning strategies to any encounter with a new medium or technology; and...[to] expect a range of usages and experiences and a variety of outcomes from any encounter between an individual and a computer. It is particularly important to carry out background research before computers become completely pervasive in the educational environment. (Salomon and Gardner, 1986, p. 13)

It is now ten years later and too late for the background research to be carried out. The computer is present in many classrooms and serves primarily an ornamental function. The suggestion to be made here is that as we prepare to welcome new technologies into the classroom, the initial baseline data we collect can be of invaluable help during later efforts at infusion into instruction.

There are many technologies that previously maintained a presence in science teaching but are seldom seen at this date. The filmstrip represented a very popular technological tool for teaching, but is not commonly seen at this time. The greater availability of videotape and computer technology appears to have eliminated the use of the filmstrip as a commonly found teaching tool. By the late 1990s, only one manufacturer of filmstrips could be located, and the content of the filmstrips was not a topic useful to a science teacher. Examining how or why improvements in the computer and motion picture technologies led to the demise of the filmstrip as a teaching tool would be useful in terms of developing data regarding the useful lifetime of a technology. The value of the filmstrip still remains in terms of its content and value as an instructional tool; the machine, however has vanished. Seeking out the reasons for the demise of the machine may prove to be informative.

Other technologies, such as the radio and film loops, likewise had estimable tenures within science education. A determination of why so little software was produced to support their use would be enlightening for the same reasons as for the filmstrip. With respect to the radio in science education, what became of the radio? A technology as simple and ubiquitous as the radio must have disappeared from education for specific reasons.

An investigation into the use of technology informed by social psychology--particularly the use of expectation-value theory--can provide further insights into teachers' uses of technology. From the perspective of expectation-value theory, individuals engage in certain behaviors based on two factors: the value they attribute to engaging in the behavior and the expectation they have for success. Technology, with its promise of serving as an effective tool for teaching coupled with the challenge of requiring new skills for its user, would be well-served by a critical examination of the relative weight applied to these two factors.

An additional area warranting further investigation based on classroom observations of actual teacher practices. Actual classroom practice often departs greatly from what is reported on surveys and other forms of teaching inquiry. Time spent observing the actual classroom practices associated with the use of technology in science teaching could be most revealing. Findings from this body of investigation might well be applicable to both preservice and inservice education as teachers evaluate the benefits of using technology when weighed against the costs involved in its infusion.

An investigation into classroom uses of technology in other fields would also be of interest. Rather examining the use of technology in the context of scientific literacy, as was done here, examining the use of technology from the point of view of the dominant theories from educational psychology could prove to be most illuminating. How the dominant behavioral perspective from early in the century impacted the use of technology compared with the cognitive orientation present today would be highly engaging and illuminating.

A critical element missing in many instances is the modeling needed in colleges of education. The role of modeling has been well documented in the teacher education literature. Until such time as colleges of education promote the use of technology by modeling its use in all methods courses and requiring its use by preservice teachers, it is likely to remain a seldom-used tool.

And finally, the literature would be well served by an extension of the heart of this study into the next century. A continued and detailed accounting of the use of technology to achieve scientific literacy into the next century will provide a depth and scope of detail as to science teacher practice with the use of technology.

Reflection on this Study

At the outset of this study, the author would have predicted that numerous teachers would infuse technology simply for the sake of using technology. In essence, it was anticipated that the technology itself would provide a driving force for the infusion of technology into instruction. The technologies examined related a different story. Technology was more often than not implemented to achieve a particular instructional end--such as achieving scientific literacy--and not to promote the use of technology for its own sake. A typical article cited the advantages of using technology to assist teachers as either an "extra set of hands" or as a means of helping to develop science process skills and higher order thinking skills. The connection between the goals of scientific literacy and the potential that technology has offered to achieve that end has been consistent. Technology has provided such a tool for achieving scientific literacy.

The use of technology in science education underscores the need for a strong and coherent curriculum. Technology can serve as an excellent tool in the pursuit of scientific literacy, regardless of the device.

The recognition that most uses of technology are devoted to automating instruction rather than innovating instruction is a point worth making. Most practices, particularly related to the use of the computer, had an antecedent that did not make use of the computer. Dissections, communication, accessing information, and many other practices were common experiences in the classroom. Technology allowed these activities to occur with greater efficiency in some instances, and opened up opportunities to students that would not otherwise have existed.

Another trend with technology use has been the movement away from the view of teaching the entire lesson--viewing technology as a substitute for the teacher--to using the technology in only certain capacities. Though many educators in the early part of the century would have advocated the efficiency of a teacherless classroom--with all instruction offered by motion picture--this approach never really became common. Most examples from the literature described practices that attempted to do this, but the review of the literature did not reveal many instances of this becoming standard instructional practice. In essence, selecting the best tool for the task has become the common practice. Science fiction dreams of teacherless classrooms remain a fiction rooted in the past.

Another issue to consider regarding the use of technology in the classroom relates to student access. Democratic issues regarding access to technology for all students are a real concern. For all students to experience the advantages of technology, more equitable funding practices need to be implemented for American schools. As long as poor urban schools have to "ration crayons, pencils [and] writing paper" (Kozol, 1991, p. 64) technological equality is chimeral at best.

The final word: good teachers use a variety of tools. Technology represents one of the most important and effective tools available to a classroom teacher. In all of its manifestations, technology represents a dynamic and engaging tool: a tool with which teachers may elevate their students' understanding and appreciation of the goals of scientific literacy, now and in the future.

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TEACHER PREFERENCES FOR AN ADVANCED MASTERS DEGREE BASED ON NBPTS AND NCATE STANDARDS

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Many universities are in the process of modifying or restructuring their Masters Degree programs for teachers. In North Carolina, the 1997 Excellent Schools Act requires state universities to restructure their Masters Degree programs for teachers for implementation in the fall of 2000. The goal of the process is to shift from programs that emphasize scholarly preparation to those that target teaching practice and student achievement. University teacher educators are ultimately responsible for developing the new programs, but it is important to consider teachers' opinions about what they value most in a proposed Masters Degree program.

Development of Standards

Following the publication of *A Nation Prepared: Teachers for the 21st Century* (Carnegie Forum on Education and the Economy, 1986), a series of connected events resulted in a national focus on the development of Masters Degree programs relevant to the work of the profession. The National Board for Professional Teaching Standards was organized "to establish high standards for what teachers need to know and be able to do, and to certify teachers who meet that standard" (Carnegie, 1986, p. 55). Following the lead of the NBPTS, other agencies joined the movement toward standards-based preparation of teachers. As outlined in *What Matters Most: Teaching for America's Future* (The National Commission on Teaching & American's Future, 1996), the National Council for the Accreditation of Teacher Education (NCATE) and the Interstate New Teacher Assessment and Support Consortium (INTASC) set their own standards for initial teacher preparation and for state licensure as consistent extensions of the NBPTS standards (Blackwell & Diez, 1998).

Framework

Three current influences were considered in constructing a framework for the study: (a) the core propositions of the National Board for Professional Teaching Standards, (b) the core competencies proposed for inclusion in the Advanced Masters Degree programs required in North Carolina's universities, and (c) the sociocultural understandings of learning.

The NBPTS core propositions include the following: (a) commitment to students and their learning, (b) knowledge of subjects and subject-specific pedagogy, (c) responsibility for managing and monitoring student learning, (d) systematic reflection about practice, and (e) participation in learning communities (NBPTS, 1994). Reflecting the philosophy of NBPTS, the Advanced Masters competencies for North Carolina address these areas: instructional expertise, knowledge of learners, research expertise, ability to connect subject matter and learners, and professional development and leadership.

A theoretical framework, implicit in the priorities of both the NBPTS and the Advanced Masters competencies, is that suggested by sociocultural analysis. Traditional learning theories have emphasized the transmission of existing knowledge without recognizing the invention of new knowledge in the context of practice (Chaiklin & Lave, 1993). The work of sociocultural analysis has provided a means to relate mental functioning to a cultural, institutional, and historical context (Wertsch, 1998). The proposed graduate programs incorporate the theoretical foundation of sociocultural analysis by incorporating the complex relations among person, activity, and situation into a single entity, encouraging the teacher to learn in the context of practice and reflection on that practice.

Design and Procedure

A survey was designed to gather demographic information and to assess beliefs and attitudes from teachers about the proposed Advanced Masters degree. Surveys were completed by approximately 300 teachers attending 1998 summer workshops and courses at the university centers comprising the Mathematics and Science Education Network. Frequency data were analyzed to reflect trends in teachers' thinking and then re-examined to investigate relationships among the survey data. The survey was developed with three sections: (a) teacher demographic data, (b) ranking of various components of the proposed new degree program, and (c) a Likert opinion scale linked to specific statements related to the North Carolina competencies.

The instrument development process included review by a panel of experts and trials and interviews with a dozen K-12 science and mathematics teachers. Surveys were mailed to UNC-MSEN center directors who distributed them to teachers attending their summer workshops. While some sections were left blank, the response rate was approximately 95%.

Summary of Results

Demographic Data/Teacher Backgrounds

Demographic data provides a picture of the teachers who responded to the survey. Table 1 shows years of experience.

Table 1
Years of Experience

Years of Experience	0-5	6-10	11-15	>15
% of teachers	30	20	11	39

Table 2 shows the numbers of teachers who have received National Board Certification, who anticipate going through the Certification Process and who have Masters Degrees.

Table 2
Certification and Degrees

% of teachers who hold National Board Certification	% of teachers who plan to pursue National Board Certification	% of teachers with Masters Degree
6	36	38

It is important to note that North Carolina provides two financial incentives for teachers to pursue National Board Certification--payment of the $2000 fee for the process (upon successful completion) and a 12% pay raise. It is, therefore, not surprising to find that over one-third of the teachers surveyed plan to go through the process.

Table 3 indicates the factors that teachers listed as incentives that would influence them to pursue a Masters Degree. They are listed in descending order of importance.

Table 3
Incentives for a Masters Degree

Incentive (See below)	1	2	3	4	5	6	7
% of teachers	60	52	48	46	44	39	3

Incentives: 1 = Improvement of Teaching; 2 = Financial Reward; 3 = Improvement of Students' Learning; 4 = Personal Satisfaction; 5 = Professional Development; 6 = Career Advancement; 7 = Other

The most commonly noted incentive that would influence the respondents is "Improvement of Teaching", and the least important is "Career Advancement." These responses suggest that the teachers surveyed are interested in remaining in the classroom and improving their practice there rather than in preparing themselves for administrative positions that would take them from the classroom.

An open-ended question (#10) asked teachers to list barriers to pursuing a Masters Degree. As one could expect, time (65% of respondents) and money (57%) are the two most influential barriers. "Family Reasons" is a distant third at 14%. Various other reasons were listed, such as fear of tests, missing work, time limit on courses.

Preferences Regarding the Masters Degree

Recipients were asked in Section 2 of the survey to rank seven areas in order of value. Table 4 shows the percentage of teachers who ranked each area as most important as well as the percentage of teachers who ranked each area as least important.

Table 4
Ranking of Masters Degree Components in Terms of Importance

Components of Program	% of Teachers Ranking as Most Important	% of Teachers Ranking as Least Important
Knowledge of Instruction (theories, philosophies, research, current practice)	15	10
Knowledge of Learners (diversity; intellectual, physical, and emotional development)	17	6
Knowledge of Research (data-collection methods, interpretation of findings)	7	30
Knowledge of Subject Matter and Learners (content knowledge, best teaching practice for student learning in specific disciplines such as math or science)	57	4
Teaching Practice (applications of teaching strategies, management, pedagogy)	22	4
Assessment (assessing one's own teaching practice, student learning, program effectiveness)	10	10
Professional Development and Leadership (professional inquiry, collaboration, mentoring)	7	26

Note that the two highest ranked areas focus on teaching practice, particularly teaching practice in the context of specific disciplines. The areas of least interest are knowledge of research and professional development and leadership.

Section 3 of the survey consisted of 30 statements and asked teachers to give their opinions ranging from "Strongly Agree" to "Strongly Disagree" on a five-point Likert scale.

While some statements had almost uniform support (or rejection, in case of negatively stated statements), other statements were controversial. Table 5 shows the statements that showed the most agreement among respondents. Some of the more controversial statements are shown in Table 6 below:

Table 5
Statements That Show High Agreement Among Teachers

Rank by Agreement	Statement	Agree	No Opinion	Disagree
1	#22 "I value the suggestions of other professionals as I try to improve my teaching"	97%	2%	1%
2	#15 "Technology does not have many practical applications in my subject area."	4%	2%	95%
3	#25 "If I use my knowledge of student differences, I can improve student achievement."	93%	6%	1%
4	#17 "It is important to recognize and assess diverse learning behaviors and outcomes within my classroom"	93%	5%	2%
5	#13 "I would profit from learning additional assessment methods of student achievement."	92%	5%	3%
6	#24 "It is imperative for me to use technology tools to enhance instruction."	92%	5%	3%

Table 6
Statements That Show High Disagreement Among Teachers

Statement	Agree	No Opinion	Disagree
"I expect a Masters Degree will change my philosophy of education."	34%	28%	37%
"The GRE entrance requirement could prevent me from pursuing a Masters Degree."	22%	25%	53%
"It is essential for me to learn theory, philosophy and research to improve my students' achievement."	56%	28%	16%

Statements 1-29 were grouped into clusters in accordance with their relationship to the general areas used in Section 2 (for ranking by teachers). Two categories were collapsed into one (knowledge of subject matter/ learners and teaching practice) because both of these categories addressed instructional implementation. Table 7 shows the responses of teaches to six categories.

Table 7
Teachers' Responses to Statements

Category	Positive Response	No Opinion	Negative Response
Knowledge of Instruction	62%	23%	16%
Knowledge of Learners	89%	5%	6%
Knowledge of Research	70%	20%	10%
Knowledge of Subject Matter	84%	9%	8%
Assessment	90%	7%	3%
Professional Development and Leadership	77%	18%	5%

It is interesting to note that the teachers' responses to specific statements indicate different priorities from their responses to the general categories (as seen in Table 4). For example, only 10% of the teachers ranked assessment as #1 in importance in table 4, but 90% of the teachers gave positive responses to specific statements regarding the importance of assessment. All topics received positive responses from most participants (from 90% for "Assessment" to 62% for "Knowledge of Instruction").

Conclusions

There were, for the most part, positive responses to almost all of the specific statements; therefore, there was little discrimination except for the few controversial statements seen in Table 6. In the cases where the respondents were forced to rank categories, trends in priorities are more obvious. The data suggests that the areas of greatest interest to them for Masters Degree programs are those that directly address instructional issues. They are not as interested in philosophical issues that relate to instruction nor to research issues (as they would define them).

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DEVELOPING PARTNERSHIPS: TEACHER BELIEFS AND PRACTICES AND THE STS CLASSROOM

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Science Reform

Reform of science education and scientific literacy: these issues dominate science education literature today. Our global society demands scientific literacy, which can be achieved through the reform of science education in public schools. The citizenry of the United States must be literate enough to comprehend and make intelligent decisions about everyday issues such as health, water quality, and global warming. Furthermore, the implications of such decisions must be understood. Scientific literacy is the knowledge and understanding of scientific concepts and processes required for making these decisions (National Research Council, [NRC], 1996). National reform efforts have mandated the changes needed in order to create a generation of students that possess a level of scientific literacy significant enough to allow them to take an active part in discussions and decisions about these community and global issues. The reforms of the last 50 years have given educators curriculum materials, teacher proof science kits, and teaching activities. The missing piece, essential for true reform, is the consideration of teacher beliefs and how those beliefs influence teacher practice and student learning (Bybee, 1997).

Science education reform literature is also dominated by calls to improve the teaching and learning of science in order to meet the demands of diverse students in a highly technological society. Successful reform requires input and support from all participants: teachers, parents, college faculty, business mentors, and students. It also requires a long-term commitment of human resources and materials and is made by teachers in the trenches of local schools districts. These types of reforms are collaborative programs of long-term change (Ellis, 1993). Attempts at change, or reform are often made by training teachers through workshops or conferences with little lasting change. In the review of information about science education reform, teaching and learning, and teacher training, one question became prevalent, however, to this researcher. What type of collaborative effort or professional development would facilitate rather than limit reform efforts in science education?

The purpose of this proposal for study is to investigate a long-term collaborative program termed the Kansas Collaborative Research Network (KanCRN). KanCRN is a science-technology-society (STS) based professional development program of curricular reform in collaborative partnership with the Kansas City, Kansas Public Schools. The intent of this investigation is to develop a study that ties teacher beliefs and practice together with a STS professional development model. An effort will be made to embark on the development of a theory that can be used to interpret types of professional development that would assist in the evolution of teacher beliefs and instructional practices in the science classroom.

Through this paper, the relationship between teacher beliefs as they relate to instructional practices in the classroom will first be addressed. Secondly, a review of the information concerning teacher beliefs in relation to STS themes of instruction is provided. In the third segment, insight into the role professional development plays in the evolution of teacher beliefs and practice is given. In the last section, the KanCRN STS model of professional development, in partnership with the Kansas City, Kansas (KCK) public schools, and how it relates to the concepts of teacher beliefs, practice, and training of teachers will be described. Finally, the proposal for further study is made.

Teacher Beliefs: Impact on Practice

Teacher beliefs play a vital role in the reform of science education. All teachers of science have implicit and explicit beliefs about science, inquiry, teaching, and learning (NRC, 1996). Change in practice can happen only with a corresponding change in the beliefs that govern those practices. Current research on teaching and learning emphasizes a shift in focus from observable teacher behaviors to teacher beliefs and their impact on teacher behaviors and practices. This research differs radically from earlier research that viewed teachers as technicians who delivered pre-packaged curriculum (Isenberg, 1990). Researchers now acknowledge the powerful influence teachers have on curricular implementation, and that often, curriculum is not implemented in the way it was designed to be (Cronin-Jones, 1991). This could be because teachers have difficulty implementing curriculum that does not support their own personal beliefs about teaching and learning. It becomes apparent that teachers' beliefs are at the apex for the choices they make concerning instruction. Teacher beliefs can actually act as a filter through which instructional judgments are made (Shavelson, 1983). These beliefs shape the nature of instructional practice. We must then realize that no matter how pre-packaged the curriculum is, each teacher is an individual with individual beliefs. Consequently, those beliefs will affect the implementation of any curriculum.

In the quest for educational reform, understanding teacher belief systems will contribute to enhancing educational effectiveness (Brophy & Good, 1974). As a result, several researchers are devoting time to understanding the impact of teacher beliefs on practice. Through their work with the Theory of Planned Behavior, Haney, Czerniak, and Lumpe (1996, 1998) determined that teacher beliefs are "significant" indicators of the behaviors that will be present in the classroom. Given that these behaviors or actions impact students, they play a large role in science reform. Ellis and Maxwell (1995) have shared information concerning the relationship between a teacher's predisposition about implementing various educational innovations and the behaviors and practices that occur. For implementation of the innovation to be successful, teachers must believe that the new innovation is not a "fad". Additionally, they must believe that the innovation will improve teaching and learning, be cost effective, and easy to master. Teachers must be allowed to experiment with the innovation in a low-risk environment and receive positive feedback for using the innovation. From works such as these, the complexity involved in the relationship between teacher belief systems and practices that occur in a classroom can be seen. Hence, reformists and innovators "can only ignore these belief systems at their own peril" (Clark and Peterson, 1986). Reform efforts cannot be top down, quick fix efforts. Further investigations of teacher belief systems in the context of science reform are needed to guide current science reform into lasting change.

Teacher Beliefs about STS

A major movement in the reform of science education is the presence of STS themes of study (Bybee, Ellis, Giese, Parisi, & Singleton, 1992). The STS focus is associated with new goals of science education aimed at the critical thinking, problem solving, and civic decision making capabilities of all students. (Ben-Chaim, Joffee, & Zoller, 1994). With STS themes of study, students work at self-directed rates with several activities going on in the classroom concurrently. The teacher facilitates and coordinates the learning tasks, and students become active participants, working at higher levels of thinking. (Loucks-Horsley, Kapitan, Carlson, Keurbis, Clark, Melle, Sachse, & Walton, 1990). STS implementation practices open paths to instructional strategies that engage students in long-term, inquiry, discovery, or research-based approaches to learning with real world applications.

Teacher beliefs play a major role in classroom reform. Teacher participation in reform is critical. Thus, when considering a STS approach to classroom instruction, teacher beliefs about STS implementation require attention. Teacher beliefs concerning STS implementation and inquiry learning can defeat the reform movements emphasizing STS themes. In fact, a problem noted in the work of Ben-Chaim et al. (1994) was that teachers had trouble distinguishing between science technology tools and general technology. This indicated that teachers must be involved in the actual development of STS curriculum so they can build their knowledge concerning STS themes of teaching and learning and reform their beliefs along the way. As students are constructing their own knowledge about STS themes of study, teachers must also have the opportunity to construct their views and beliefs about STS. For STS directed change to be successfully institutionalized teachers must be empowered as researchers and participants in the decision making process (Ben-Chaim et al., 1994). Beliefs built through participation and active research of teachers will translate into whether or not they effectively implement a STS program of study.

Beliefs about the inclusion of STS study should first be identified so training can focus on the identified beliefs. When asking teachers open-ended questions about STS instruction, Lumpe et al. (1998) found that teachers believe including STS can develop decision making skills in students and provide meaningful applications of science to real life. However, their concern lies in the time it takes to do this type of teaching and learning, as well as the controversial issues that are involved in some STS themes. Identifying these concerns is important because they form the beliefs teachers hold toward STS themes of study, and the practices that occur in the classroom. However, addressing these concerns takes time. The NRC (1996) tells us that teachers can be effective guides for student learning if they have time to examine their own beliefs. Therefore, identifying beliefs is the first step in fostering true change.

Beliefs about STS instruction can be reformed by means of appropriately designed inservice training consisting of intensive training in the areas of scientific knowledge and inquiry skills (Ben-Chaim et al., 1994). This type of professional development however, cannot take the form of an after-school inservice meeting. Teachers need time to reflect and reshape their beliefs. This period of time is stressful for teachers. However, as stated by Dwyer, Ringstaff, and Sandholtz (1991), "teacher beliefs may best be modified while they are in the thick of change, taking risks, and facing uncertainty" (p. 46). So while this might be overwhelming, positive beliefs about STS can be fostered. Moreover, long-term professional development gives teachers the time and opportunity to correlate their beliefs with reform recommendations.

Beliefs, Practice, Change, & the Role of Professional Development

What is meant by long-term professional development? Previously, professional development consisted of one-hour, after school inservice meetings, or two daylong conferences. Additionally, teachers have not been seen as sources of information on what is needed in their professional development. As Liberman (1995) reported, "teachers have been told all too often that other peoples' understandings of teaching and learning are more important than theirs and that their work with students everyday is of less value" (p. 67). Traditional approaches to teacher development are limited because they lack knowledge of how teachers learn, ignore teachers' voices, and revolve around the belief that teaching is a technical set of skills void of teacher invention or the crafting of knowledge. Additionally, traditional professional development has often ignored the context within which teachers work (Liberman, 1995). School administrators are beginning to discover the power and critical importance of professional development when it is viewed as an integral part of life in a school.

Professional development in contemporary education is evolving into a model consistent with the way teachers are expected to work with their students. That model consists of knowledge building, or the constructivist approach to the development of knowledge and techniques, verses information dissemination (Liberman, 1995). People learn best when they are actively involved in thinking about and discussing what they have learned. Contemporary professional development is seen as an active, ongoing, lifetime process that occurs in the daily context of classroom practice. Professional development practices that are built on this approach are at the heart of an expanded view of teacher development. Furthermore, Liberman (1995) found that professional development practices of this type allow teachers a voice in dictating the direction of their professional learning and allow for the construction of ways to bridge the gaps between theory and practice. Teachers get more from their professional development activities because they help determine them.

Included in the new conceptions of professional development is the idea that teachers must participate in a form of daily inquiry about their profession. This type of action-based research should be seen as part of the expectations for the role of a teacher. If teachers want their voice to be heard, they must be willing to be involved with rigorous, daily research about the teaching and learning that happens in their classrooms. Teacher learning does not end with preservice training. Professional development for teachers should be as rigorous as the professional development for other professions. It should be a lifelong process that is an integral part of the culture of the school day (NRC, 1996). Teachers are involved in continuous decision making about the actions that will facilitate student learning. Skills in making these decisions are developed by active participation in the development of knowledge and reflection concerning effective techniques of practice. Professional development activities must also be sustained, contextual and require participation and reflection (NRC, 1996).

If reform plans are to be made operational, enabling teachers to change the way they work, teachers must have opportunities to talk, think, try, and hone new practices. This means they must be involved in learning about, developing and using new ideas with their students (Liberman, 1995). Teachers must be allowed to be the sources of their own growth and professional development. As professional development moves from a traditional inservice model toward long-term continuous learning, the idea of professional development takes on new meaning and status. Involved in that new meaning is the idea of collaborations between teachers, parents, universities, business mentors, and schools.

A Partnership: The Kansas Collaborative Research Network

Although there is a vast amount of professional development that takes place inside the school, there are a growing number of partnerships that exist with schools that offer opportunities for teachers to work on topics they develop, or that are of interest to them. Benefits of such partnerships are the development of a community of shared understandings that support change in teaching practices and provide the intellectual stimulation necessary for lasting growth and reform (Liberman, 1995).

One such partnership is the Kansas Collaborative Research Network (KanCRN). KanCRN is a community of researchers, teachers, and students interested in conducting collaborative research. The U.S. Department of Education funds KanCRN under a technology innovation challenge grant. Developed originally by the Kansas City, Kansas Public Schools, the

Olathe, Kansas School District, and the University of Kansas, this cohort is working together to create a professional development model that demonstrates that doing science is a better way of learning science. The new Kansas State science standards are clear about the central importance of real science. The partnership has grown to include the Kansas City, Kansas Public Schools, the Turner School District, the City of Kansas City, Kansas, the County of Wyandotte in Kansas, the Catholic Archdiocese of Kansas City, Kansas, Environmental Systems Research Institute Inc., High Performance Systems Inc., Genentech Corporation, the Kansas Data Access Center at the Kansas Geological Survey, Silicon Prairie Technology Association, and the Advanced Learning Technology Alliance at the University of Kansas. Consortium partners such as the University of Kansas, Silicon Prairie Technology Association, and Science Pioneers provide the "mentor connection" arm of the partnership. These groups have joined forces in an effort to develop a community of researchers, mentors, teachers, community persons, parents, and students interested in conducting collaborative research into the nature of the natural, social, and economic world. As Ellis (1995) states, with the stakeholders as the creators of the projects, relationships are developed around naturally occurring commonalties and interests and not with a "top down," "teacher proof" approach. The community of KanCRN seeks to expand to nationwide participation and is committed to promoting the processes of scientific research among students.

Following is a description of the KanCRN Professional Development Model, Student Involvement with the Model, the Role Technology plays in the partnership, the Societal Link present in the model, and KanCRN's consideration of Teacher Beliefs. Baseline Data Collection will then be shared, and finally, proposal for study will be made.

The Professional Development Model of KanCRN

As stated previously, teacher voice and active involvement in knowledge building within their own professional development is essential in order to bridge the gaps between beliefs, theory, and practice. Educational change has a greater chance to be successful in programs where all stakeholders work collaboratively and voluntarily to establish and embrace common goals and courses of action (Woodrow, Mayer-Smith, & Pedretti, 1996). Additionally, when implementing programs of change, there must be multiple training sessions over extended periods of time by credible and knowledgeable instructors. Training activities must be matched to the concerns and needs of the teachers, and teachers must be involved in the planning of the program. Implementation should occur with an appropriate balance between training and practice in a comfortable, low-risk environment. (Ellis, 1995).

The KanCRN model exists in an environment where teachers and business mentors jointly create the learning experiences and develop courses of action to improve the teaching and learning of science. KanCRN selects teachers who sign on with the collaboration to develop new projects. Furthermore, minigrants are offered to teachers who have collaborative ideas they are interested in developing. Teachers are active participants in the decision-making processes of the program, because they are learning by doing. Additionally, their professional development occurs through active participation in the context of their classrooms where the improvements in their teaching lend themselves to greater opportunities to improve student learning. This opportunity to experiment and work with new curriculum in the low-risk environment of their classrooms is seen as a precursor to the effective implementation of innovative curriculum. Not only are the STS curricular projects of KanCRN developed by teachers, but the teachers also govern the multiple types of professional development activities that are offered by the qualified KanCRN developers, mentors, and teachers. The suggestions for professional development needs come from interviews, surveys, and discussions with teachers. Through their active participation in the development, implementation, and collaborative meetings with the KanCRN developers and mentors, teachers have the interaction, voice, and time needed to correlate their beliefs and practices with reform recommendations.

There are various additional types of support available for teachers involved in the KanCRN projects. On-line support for teachers includes descriptions of development opportunities that teachers have requested along with a calendar of the times they are offered. A teacher chat room for sharing ideas and questions, a list serve, and many links to outside resources are also available on-line. Teachers involved with the KanCRN partnership meet together after school three days a week to monitor and assess the effectiveness of the program. They also meet with the developers one time a month and for five days during the summer to evaluate the program and plan new projects. Teachers are paid for their professional development time. Opportunities to attend presentations and classes developed around topics requested by the teachers ensure that their needs are matched with development opportunities. This active participation also gives teachers needed ownership in their professional development.

Student Involvement

Noteworthy instructional models for science and technology learning need to be consistent with the way scientific investigations are carried out. Students working on KanCRN projects collect and analyze data. They then develop a social action plan based on the data. The hope is that this discovery-oriented approach to knowledge acquisition will develop students who take an active role in their learning, assume more responsibility for the direction of their work, and become literate decision-makers.

The basic activities of KanCRN include structured research projects located on the KanCRN web site. The web sites are fully interactive, allowing students to communicate with other students working on the same or similar projects. These posted research ideas include background information on specific themes, protocols for conducting experiments, data submission forms, databases linked to the web site for storing collected data, display of school data, and form-based web pages for submitting personal research work. Teachers, students and research mentors communicate about research projects using the discussion forums also located on the KanCRN web site. The web site also serves as a repository of student work, submitted on-line and made available for evaluation, scoring, publication, and dissemination. Students use the structured research projects as a sounding board for their own research. Mentors provide feedback to students and teachers about the research questions they generate, about their experimental investigative procedures, and about the data they collect. Additionally, mentors provide helpful and suggestive feedback about the conclusions they reach. A student research conference is held annually at the end of the academic year for students to present the results of their research in a "professional conference" atmosphere.

Table 1
Sampling of KanCRN Projects

1. Ground Level Ozone—ground level ozone is believed to be the most ubiquitous air pollutant and the cause of most of the injury to biological resources. Using a combination of ground level testing and a bio indicator, students will determine the extent and impact of ozone on local ecosystems. (Elementary-high school grade levels).

2. SO2 and Lichens—research indicates that lichens and the tardigrades living on them can be used to access atmospheric levels of SO2. When lichens are exposed to some kinds of air pollutants, especially to sulfur dioxide, lichens are injured and die. They therefore make good indicators of air pollution. The effect of these pollutants may be observed on the distribution and diversity of a simple community living on the lichens. (High school grade levels).

3. UV and Yeast—human activities, including the production of chlorofluorocarbons, have reduced the concentration of stratospheric ozone. Ozone molecules in the stratosphere filter biologically harmful ultraviolet radiation (UV-B) coming from the sun. A possible biological UV dosimeter is an ultraviolet sensitive strain of yeast. Students use this indicator to gain a deeper understanding of this global change. (High school grade levels).

4. Amphibian Biomonitoring—because amphibians have a biphasic life cycle, permeable skin, and are exposed to pollutants and other environmental stresses on a daily basis, they can serve as an early warning indicator of potential drastic changes in the ecosystems. Students investigate the worldwide decline in amphibian population as a possible indication of declining environmental conditions. (Middle-school grade levels).

5. Natural Dyes and Stain Removal—this projects invites students to participate in using the scientific research methods to explore introductory biochemistry. Using local plant species, the students will hypothesize about the colors that will be generated. Questions to be investigated include: Are natural dyes more environmentally friendly than synthetic dyes? Do natural dyes resist stains? Do the natural dyes hold their color? (Elementary and middle school grade levels).

The Role of Technology

KanCRN uses technology as a tool to allow students the ability to do things they would not otherwise be able to do. Students use technology as the avenue to work within the projects, for information gathering, communication, data collection, data sharing, data analysis, and publication of work for review. Teachers use technology in many of the same ways. Technology, however, is much more than hardware. Technology originates in problems of human adaptation to the environment. From the problems identified in adapting to the environment, solutions to problems are developed. Through interaction with KanCRN projects, science is linked to technology in order to facilitate problem solving and meaningful learning. The hope is that students will be prepared to understand the implications of both science and technology in their own lives.

The Societal Link

The integration of technology underlies KanCRN. Technology is used to allow students the ability to do things they would not otherwise be able to do. KanCRN is a local collaborative research model that uses technology to incorporate the fundamental vision of the national standards of both science and math, and the benchmarks in science. The project includes elements of communication, data collection, data sharing, data analysis, and publication of work for review.

The KanCRN model contains a clear link to the social sciences. The science problem solving cycle and a cycle of societal ethical decision making drive one another. This link provides a pathway for students to follow as they use the knowledge they have helped generate to begin effective social action. The model posits student movement from just being activists to becoming decision-makers who base their actions on knowledge.

While the focus of this project is science and math education with a link to the social sciences, the tools of KanCRN are flexible enough to be used by any curriculum area that incorporates inquiry, research, and/or modeling as a part of their curriculum. It is anticipated that teachers across a broad spectrum of disciplines will be interested in applying KanCRN tools to their curricula. Because of the nature of student work in KanCRN that includes emphasis on reading, writing, and oral presentations, it is anticipated that technology will also support the goals of communications and language arts programs.

The goal is to create a scientifically and technology literate population of students that will create and act on knowledge and make educated decisions on the personal, ethical, and societal questions raised by their interaction with, and dependence, on the natural world.

KanCRN's Connection to the National Science Standards

The project proposes a new relationship between research and education. This type of daily inquiry is essential for teachers in their building of knowledge and consequent change in practice. Additionally, the result of this type of inquiry research aids student learning and adds significance to student understanding of the natural world. Inquiry is central to science learning. Students involved in inquiry ask questions, make predictions and inferences, and work toward solutions. Through scientific inquiry the students' questions can be derived from curiosity about everyday life. As individual students share their findings with others, they evolve into scientific communities (NRC, 1996). Good school science, as Loucks-Horsley et al. (1990) tell us, engages children in the study of the natural world. The desired outcome is for children to be good explorers. We also want them to pose good question, make predictions, and construct their own knowledge about scientific principles along the way. This is the ultimate vision of KanCRN: doing science.

From this perspective, it can be seen that KanCRN addresses the vision of the National Science Standards by modeling the research process and by providing for student reading and writing applications. In the vision presented by the Standards, inquiry is a step beyond "science as a process," in which students learn skills such as observation, inference, and experimentation. The new vision includes the processes of science and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Combining the conceptual with the procedural unifies the science disciplines and provides students with powerful ideas to help them understand the natural world. Science as inquiry is basic to science education and is a controlling principle in the organization and selection of student activities. Engaging students in inquiry provides them with opportunities to develop an understanding of the nature of science. Science should not be something that is done to the students, but by them. KanCRN also ties with the National Science Standards in the area of professional development. Those ties are in the process of being defined.

The KanCRN model of professional development involves teachers in long-term professional development in the context in which they work, the classroom. It is an integral part of the school day. Teachers and students are both involved in "doing" science. Teachers, as the developers, researchers, and participants with students in inquiry, are the source of their own growth and professional development. This is essential in order to achieve true reform of teacher practices.

KanCRN and Teacher Beliefs

The successful implementation of an innovative curricular program in the classroom is dependent upon the full participation and shared vision of the teachers involved in the decision making process. This shared vision cannot be achieved without attending to the beliefs of the teachers involved. Teachers fall along a continuum from those who teach using demonstration laboratory exercises, to those who involve their students in original research. The decision of a teacher's place on the continuum is based on their beliefs. The relationship between teachers' written statements of beliefs are inconsistent with practices. Liberman's (1995) work with the Southern Maine Partnership supports this inconsistency theory. This nine year partnership between the University of Southern Maine and a group of surrounding school districts brought teachers together to discuss research and educational practices. It became apparent that what they believed and valued and what they practiced were not always in synch. The result of the partnership has been a reform in the teacher education programs in both the university and the public school. This bringing together of teachers and university faculty provided both with access to new ideas and a supportive community aimed at reform of teaching and learning. Members of the KanCRN partnership hope to achieve this type of result with the implementation of its STS model of professional development.

In an effort to achieve more congruence between the intended and implemented curriculum, professional development should put more effort into determining teacher beliefs by soliciting input from teachers during all phases of the program implementation. Several studies have focused on teacher beliefs involved in innovative programs and the implications for practice. Haney et al. (1996) worked extensively with the Theory of Planned Behavior Model. With this model, beliefs were used to predict individual intention to engage in specific behaviors. Through their work, they discovered that teacher attitudes and beliefs were critical to change in practice. They reported that attendance to beliefs is a precursor to change. In their latest work, Lumpe et al. (1998), involve teacher beliefs and STS themes of instruction. They reported that teachers believed that including STS in classroom practices could develop decision-making skills, enhance science learning, and provide meaningful applications of science to real life. However, they were concerned with the time it takes to teach STS, staff development issues, and needed resources and support. Moreover, they stated that fostering positive beliefs and attitudes about STS may involve providing teachers with concrete and positive experiences with actual STS issues as well as involvement with real scientific investigations of STS issues where opportunities exist for teachers to operationally define STS. This would suggest that change in beliefs could be an interactive process, and change in practice might be the end result.

This is the structure of the KanCRN STS model of professional development. Through KanCRN teachers are provided opportunities to facilitate and participate in scientific investigations of STS issues which will allow them to operationally define STS. When teachers are given the opportunity to correlate their beliefs with those of the innovative program, true reform will occur. Teachers must actively engage in dialogue and reflection about the inclusion of STS (Lumpe et al., 1998). KanCRN provides these opportunities through active teacher participation in the development and monitoring of the program. As the NRC (1996) confirms, when teachers have the time and opportunity to describe their own views about teaching and learning, conduct research on their own teaching, compare and revise their views, they will come to understand the nature of exemplary science teaching.

STS is a theme in science education reform that can empower teachers to change their practices in the classroom. Beliefs about the inclusion of STS must be identified so the professional development activities can target those identified beliefs that appear to influence teacher practices and actions. The intention is that once beliefs are identified and targeted, a fostering of positive beliefs about teaching STS can occur. To this end, KanCRN's evaluation activities in the months of initiation focused on the development of a survey instrument for baseline data collection. Survey questions included information concerning teacher beliefs and practices, teacher utilization of inquiry-based learning opportunities, and instructional uses of technology.

Baseline Data Collection

For the purpose of this investigation, a subset of questions dealing with STS issues were extracted from the survey instrument and reviewed in order to measure information on teacher beliefs concerning teaching and learning and the practices that occur in the classroom. For the purpose of clarity, the questions selected dealt with STS beliefs and practices that are qualified as follows:

1. Long-term, inquiry, discovery or research-based approaches.

2. Self-directed learning.
3. Class work emphasizing authentic work for audiences outside the school.
4. Class work and assignments including real world societal applications.
5. Technology used as a tool to gather and analyze data or information.
6. Technology used as a tool for research.

With more than 1000 teachers responding to the survey, initial findings support the incongruency theory Liberman (1995) found in the Southern Maine Partnership. Data based on a five point Likert Scale indicate that 74.8% of teachers considered long term, inquiry, discovery, or research based approaches to learning desirable. However, only 27% of respondents stated that these practices occur often or very often in their classrooms. Secondly, 52% of teachers believed that student self-directed learning is beneficial. Nonetheless, 74% reported that students working on the same assignments at the same time were the most frequently occurring practice in their classrooms. Teachers also reported that they believed that student class work should include rich and lengthy applications to real-world situations. While 64% stated that they agreed or strongly agreed with this, only 42% stated that these practices occur often or very often in their classrooms. The survey also showed that only 9% of teachers have encouraged students in their classes to use a computer as a tool for research or as a means to gather or analyze data. Finally, 46.3% of teachers responding believed that class work should emphasize authentic work for an audience outside the classroom or school. However, only 21% stated that these practices occurred in their classrooms.

Proposed Study

Successful change does not occur without perseverance. All constituents, teachers, students, planners, developers, and support people must have time to share ideas and beliefs and draw conclusions. For any innovation to become an integral part of a school's instructional program, the school personnel must go through a cycle of change characterized by the stages of initiation, implementation, and institutionalization (Ellis and Maxwell, 1995). Initiation refers to the time when schools are becoming familiar with the feature of the innovation. Pilot tests are being performed, and decisions about adoption are being made. Implementation refers to the stage where teachers begin to use the new program. This stage requires at least three to five years. During this time it is essential that activities for training, consultation, support, and monitoring the program's implementation be put in place. During the institutionalization stage, members of the leadership team must consider how they will ensure that the changes are widespread and are self-sustaining. KanCRN is just beginning its second year and is in the early implementation stage.

From the initial analysis of the baseline data, teacher beliefs, while encouraging, are not consistent with their practice. In further study, the intent is to use this baseline data as a measure of the status of the relationship between teacher beliefs concerning STS instruction and the practices that occur in the classroom. The baseline measure will be used as a comparative measure to assess the effectiveness of the implementation of the KanCRN STS model of professional development. The purpose is to determine if providing teachers concrete experiences with STS issues, which involve scientific investigations, will foster changes that will bring consistency between their beliefs and their practices in the science classroom. Further evaluation processes might include data collection methodologies comprised of videotapes, observations, and interviews of teachers. It is important to discover the reasons for these inconsistencies and find ways to assist teachers in improving and stimulating an inquiry-based instructional environment.

Final Reflections

Providing support structures such as resources, staff development, and inclusion of STS issues in local curriculum may help teachers develop a more positive sense of control for teaching STS (Lumpe et al. 1998). Collaborative partnerships such as KanCRN can provide these tools. These subject-specific teacher collaboratives are growing in number. They open up a new definition of professional development that encompasses teacher knowledge of student learning and instruction. In addition, teachers have access to a broader network of professional relationships. Teachers become partners in producing and leading the reform of their profession instead of consumers.

The changes occurring in science education create conflict with the fundamental teaching beliefs of many teachers. Despite the overwhelming push toward teaching methods involving research and inquiry, there is little evidence that these practices are happening. Successful reform requires input and support from all participants: teacher, parents, college faculty, business, and students. True reform also requires a long-term commitment of human resources and materials. KanCRN possesses these qualities. Hopefully, an outcome of this investigation will be a contribution to the understanding of the relationship between teacher beliefs and practices in the science classroom and the types of professional development that would assist in the evolution and correlation of these beliefs and practices with reform recommendations.

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PROJECT TEAM: BRIDGING THEORY AND PRACTICE IN SCIENCE TEACHER PREPARATION

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What is Project TEAM?

Project TEAM--Teacher Education for the Approaching Millennium, represents an partnership designed to improve science teacher preparation, content knowledge among both students and teachers, and the desire to better connect the theoretical constructs offered in a science methods course with the practical concerns expressed by students during an in-school clinical experience.

As a systemic partnership bridging theory and practice in science education, Project TEAM recognized at the outset the challenges of connecting university models of best practice with the realities of the school setting. By involving the cooperating teachers in the beginning of the program and having them provide models of the best practice-- ranging from pedagogy through lesson planning-- a strong and vibrant connection between methods course theory and classroom practice were seamlessly fused.

The content materials used were an extension of Operation Primary Physical Science (OPPS) program. OPPS is attempting to meet the challenge of providing exemplary staff development materials for elementary teachers, assisting them in the development of their science content knowledge. The physical sciences represented the area of emphasis for the OPPS materials, and a strong commitment to learning by doing-- a constructivist approach--is evident throughout the program. Teachers learned fundamental physical science topics ranging from magnetism though sound by engaging in tasks that forced them to frequently ask the question "why?" and though investigation, obtain an answer.

Meet the TEAM Institutions

Three institutions were involved in Project TEAM. Northern Illinois University, located in DeKalb, IL, offers a large teacher education program, with approximately 250 graduates yearly in Elementary Education.

School district U-46, in Elgin, is the second largest school district in the state of Illinois. It is a large and varied district, with a large number of students from underrepresented populations and a wide range of socioeconomic levels. In 1998, U-46 served over 34,000 students. The district reported that approximately 66 different languages were noted among U-46 students in a recent bilingual census. Approximately 26% of U-46 students are of Hispanic origin, 8% are African-American, 6% are Asian-American, and less than 1% are Native American.

St. Joseph's, a Parochial School in Elgin, serves the same community, with an even higher (approximately 50%) number of the students enrolled as members of underrepresented populations.

Common Goal

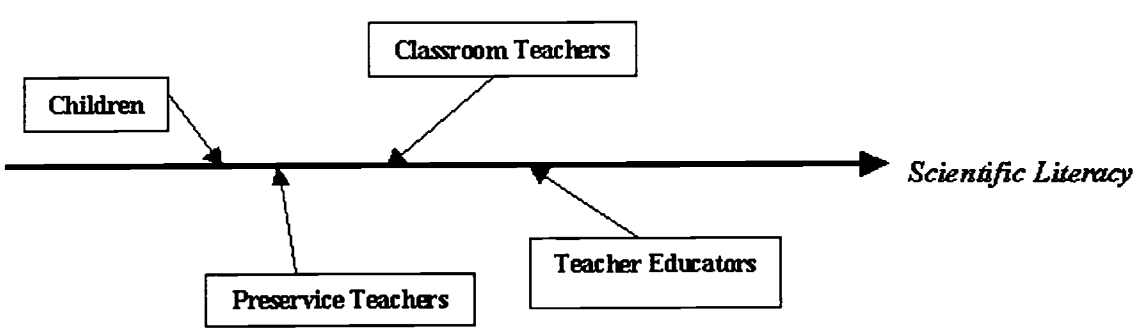
Uniting these institutions was the overall goal of the project. Promoting a more sophisticated understanding of scientific literacy formed the strand that connected the interests of the participants in Project TEAM. For preservice teachers, developing their science content knowledge and teaching skills offered the first issue of concern.

Classroom teachers also shared in the overall goal of improving scientific literacy. In addition to enhancing their own knowledge, their role as classroom teacher and mentor teacher to the preservice teacher offered them two audiences to work with, in addition to their own professional growth.

Elementary school children represented the third part of the program, with all of the teacher education and science education goals designed, in principle, to help better meet their needs.

All of the participants in Project TEAM were considered to have some knowledge of scientific literacy. The concept, scientific literacy, was envisioned as a continuum, with some stakeholders possessing more knowledge than others. Project TEAM's objective was to move each participant as far to the right (as shown in Figure 1) as possible. It was recognized that all participants started at different points along the continuum, and each would move different distances, but it was anticipated that all would experience professional growth by the end of the project.

Figure 1. Scientific Literacy Continuum



Teacher Education Model

Project TEAM, then, was developed to provide a model for teacher education. The challenge of connecting theory with practice is one that has been writ large over the face of teacher education. By serving the needs of preservice teachers, practicing teachers, and ultimately children, Project TEAM bridges that gap in important ways.

What are the TEAM Objectives?

Project TEAM addresses a number of objectives related to staff development, science knowledge, clinical teaching settings, and educational partnerships. To provide staff development for teachers represented one of the key areas of interest in developing Project TEAM. Recognizing the call for enhanced content knowledge among teachers (NRC, 1996; AAAS, 1989), the development of the teacher's content knowledge represented the first phase of the program.

Development of the teacher's knowledge base was accomplished in large part through the use of materials developed at Louisiana State University (OPPS, 1996a, 1996b). The materials, comprehensive sets of documents supporting teacher learning in the physical sciences, were designed to be completely inquiry-based in approach. All movement along the scientific literacy continuum in terms of enhanced content knowledge will be obtained through the learner interacting with materials and developing their own understanding through interaction and the guidance of the staff development team.

To write physical science units provided the second objective for Project TEAM. Recognizing that the good efforts accomplished during the content knowledge workshop might be wasted if not directed toward improved student learning, the teachers of Project TEAM-constructed instructional units (under the guidance of the science educators who presented the content knowledge workshops) for use in their classrooms with their students. The knowledge gained in the content knowledge workshop was used to provide the basis for the new instructional units, showcasing the teachers' enhanced knowledge base.

The units were used in conjunction with the existing teacher education program to improve the relationship between the methods course instruction and the clinical experience. To further this connection, the supervisor for the clinical experience served in two additional capacities: as one of the Project TEAM workshop facilitators and as the instructor for the preservice teachers during their science methods course. Together, these three strands connected the theory of the university with the practice demonstrated in the public schools

The clinical experience also served to develop and to promote a teacher education partnership between the university and the Elgin school district. Using the teacher education program, staff development for teachers, and using the skills-enhanced teachers as the mentors for the student teachers provided the opportunity to address the individual needs of all of Project TEAM's constituents. Each participant was afforded the opportunity to grow professionally, moving along the scientific literacy continuum identified earlier to foster a greater connection with the tenants of scientific literacy.

What are the Major Components of Project TEAM?

The three essential strands of Project TEAM are related to the following: improving teacher's content knowledge, developing exemplary units for science instruction, and applying this new knowledge and these curricular materials in mentoring preservice teachers.

Content Knowledge

Teachers were offered choices from among four sets of topics: 1) Magnets, 2) Solids, Liquids, and Air, 3) Light, Shadow, and Mirrors, and 4) Sink or Float. These topics were selected because they represented typical topics encountered in the elementary education science curriculum. This fit well with the needs of the Elgin district, as they had recently selected FOSS as their district's science curriculum, and desired staff development training to assist in this endeavor. Teachers were to select two topics from the four content workshops, and instructional units were to be developed based on the composition of the workshops. It is worth noting that some teachers attended all of the workshops.

The workshops were structured from a constructivist/inquiry-based approach. All experiences were to be developed from the teacher's interaction with materials and guidance from the workshop's facilitators. To develop the science content knowledge, no direct instruction was offered. In the words of one of the participants, the experience helped them to better perceive the "difference between telling and knowing." The workshops were structured in this manner both in deference to the learning needs of the teachers, but also as a means of modeling the sort of practice that student teachers will be seeking during their time in the clinical setting.

Creation of Exemplary Units

During the summer workshops, teachers were asked to attend four sessions related to the development of their instructional units. Topics during the summer workshops were 1) science process skills, 2) interdisciplinary teaching, 3) assessment, and 4) infusing technology into instruction. Each workshop was offered twice, allowing for teachers to participate in traditional summer activities as well as to attend the workshops.

The content of the workshops was designed to help teachers be cognizant of the experiences of the student teachers who would be arriving during the fall and spring semesters and that would be team teaching the content of the units with the teachers when they arrived for their clinical experiences. In particular, the needs to develop pedagogy consistent with best practice in science education and to develop authentic assessment approaches were topics welcomed by the Project TEAM teachers as well.

With these skills established, the teachers of Project TEAM used these skills in conjunction with the content knowledge from the spring workshops to develop exemplary science units.

Teacher Education

During the Fall 1998 and Spring 1999 semesters, students from a Northern Illinois University science methods class spent three weeks in the classrooms of the Project TEAM teachers. During this time, they team taught the instructional units created during the previous summer by the project's teachers.

Their supervision was carried out, as mentioned previously, by one of the project's facilitators, who observed their science teaching experiences during the progress of the clinical experience.

Thirty preservice teachers were involved during each semester. Twenty five of these students interacted directly with mentor teachers involved in Project TEAM; five experienced exposure to the Project TEAM materials during the science methods course, but not during the clinical experience.

The clinical experience took place during the same semester as the methods course; however, on campus classes were suspended during the time the students were in the field engaged in the clinical teaching experience. The methods course instructor also served as the field supervisor, using the time when on campus classes were suspended to make field visits and gauge the progress of both the mentor teachers and the preservice teachers. During the fall semester, he was able to meet with each of the students twice during a three-week time period. The same schedule has been proposed for the spring 1999 semester.

Findings

The findings by Project TEAM's evaluator were most encouraging. The participating teachers demonstrated improvements in a number of areas. First and foremost, they demonstrated a significant improvement in their science content knowledge. This was demonstrated by responses to open ended questions and through the complexity of concept maps developed by the participants.

From the teacher education perspective, the participants demonstrated improvement in their understanding and application of using science education standards for lesson planning, planning units conceptually.

Learning From the Past: Project TEAM's Evolution

Project TEAM has evolved during its tenure. During the first year of its implementation, it invited participation from two school districts and a parochial school. The content knowledge workshops and the creation of two interdisciplinary units took place during the same time period, the summer of 1997. Several findings came from this experience. First and foremost, the challenges of training and producing the interdisciplinary units during the summer were quite overwhelming. Teachers struggled to infuse their enhanced content knowledge into their units over the course of a six-week period and then to compose a unit during the fall semester. The second unit was even more problematic, as the compositional demands came into conflict with the teacher's workload during the fall semester.

An additional concern arose as a consequence of working with multiple school districts. The challenge of presenting the content knowledge was challenging, as each of the districts had different perspectives on when and where the content knowledge should be introduced to students within their respective districts' curriculums. The focus of the workshops were on the development of physical science knowledge in primary teachers; for districts that presented the content information to students in the intermediate grades, the workshop was not as effective in serving their needs.

In response to those issues, Project TEAM offered the content knowledge workshop during the spring of 1998 and an additional workshop on science teaching pedagogy during the summer session of 1998. This allowed for the teachers to better consolidate their content knowledge gains during the spring and infuse the new knowledge into instruction.

In addition, working with a single school district allowed for the content knowledge to be better connected with the curriculum of a single district. U-46, which had recently adopted the FOSS program, found the content knowledge workshops and curriculum development time during the summer to better meet the needs of their staff.

Plans for current year

For the coming year, Project TEAM again received funding to continue. Based on the experiences of two previous cohorts of teachers participating in the project, a number of changes have been invoked for the 1999 series of workshops.

First, the facilitators will extend opportunity to twice the number of teachers. Rather than working with 25 teachers, 50 teachers will participate in Project TEAM during the 1999 session. In addition, the number of instructional units created by each teacher will be reduced to one from the previous two. It was determined that the returns expected from having teachers produce two units were somewhat diminished by the effort required to compose two units. This will allow the participants to focus all of their efforts on a single unit, rather than two. Finally, the opportunity to impact more students was recognized as an important consequence of this project. Doubling the number of teachers will double the number of elementary students who may benefit from the program.

Future Considerations

Partnership opportunities are recognized as one of the key issues to hopefully emerge from the work piloted though the Project TEAM experiences. The value of a partnership that provides opportunities for personal and professional growth for both the preservice and practicing teachers is essential.

Developing a group of mentor teachers for the clinical teaching aspects of the university's program represents a long-term need and consequently a long-term goal of the project. The teachers involved in Project TEAM find that their experiences mentoring the student teachers to be important parts of their own professional growth and development.

Acknowledgments

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EARLY CHILDHOOD SCIENCE –ADOPTING THE REGGIO EMILIA APPROACH

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The Reggio Emilia Approach – The Underlying Philosophy

The focus of this visual presentation is on the Reggio Emilia Approach, its underlying philosophy, its uniqueness within the constructivist paradigm, and its potential as an exemplary Early Childhood program that can be adopted to teach young children science. This distinguished program took is its roots in a town called Reggio Emilia, in Northern Italy. In 1963 the Municipality of Reggio Emilia first introduced preschools and later infant toddler centers; it has since acquired fame, for becoming one of the most distinguished community –supported childcare systems in Western Europe. According to Gandini (1997), the educators and parents at Reggio, through a strong commitment and cooperation, have developed over the years an excellent program that is exemplary not only for educators in Italy and Europe, but has made a tremendous impact on Early Childhood education here in the United States.

The Reggio Emilia Principles

While the works of John Dewey, Jean Piaget, Lev Vygotsky, and other European scientists have inspired the many experiences at Reggio Emilia, the program operates on some basic fundamental principles. Lella Gandini (1997) describes these basic principles separately, but emphasizes that they are to be considered as being connected and part of a coherent philosophy. According to her children are of prime importance, and according to educators at Reggio, are portrayed through the "image of the child." This image characterizes children as having great potential, indelible curiosity, readiness to question and construct their own knowledge through interacting among themselves and their environment. In doing so they establish relationships, learn to negotiate with everybody and everything they encounter.

The school is viewed as a system of relationships, in which the child is educated but not in isolation from their peers, family, teachers, the school environment, community and the greater society. There is immense feeling of belonging, reciprocating and sustenance in children's relationships and interactions within this system.
This program recognizes and supports the rights of children, parents and educators. Children have a right to an education that enables them to grow to their fullest potential, the parents have a right to be involved in the academic life of their children and the teachers have a right to professional growth.

Parents play an important advisory role in the administration of the school on a day to day basis and actively participate in special events, excursions and celebrations. Another important aspect is the role of space. The Reggio schools value the power of instructive space. While it provides opportunity for encounters, communication, and relationships, it also is deliberative in the arrangement of structures, objects and activities. The environment is aesthetically arranged, is inviting, encourages a variety of activities involving discovery and problem solving. Communication is fostered at all levels. It is highly valued and personal. Both students and teachers have boxes with their names written on them, arranged along the halls. These boxes are used for leaving messages and surprise notes to one another. Engaging young children in communicating through written messages increases their interest and helps them value reading and writing well before they are formally introduced to it in elementary school.

Teachers utilize the space in providing opportunities for children to interact with the teacher, with few and with many other children, or even alone if they wished. These teachers know and value that children learn effectively through forming relationships and interacting in small groups. Most often the teacher initiates communication by grouping the children and setting the stage for asking questions or responding to them. In this setting children learn to listen and pay attentive to each other. This type of grouping is also favorable to the emergence of cognitive conflicts which can result in a revelation, or a procedure that children adopt to construct new knowledge together.

Typically children stay with the same teacher for three years (infancy to 3 and 3 to 6). However, they do change environments according to their developmental needs. During this period, teachers learn the personal time of each child and their particular characteristics. The role of time provides for continuity. Activities are not set by the clock rather, a full-day schedule is planning at a leisurely pace provides children to enjoy encounters with their friends, enjoy the beautiful environment and complete projects to their satisfaction.

Teachers are considered partners in the process of learning. They pay very close attention to children's ideas, hypotheses and theories. They document what they observe by making notes, or audio or visual recordings. Teachers then discuss and compare their observations with each other, and with the pedagogical coordinator (*pedagogista*). They are now ready to offer children occasions to discover and revisit their experiences. The teacher's role is thus a reflective one, of continuous research and learning where children are also part of the team.

The Reggio schools achieve their goals through cooperation and organization at all levels. Teachers work in pairs as equals. Teachers play the part of researchers, gathering information as they work with children to continue the process of documentation. They enter into collaborative discussions and interpretations of both teacher's and children's work. A weekly schedule of about 6 hours are set aside for meetings among teachers, meetings with parents and for in-service training.

The schools are further supported by a team of *pedagogisti* who maintain the connections between the various parts of this complex system, and are responsible for interpreting the rights and needs of each child, family and group of teachers. This team of *pedagogisti* provides a supportive structure for all, teachers, parents, community members and city administrators.

The Reggio schools promote art not as a separate part of the curriculum, but as an integrated part of the whole cognitive/symbolic expression involved in the process of learning. A teacher who has been trained in the area of visual arts works closely with children. This teacher is called the *atelierista*, who works in a workshop or studio called the *atelier*. The *atelierista* works with the other teachers exchanging ideas on how and what materials and media are to be used in the various projects.

The curriculum followed in the Reggio schools is not established in advanced. Initially, teachers formulate tentative goals and make predictions as to the direction projects and activities might take. Only after carefully observation and dialoguing with children in action, they compare, discuss and interpret what activities might be suitable to offer to these children to sustain their interest and involvement. The curriculum in a sense 'emerges' and is now popularly known as the emergent curriculum.

The power of documentation is immensely felt throughout the whole school. Documentation includes, photographs, transcriptions of children's remarks and discussions and any representation of their thinking and learning. The *atelierista* with the help of other teachers display the pieces of documentation, which serve several functions. These functions include increasing parental involvement by making them aware of their children's experience and progress. It facilitates better understanding of children's experience and promotes discussions, and professional growth among teachers. It is a form of appreciating and valuing children's work. It also acts a well documented history of the school in which children take pleasure in learning.

The Reggio Approach and Science Education

Fleer (1993) in her analysis of the current science education research literature from an early childhood perspective reports that, we urgently need to determine which aspects are relevant and useful for teaching science to young children (3-5 years of age). Many models and approaches have emerged from the constructivistic paradigm that have shown to be more effective than previous approaches (Millar & Driver, 1987). However, these models have not been successful in promoting conceptual change. The Reggio Emilia Approach is exceptional and unique within the constructivist paradigm in that it upholds the teacher's role as a scaffold to a child's learning of concepts. During this process the teacher dialogues with children, offering them occasions for discovery and revisitation as, learning is not considered a linear process but a spiral one (Malaguzzi, 1993). Collaboration is the key to success of the Reggio Emilia schools. This collaboration Rankin (1997) views as "a system of social relationships whereby children and adults, including both educators and parents, coordinate their action and restructure their thinking and resources in relation to each other." (p.72).

Recently, the *National Science Education Standards* (1996) were published specifying what all children in the United States should know, value, and be able to do. The American Association for the Advancement of Science (AAAS) under the auspices of Project 2061, has also developed benchmarks for students at different grade levels. Adapting the Reggio Approach in the school curriculum in the United States is not an easy task, and adopting all its elements is a challenge. However, after observing and participating in the 1997 Spring study of the Reggio Emilia schools, my recommendation is that, adopting the project-based emergent curriculum will certainly have an impact the sciencing of young children. The learning experiences at Reggio are typically inquiry-based projects. The ideas for projects might originate from a variety of experiences in which children and teachers may have constructed knowledge together. The teacher might suggest a topic or an idea or problem may be proposed by the children. The merit in this approach is that general educational goals can be established and without formulating specific goals in advance. During this process the teacher hypothesizes what might be the outcome of some of the pedagogical decisions based on children's previous knowledge.

Thus, objectives may be established from perceived children's needs and interests, which might be expressed at any given time during the project. The direction the project takes could also be based on what he or she infers as the work progresses. This is the basis for an emergent curriculum. The process skills such as observing, communicating, predicting and understanding space and time relationships are some of the skills developed in the emergent curriculum. Children are encouraged to hypothesize, and explain how they would experiment, even though teachers know that the students' approach or hypothesis is incorrect (Edwards, Gandini, & Forman, 1993). The social nature of intellectual growth is enhanced through discussions among children and children and adults. This curriculum encourages parents to participate in the activities of their child, perhaps supply materials and supplementary books, or work with the physical environment. Katz having visited Reggio Emilia offers some advice to educators who are in the process of renewing early childhood curriculum 'we have to start somewhere, and our children cannot and should not wait until all the elements are in place. We are all deeply indebted to our colleagues in Reggio Emilia for showing us again what is possible when a whole community is deeply committed to its children. (1997, p.111)

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WRITING-TO-LEARN SCIENCE: BREAKTHROUGHS, BARRIERS, AND PROMISES

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The prime purposes of this paper are to identify breakthroughs, barriers, and promising practices of writing-to-learn science designed to enhance science literacy for all students. The analyses and recommendations are anchored in the context of current education reform, the recognition of contemporary literacy that goes beyond the 3 R's and refocuses the emphasis from basic literacy and critical literacy to dynamic literacy (Morris & Tchudi, 1996) and the increased communication demands of workplace and adult literacy. Contemporary science literary involves improving people's habits-of-mind, critical thinking, and cognitive abilities to construct understanding; increasing their understanding of the big ideas of science dealing with the nature of science, the practice of scientific inquiry and the big ideas of science; and facilitating their communications to inform others and to persuade others to take informed action. The conceptual and language demands of the current information and technological economy require people to access, understand, interpret, discuss, and produce a variety of documents—forms, applications, flow charts, maps, graphs, instructions, diagrams, persuasive arguments, and other expository genre (Gerber & Finn, 1998; NRC, 1996). Clearly, face-to-face communications and communicating-at-a-distance are both ends and a means to science literacy.

Limited research has outlined the potential value of print-based language in science learning (Holliday, Yore & Alvermann, 1994; Rivard, 1994; Rowell, 1997); and the common-sense and grass-roots supporters of print-based language across the curriculum have purported generic relationships among reading, writing, and learning. Although the relationships among reading to

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learn, writing to learn, and science are not well established, the available "research does not support the concocted claims that reading and writing in science naturally inhibit students' creativity, curiosity, and interest" (Holliday, 1992, p. 60).

Background

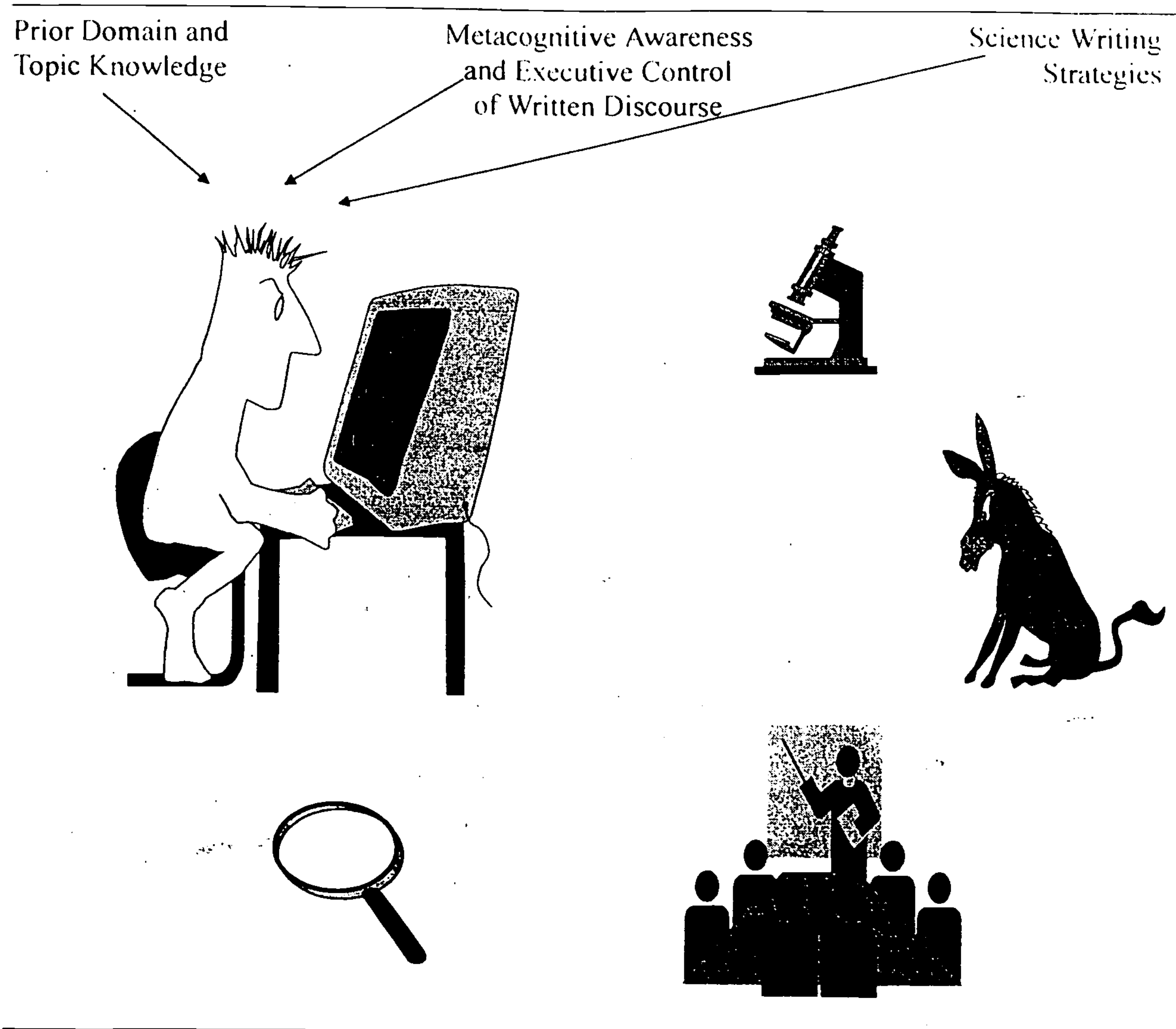
Some years ago the dominant model of science writing did not accurately reflect the transformational and recursive nature of writing, did not consider the unique characteristics of the science domains, misrepresented the pedagogical purposes for writing in science, underestimated the variety of writing tasks in science, and ignored the understandings of the participants—teachers and students. Holliday, Yore, and Alvermann (1994) identified a potential writing breakthrough:

> Writing, like interactive-constructive reading, depends upon the writer's prior domain and strategic knowledge, purpose, and interest. Bereiter and Scardamalia (1987) described the interactive and constructive processes involved in the knowledge-transforming model of writing that parallels the generative model of science learning in that it involves long-term memory, working memory, and sensory-motor activity. The knowledge-transforming model appears to be far more interactive and recursive than linear. The tasks of goal-setting and text production do not fully reveal the complex cognitive, metacognitive, and memory factors involved in the retrieval of conceptual and discourse knowledge from long-term memory and the executive control, strategic planning, and construction taking place in short-term memory. (pp. 885-886)

The mental models that most science educators have about print-based language arts are skills-oriented, unidirectional, text-driven, or text-production processes. They formulated these interpretations from their early schooling that emphasized skills and drills language arts programs involving the controlled language and writing assignments designed to evaluate what the writer knows.

Writing in science utilized a knowledge-telling model of writing. Students systematically select a topic, recall understanding, draft a product, proofread the draft, and produce a final copy. Frequently, the writing process was linear, void of any sociocultural interactions, and emphasized the mechanics of the language. Scardamalia and Bereiter (1986) encouraged teachers to help their students move from the predominant knowledge-telling writing, which involves converting knowledge from long-term memory into written words essentially unaltered, to a knowledge-transforming approach in which knowledge is actively reworked to improve understanding—"reflected upon, revised, organized, and more richly interconnected" (p. 16). The knowledge-transforming model (Bereiter & Scardamalia, 1987) clarifies the role of conceptual knowledge about the nature of science and the target topic, the metacognitive knowledge about and management of written science discourse, patterns of argumentation and genre, and science writing strategies influence on the science writing process (Figure 1). Utilizing the knowledge-transforming model as an operational framework would encourage science educators to get students spending more time setting purpose, specifying audience, thinking, negotiating, strategic planning, reacting, reflecting, and revising. Explicit instruction embedded in the authentic context of scientific inquiry designed to clarify language as a symbol system; what writing is; the purpose-specific nature of scientific genre; the author's responsibilities to the audience; the interactive, constructive, generative nature of science language; the relationship between evidence, warrants, and claims; and what, how, when, and why to use specific writing strategies should be provided as an integral part of science courses (Ferrari, Bouffard & Rainville, 1998). The embedded instruction needs to convert the metacognitive awareness into action to improve self-regulation (planning and generating ideas, translating ideas into text, checking and revising text) and actual writing performance (Hayes & Flower, 1986; Sawyer, Graham & Harris, 1992).

Figure 1
Knowledge-transforming model of writing
(Bereiter & Scardamalia, 1987)



Surveys of teachers and analyses of school writing tasks reveal teachers were unfamiliar with many genres and a dominant use of narrative and factual recounting (Wray & Lewis, 1997). Gallagher, Knapp, and Noble (1993) suggested the need for explicit instruction in a full range of genre (Table 1). **Narrative** involves the temporal, sequenced discourse found in diaries, journals, learning logs, and conversations. Narratives (document recollections, interpretations, and emotions) are far more personal and informal than most scientific writings. **Description** involves personal, commonsense and technical descriptions, informational and scientific reports, and definitions. Frequently, descriptions will be structured by time-series of events, scientifically established classification systems or taxonomies, or accepted reporting pattern of information (5 Ws). **Explanation** involves sequencing events in cause-effect relationships. Explanations attempt to link established ideas or models with observed effects by using logical connectives of "if this, then this." **Instruction** involves ordering a sequence of procedures to specify directions, such as a manual, experiment, or recipe. Instructions can effectively utilize a series of steps in which the sequence is established by tested science and safety. **Argumentation** involves logical ordering of propositions to persuade someone in an essay, discussion, debate, report, or review. Arguments attempt to establish the boundaries and conditions of the issue and then to systematically discredit, destroy, or support components of the issue, to clearly disconfirm or support the basic premises.

Table 1
Genre, Purpose, Outcome and Audience of Writing-To-Learn Science
(Adapted from Gallagher, Knapp & Noble, 1993)

Genre	Purpose	Outcome	Audience
Narrative	Recording emotions and ideas	Attitudes	Self and others
Description	Documentation of events	Basic knowledge	Others
Explanation	Causality	Cause-effect relationships	Others
Instruction	Directions	Procedural knowledge	Others
Argumentation	Persuasion	Patterns of argument	Others

Each genre is flexible, and the writer must control the form to address the function or purpose. No lengthy piece of text uses a single genre (Anthony, Johnson & Yore, 1996). Analysis of effective writing illustrates micro-structures embedded within the macro-structure. In argumentation, a writer might start with a descriptive passage to engage the reader, later use an explanation passage to illustrate a critical cause-effect relationship, and in closing may use an instruction passage much the way a judge clarifies the issues, critical evidence, and the charge to a jury. Prain and Hand (1996a) utilized writing type (booklet, travel brochure, letter to editor, article, etc.) to capture the essential aspects of genre, to recognize the variation of micro-structures in text and to represent the variety of writing tasks literate adults and scientists use.

Connolly (1989) suggested that this new writing-to-learn rhetoric was compatible with constructivist perspectives of science learning and illustrated that the symbol systems used to communicate play a critical role in constructing meaning. He emphasized:

> Writing-to-learn is not, most importantly, about 'grammar across the curriculum' nor about 'making spelling count' in the biology paper. It is not a program to reinforce Standard English usage in all classes. Nor is it about ... mastering the formal conventions of scientific, social scientific, or business writing. It is about the value of writing 'to enable the discovery of knowledge.' (p. 5)

However, writing-to-learn science tasks do provide authentic opportunities to develop scientific vocabulary, grammar, spelling, punctuation, patterns of argumentation, and technical genre utilized in the science professions. Writing to learn and technical writing have much in common; effective instruction should utilize authentic technical writing tasks to promote science learning, reflection, and practical technical writing for science professionals and adult lay people alike.

Howard and Barton (1986) stated that the "idea is to learn to think in writing primarily for your own edification and then the eyes of others. This approach will enable you to use writing to become more intelligent to yourself — to find your meaning — as well as to communicate effectively with others" (p. 14). Holliday (1992) suggested that effective science writers consider their audience and purpose; strategically plan, draft, revise, and edit; structure writing for maximum effect; typically read, listen, and speak well; and understand language is interpretative, interactive, and constructive.

The following principles should guide the development of writing-to-learn tasks in science (Tchudi & Huerta, 1983):

- Keep science content central in the writing process
- Help students structure and synthesize their knowledge
- Provide a real audience for student writers that will value, question, and provide supportive criticism
- Spend time prewriting, collecting information from various sources (concrete experiences, print materials, experts, electronic data banks, visuals, etc.), sharpening focus, and strategic planning
- Provide on-going teacher support, guidance, and explicit instruction
- Encourage revisions and redrafts based on supportive criticism to address conceptual questions and clarify understandings
- Clarify the differences between revising and editing (format, spelling, mechanics, grammar)

Much has happened recently in the writing-to-learn science community. What are the current breakthroughs, barriers, and promises? The following pages will address these issues from new perspectives and improved optics.

Breakthroughs

A quick survey of the 1988-98 (emphasizing the post-1994 entries) science education research and professional journals confirms the renewed interest in writing-to-learn science and writing in science. Nowhere is this breakthrough more apparent than in universities, but increasingly more evidence of interest can be found in middle and elementary school science journals with less evidence of interest in secondary school science journals. This interinstitutional variation in part reflects the barriers present in different educational environments. Unfortunately, writing-to-learn science and writing in science are more like a technology than a science. Many proposed uses have not been fully verified by associated research.

Universities

Writing in university/college science to promote epistemic insights, thinking, and conceptual understanding requires utilization of science-appropriate genre (Martin, 1993; Mullins, 1989). Moore (1993) found college students' science achievement improved if writing was coupled with explicit writing instruction and embedded in actual science courses. Liss and Hanson (1993) found that students who had an internal locus of control appeared to value writing tasks and worked harder than students with an external locus of control. Generally, application of write-to-learn approaches is being more widely used in university/college level science courses than ever before. The University of Hawaii adopted a writing-intensive course requirement for AA, BA, and BS degrees in 1987 (Chinn, Hussey, Bayer & Hilgers, 1993). All students must complete five writing-intensive courses in their major area. Writing-intensive courses require that:

1. writing be used to promote learning.
2. student and professor interact during the writing process.
3. writing plays a major role in course grades.
4. students produce a minimum of 4,000 words or 16 pages of text.
5. class enrollment be limited to 20 students.

Iding (1994) and Iding and Greene (1995) addressed the type of feedback that influenced university/college writers. Iding (1994) found that college composition students benefited most from comments that described the desired changes, such as additional information, local structure, and global structure. Students believed comments that provided a different perspective were useful. Iding and Greene (1995) found that peer-review comments were useful to education students.

In a recent article, Hallowell and Holland (1998, p. 29) stated that "scientific illiteracy among college students is a persistent problem ... yet the need to understand science principles and to be able to make judgments about the value of scientific knowledge and research has never been greater." Science literacy and the related print-based communication requirements need to address the dual goals (writing-to-learn science and science writing) of literate adults and literate science professionals. Attempts to address this problem are many; for example, Carle and Krest (1998) described a collaborative effort between a science department and university library to improve the access, collection, and evaluation of science information. This program addresses the "out of context" problem that many university library orientation and instruction programs encounter by focusing the effort on science for science majors and instruction on realistic writing tasks for scientists. They utilized print and electronic science citations and references to track the influence of science discoveries and to locate and evaluate information. Koprowski (1997), Rice (1998), and Yore (1996) provided explicit instruction on science writing, exposure to various science writing genre, and actual experience as a reviewer. Koprowski and Yore infused writing instruction, writing assignments, and peer-review into an upper-level general ecology course and an advanced elementary school science education course, respectively. Students were positive about the overall experience. Rice described an advanced stand-alone scientific writing course designed for upper-level science majors in which he served as "guide, coach, cheerleader, critic and occasionally referee" (p. 268). Central to the success of the course were specific instruction and creatively crafted assignments that provided insights into the different genre scientists use to communicate with different audiences: narrative (scientific autobiography), description, explanation, argument, and report of their original laboratory work (mixed genre). Throughout the course, Rice infused explicit instruction on grammar, appropriate voice, word usage and choice, sentence structure, and logical development at opportune times as needs arose.

In chemistry, Burke (1995) asked students to write creative stories about a particular element from the periodic table; and Venable (1998) asked students to re-write articles from the mass media once they identified incorrect reporting of science concepts. Working with journalism professors on a limited basis, Hallowell and Holland (1998) introduced journalistic writing into their freshman program.

Such tasks described above begin to maximize student learning because they require students to reflect, consolidate, elaborate, reprocess concepts and ideas central to the topic, hypothesize, interpret, synthesize and persuade, and hence develop higher order thinking skills and the construction of a deeper understanding of science concepts (Resnick & Klopfner, 1989; Schumacher & Nash, 1991; Sutton, 1992). While these studies have demonstrated potential benefits of writing-to-learn strategies, they have identified additional issues that need to be explored in subsequent research. One issue is the need for more interactions with professional people outside of the academic community in order to understand better the particular writing demands that scientists face in their careers and personal lives. Thus, there is a need for collaboration with journalism or English professors. Another issue is that nearly all the studies were focused on a single writing task that was different from normal lecture notes and laboratory reporting.

Secondary Schools

The major reason for the renewed interest about writing-to-learn science and science writing in public schools of the English-speaking countries is the recognition given to science literacy in major curriculum reform documents, such as the National Science Education Standards (NRC, 1996) and Project 2061 (AAAS, 1990, 1993). These documents place emphasis on students being able to communicate much more broadly than reporting to the teacher. Students are expected to engage in intellectual public discourse and debate in order to be able to communicate their ideas to others and to maintain or enhance their understanding. Such an emphasis places expectations on the expansion of writing in secondary school science classrooms to be broadened from the traditional forms of note-taking, laboratory reports, and tests to incorporate more non-traditional types focusing on encouraging students to inform, explain, defend, debate, and persuade others of their understandings.

The use of writing-to-learn strategies in the secondary school has become much more widespread with Holliday, Yore, and Alvermann (1994) clearly arguing for a broader range of uses for writing within school classrooms. Rivard (1994) expanded on this view to identify a range of crucial factors for using writing within science classrooms including the demands on the learner of the writing task, the learner's metacognitive understanding of appropriate strategies to use, the contextual aspects including a classroom environment focused on deeper conceptual understandings rather than factual knowledge, and a complementary match between genre or type of writing, conceptual structure of the topic, and broader curricular goals. In translating these considerations into a model for implementation, Prain and Hand (1996a, 1996b) provided a framework of five separate but inter-related components to guide improved writing practices within secondary school science classrooms: writing type, writing purpose, audience or readership, topic structure including conceptual clusters, and method of text production including how drafts are produced, both in terms of technologies used as well as variations between individual and composite authorship processes. The framework is intended as both a theoretical model to examine writing-to-learn strategies within science classrooms and as a pragmatic pedagogical model to assist science teachers in the implementation of these strategies.

Harmelink (1998) recognized the dual goals of improved science understanding and enhanced science writing effectiveness with the use of journals or learning logs. She recognized science teachers' reluctance based on lack of professional development related to writing and the time limitations of the secondary science curricula, but believed the constructive aspects of writing structured journal entries and related explicit instruction was well worth the time and personal energy invested.

Elementary Schools

Most of the increased interest in writing in science in the elementary schools has to do with the willingness of elementary teachers to expand their language arts program across the curriculum (Baker, 1996). Contemporary approaches in language arts involve establishing a language community in the classroom that addresses a wider variety of authentic speaking, listening, reading, and writing tasks (NCTE/IRA, 1996; Rowell, 1997). There is some hesitation to infuse these language tasks into science and mathematics, but the recognition of science literacy and mathematics literacy that involves communications to inform others and persuade people to take informed action has encouraged more generalist teachers with strong language arts backgrounds to include writing-to-learn activities in their instructional programs.

Nesbit and Rogers (1997) described how using cooperative learning approaches could be used to improve print-based language arts in science. The use of culminating writing activities can encourage students to reflect, integrate, and elaborate on their science understandings developed during verbal interactions in the cooperative groups. Peer-review and jigsaw writing activities can be very effective.

Wray and Lewis (1997) developed a series of factual writing frames to support young writers in their early attempts to use factual genre. They viewed writing as a social process and the textual product as a social object. The use of teacher scaffolding and structured frames allowed students to develop discourse knowledge about the specific genre used.

Tucknott (1998) explored the effects of writing-to-learn activities infused with an inquiry-based science unit on simple machines and inventions. Grade 4 students used several writing tasks—completion of a patent application, summaries of reading materials, laboratory reports, data displays, labeled diagrams, and explanatory paragraphs. The results indicated that teachers needed to use a series of writing tasks that required students to transform their ideas and writing form to increase higher-level thinking and science achievement. This appears to achieve revision without repletion.

Shelley (1998) describes the use of prewriting activities and writing tasks to improve science understanding and to enhance compare-contrast thinking. She states "prewriting activities, particularly those including visual aids, focus writing so that students can successfully compare and contrast information" (p. 38). Here again, the structured tasks are sequenced to require students to process and internalize information, not just copy textual materials.

DiBiase (1998) and Linton (1997) utilized inquiry letters to seek relevant information to supplement classroom investigations. Letters designed to request information from experts require students to venture into different language and scholarly communities. New information technology makes these approaches much more time efficient and effective.

Barriers

The barriers to effective use of writing in science and writing-to-learn science appear to concentrate around not having a clear image of a successful, efficient science writer; the general lack of evidence-based studies of writing-to-learn activities; and the limited understanding of implementing writing into science instruction.

Desired Image

Ferrari, Bouffard, and Rainville (1998) started to address the desired image issue in terms of a general writer. They documented the discourse awareness of good and poor writers and found that good writers introduce fewer surface errors during revision and produce longer text. Good writers also spend more time in prewriting than do poor writers. Unfortunately, no attempts to describe the characteristics of a successful, efficient science writer could be found. A synthesis of the limited science writing research, the much larger writing research, and an ethnographic documentation of science writers is needed.

Research-based Approaches

Few research studies have documented the effects on achievement and technical writing abilities by various writing in science and write-to-learn tasks. The large majority of writing in science and writing-to-learn science articles are based on unique case studies and testimonials. Fewer research studies have verified their effects with carefully collected qualitative and quantitative evidence. But, there is a growing network of science education researchers and teacher educators who are attempting to document the influences of writing on science literacy and science writing (See the 1997, 1998, and 1999 conference programs for AETS and NARST).

Implementation

When looking at the barriers to implementing writing-to-learning strategies and science writing tasks currently confronting educators, there is a sharp difference between elementary teachers and those in secondary and tertiary settings. Elementary teachers, in general, have a strong language arts background and thus have an understanding of the writing process and the construction of knowledge that results. These teachers are able and willingly implement a range of writing types and processes within their classrooms. However, these teachers are generally science-phobic and are reluctant to engage with many science-related issues within their classrooms. Conversely, secondary and tertiary educators have confidence in their understandings of science but lack knowledge about the writing process. Thus, they are reluctant to implement non-traditional writing types within their classrooms. A lack of knowledge about contemporary models of writing and personal experience with non-traditional writing types means that secondary and university science educators often do not have an understanding of the value of such writing tasks.

In summarizing the outcome of a five-year inservice program with secondary school science teachers, a number of assertions have been generated as barriers to implementation (Hand & Prain, submitted):

1. Teachers view writing in science as primarily as assessment technique since they have not experienced non-traditional writing types. Therefore, teachers limit the use of writing to recalling knowledge (i.e., knowledge-telling model of writing) rather than as a means of constructing knowledge (i.e., knowledge transformation model of writing). Teachers need to change their epistemological commitment to writing as a learning tool to change their understandings of the value of writing.
2. Teachers' lack of understanding of the writing process impedes the planning necessary to provide sufficient support to maximize the learning potentials of non-traditional writing types when used in the science classroom. This is not a criticism of science teachers but rather a comment on their lack of background. Such issues as when to model the particular writing type, what to model, how much explanation of

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the writing type do students need, the emphasis to be placed on the purpose for the writing, and the value of writing for the audience chosen require specific attention in teacher education and professional development programs.

3. Implementation of writing-to-learn strategies requires adoption of constructivist teaching/learning approaches within science classrooms. Placing emphasis on students' active construction of understanding through writing means that teaching/learning strategies within science classrooms need to reflect this student-centered emphasis. An inherent function of adopting constructivist approaches is the consequential changes in the roles adopted by teachers and the amount of control of learning that by necessity needs to be given to students.
4. Although teachers become comfortable with using non-traditional writing types within their classrooms, they have yet to use them as the major means of assessing students' conceptual understandings. Teachers who have successfully implemented a range of writing types are enthusiastic about their understanding of students' conceptual knowledge, but they have been reluctant to rely on these products as evidence for assessing students. A major problem for the teachers is how to actually mark writing pieces that are centered on conceptual understanding and allow students to have some creative license.

While these barriers exist, they are not insurmountable. As teachers begin to implement a broader range of writing types in their classroom, they will have to engage these concerns and develop pedagogical strategies and procedures to overcome them. Experiencing writing in university science courses will do much to legitimatize writing in elementary and secondary science classrooms.

Promising Practices

The remainder of this paper describes three specific instructional practices that address science writing to enhance students' science literacy, habits-of-mind, critical thinking and meaning-making abilities, their understanding of the big ideas of science, and their communications to inform and persuade others in instructional and professional settings. The process used to select these ideas assessed the power, the appropriateness for the target audience, the background demands placed on students and teachers, and the practical utility for science classrooms of each practice.

Reaction Papers

The reaction paper, a read-write activity, can be used with a variety of students to teach the strategies of summarizing and reflecting and to improve understanding (Yore, 1996). The students read a science education, science, or Science-Technology-Society article and wrote a one-page summary of and reflection on the article. The assignment limited the response space for the article summary to about 125 words and the reaction to about 125 words. The space limitation requires students to be critical, concise, and succinct.

Summarizing is a strategy related to both science reading and science writing, and it incorporates a cluster of subordinate strategies that are characteristic of good science students and respond to instruction. Summarizing requires the writer to recall or comprehend information, to select important main ideas and supportive details, and to craft a concise understandable synthesis of this information while retaining the original author's intent. Hare (1992) provided specific instructional hints and rules for summarizing—delete redundancies, identify relevant and important ideas, synthesize main ideas into a concise, unified text representative of the original author's intentions. The reflection requires the writer to assess the internal consistency,

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credibility, and applicational value of the ideas summarized. The writer is expected to deliberate, draw conclusions, and articulate a rationale. Reflection involves many critical response skills, such as evaluating sources, questioning claims, evidence and warrants, and assessing research methodology (AAAS, 1993). Furthermore, reflection is designed to encourage writers to make connections among ideas found in the summary with ideas from their knowledge, other articles, and other courses by using cross-references. Quality reflections not only provide a judgment but also specify the criteria and thinking used to reach the judgment, thereby reinforcing critical thinking. The audience for these reaction papers can be the professor, the teacher, or other students. Explicit instruction following each reaction paper focused on exemplary reaction papers and common concerns. The length restriction was a common early concern, but discussions clarified why it was necessary to limit the response space to necessitate the analysis and evaluation of the article and to avoid the "tell all" approach of novice writers and less critical readers.

Breger (1995) used a similar approach called inquiry papers and a variety of publications to encourage middle school students to learn about science or science-related topics. Bringing together reading and writing into one assignment enhances students' science reading strategies and comprehension of the print material. Writing about what they have read encourages students to organize and react to the ideas that they have just read. The use of periodical literature makes a connection between science and everyday life. To start the inquiry paper, students create a reading log in which they write down what they think they will be reading about, based on the title, the pictures, graphs, etc. They write down key pieces of information that may or may not agree with their prediction as they read. These ideas become the "raw material" for the inquiry paper. The summary consists of the main idea with supporting details of "Who? What? Where?

When? Why?" Students then reorganize (transform) the summary or key ideas in a visual way, such as a flow chart, concept map, chart, diagrams, etc., showing how the ideas are connected. The third section of the inquiry paper asks the students to choose three words that were important to the concept being discussed in the reading. If any of the words are unfamiliar to the students, the definition should be included in the paper. The final section of the inquiry paper requires the students to come up with three questions that came into their minds during the reading and writing process. At least two of the questions should be science related. These questions allow students to get involved with the topic, to further understand, or to clarify the ideas presented. The audience for the inquiry paper is the other students who are encouraged to respond with a positive comment, another questions, related readings, or related activities.

Collaborative Explanatory Essay

This explanatory essay did not specify a single genre, but the assignment was expected to promote expository-type writing that involved analytic strategies of acquiring information and reformulation of personal understandings to inform or persuade an uninformed audience about a specific issue (Yore, 1996). It was further expected that the task would require an analysis of the audience, an evaluation of the necessity and sufficiency of information, an assessment of the epistemic character and logic of the argument, a clarification of ideas and issues, an explanation of the central position, and an integration of new understandings.

Explanatory essays encourage conceptual change, depth of processing, connecting isolated ideas, and clarification of patterns of evidence, claims, and warrants (Scardamalia & Bereiter, 1986). Kempa (1986) suggested that the following explanatory tasks be used to enhance science learning:

- Developing causal relationships among facts, observations, theories, and models
- Proposing hypothetical relationships between unfamiliar and familiar ideas

- Applying scientific ideas to real-world issues

This assignment was used with upper-level undergraduate students majoring in elementary school science education. The collaborative explanatory essay was designed to:

1. develop insights into the knowledge-transformation model of writing.
2. develop insights about the persuasive, explanatory genre.
3. develop knowledge about central issues, topics, or ideas.

The explanatory essay assignment provided a concrete experience with a collaborative, interactive, write-to-learn strategy. The 10-page essay assignment utilized a jigsaw cooperative learning approach (Also see Nesbit & Rogers, 1997). Each member of the "home" group was randomly assigned one of three topics. Students from different home groups formed topic-specific "expert" groups. Each expert group collaboratively planned, located information, shared resources, and supported one another; but each expert wrote individual papers. The expert group discussions frequently negotiated meaning, evaluated evidence and inferences, elaborated ideas, and provided divergent interpretations.

The non-expert members of the home group (students assigned a different topic) served as an authentic audience for the experts and provided conceptual and editorial feedback on the topical papers for which they were not experts. The peer-reviews assessed clarity, conceptual development, appropriateness of examples and grammar, spelling, punctuation, and writing style. Since students were to be tested on all three topics, they were responsible for developing conceptual understanding by carefully reading these papers and seeking consultation with the author to clarify any fuzzy ideas. The assignment required a progressive development in which each of two drafts was submitted for peer-review by a different member of their home group. Each draft was revised utilizing the peer comments and editorial suggestions. The third draft was submitted to the professor for evaluation. Koprowski (1997) used peer review with explicit reviewer instruction to achieve similar results.

Science Writing Heuristic for Laboratory Work

The problem with "canned" laboratory experiences is that they do not maximize the opportunities for students to construct explanations for the activities they are undertaking. The use of different approaches to laboratory work is the focus of some promising work through the development of a Science Writing Heuristic (SWH) (Keys, Hand, Prain & Sommers, 1998). The SWH, consisting of two components, extends the Vee-diagram to incorporate a greater focus on social negotiation of understanding, negotiation of scientifically acceptable explanations, and reporting using non-traditional writing types. The first component focuses on the role of the teacher in organizing the activities associated with the laboratory work (Figure 2). The teacher scaffolds the inquiry by using a series of semi-structured activities and tasks. Steps 1 and 2 encourage students to access and engage prior knowledge, set purpose, and predict outcome. Step 3 allows students to explore and experience the central idea and to collect evidence. Steps 4, 5, 6, and 7 provide public and private opportunities to make sense of the experience, assess strength of the evidence-inference chains, and internalize and reflect on ideas. Step 8 allows the student to monitor understanding (compare post-instruction and pre-instruction maps) and to integrate the current experience with prior knowledge network.

The second component of the SWH is a template designed to facilitate students in constructing explanations for their laboratory observations (Figure 3). When the questions are carefully answered, students will make connections between their investigation questions, evidence, and claims (inferences). The initial question asks students to put forward what they believe is the central question(s) that should be addressed in the related inquiry to follow. The next two questions are fairly typical of normal laboratory reports in terms of reviewing procedures and observations. However, questions 4 and 5 require students to put forward their understandings gained from the laboratory experience and provide a coherent set of reasons for their claims. Question 6 is intended for students to check their explanations with an authority figure, such as the textbook or the teacher. If there is a difference between the authorized scientific version of the concepts and that which the students have constructed, then there is a need for students to further negotiate their understandings (question 7). By putting the two templates together, the SWH becomes a powerful tool to involve students in constructing explanations and understandings of laboratory concepts.

Figure 2
A Template for Teacher-Designed Activities
to Promote Laboratory Understanding

1. Exploration of pre-instruction understanding through individual or group concept mapping
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions
3. Participation in laboratory activity
4. Negotiation Phase I. Writing personal meanings for laboratory activity: Example- journals
5. Negotiation Phase II. Sharing, comparing individual data interpretations in small groups: Example- group chart
6. Negotiation Phase III. Comparing science ideas to the textbook or other printed resources: Example- writing group notes in response to focus questions
7. Negotiation Phase IV. Individual reflection and writing for communicating: Example- creating a presentation for a larger audience (poster, report, power point)
8. Exploration of post-instruction understanding through concept mapping

The SWH has been successfully used with Grade 7 students in the USA participating in a water quality unit and with Grade 9 students in Australia working on an optics unit. After negotiating with each other and the textbook, students working on the optics unit were asked to write a letter to a Grade 9 student explaining what they had done and what they had learned. When tested against a group of students undertaking traditional laboratory activities associated with optics, this group performed significantly better on conceptually orientated test questions. A study is now underway to look at the value of SWH when applied to a first-year undergraduate chemistry laboratory course.

Figure 3
A Template for Student Thinking

1. Beginning Ideas — What are my questions?
2. Tests — What did I do?
3. Observations — What did I see?
4. Claims — What can I claim?
5. Evidence — How do I know? Why am I making these claims?
6. Reading — How do my ideas compare with others?
7. Reflection — How have my ideas changed?

Concluding Comments

The most difficult issues involved in writing-to-learn activities and technical writing tasks is to convince science teachers and science professors who did not receive such instruction or experience that such activities are valuable. It is easy to see by a quick review of the references in this paper that many university/college science professors realize that students, even good students, can benefit from explicit science writing instruction. A trip to your teaching and learning center or visit with your reference librarian will reveal many things you can do to help your students become better communicators.

The amount of emphasis placed on writing to learn within science classrooms is increasing. Educators at all levels of education, elementary, secondary, and tertiary have begun to realize the cognitive value of encouraging learners to engage in writing activities that ask them to do more than simply record or recall knowledge. Such writing incorporates the nature of science-related concerns about evidence, claims, and warrants. By using a broader range of writing types within classrooms, science educators can promote an enriched conception of science literacy within their students. This array of genre will serve these students well as they become literate adults and workers.

However, while there have been many breakthroughs and promising practices, there are some barriers that need to be addressed by teacher educators. In particular, there is a need to address the pedagogical implications for teachers when using writing-to-learn strategies. Science teachers are not educated to use a broad range of writing types within their classrooms, and thus there is a need for the development of appropriate preservice and professional development programs to help them construct meaningful pedagogical strategies. Along with the development of pedagogy is the need for relevant assessment strategies for marking students' written products. How best to assess unfamiliar writing types in terms of the conceptual science knowledge and the actual writing product are issues with which science teachers are unfamiliar and uncomfortable. These need to be addressed in pragmatic and useful ways so that science teachers can monitor and assist student learning within their school settings. This may mean that science teachers at all levels begin to use the total learning community by seeking cooperative ventures with people from other disciplines, for example, graphic design faculty when constructing posters and brochures, and English faculty.

Another issue that has to be addressed by both researchers and teacher educators is what writing type best fits the particular learning situation. The use of inappropriate writing types may be a barrier to maximizing conceptual understanding in a particular situation, while in another situation may provide the breakthrough needed for students. There have been many promising developments in the use of writing-to-learn strategies in science classrooms, but there is still much that needs to be done. More well designed studies using a broad range of writing types need to be conducted within actual learning settings to judge the relevant merit of particular writing types in particular situations. Further studies need to be conducted that examine the possibility of cumulative benefits when using multiple writing types within an instructional unit.

As an introductory writing activity, students can be exposed to laboratory experiences, video materials, Internet information, and science text on a specific topic, e.g., pill bugs. The information can be recorded in an information matrix (Anthony, Johnson & Yore, 1996). Students randomly draw a synthesis question to write about (100-150 words) that is crafted to stress a form-function genre—describe the organisms investigated, explain how the organisms are adapted for survival, establish an argument that indicates if the organism is an insect, or provide directions for building an appropriate cage for the organism. Another assignment could explore the appropriate and inappropriate use of graphs, diagrams, and visuals in science materials. Information technology needs to be incorporated into writing tasks to increase response rate and to document its influence on reading and writing as linear technologies (Hedges & Mania-Farnell, 1998/1999; Maring, Wiseman & Myers, 1997; Martin, 1993).

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PowerPoint presentations, evaluating the accuracy of specific web sites, resolving discrepant information, and creating multi-media, non-linear text are interesting possibilities.

Your efforts to enhance students' reading and writing will pay off with increased science literacy, realized academic potential, and effective professional careers. The students you teach will appreciate your efforts to enhance their print-based communications.

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CHANGING ELEMENTARY TEACHERS' VIEWS OF THE NOS: EFFECTIVE STRATEGIES FOR SCIENCE METHODS COURSES

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The objective of helping students develop adequate conceptions of the nature of science (NOS) has been agreed upon by most scientists, science educators, and science education organizations during the past 85 years (Abd-El-Khalick, Bell, & Lederman, 1998). Presently, despite their varying pedagogical or curricular emphases, strong agreement exists among the major reform efforts in science education (American Association for the Advancement of Science, 1990, 1993; National Research Council, 1996) about the importance of enhancing students' conceptions of the NOS.

However, research has consistently shown that students' and teachers' views are not consistent with contemporary conceptions of the NOS (Duschl, 1990; Lederman, 1992, among others). In an attempt to mitigate this state of affairs, recent research has focused on helping science teachers develop desired understandings of the NOS (Aguirere, Haggerty, & Linder, 1990; Bloom, 1989; Brickhouse, 1989, 1990; Brickhouse & Bodner, 1992; Briscoe, 1991; Gallagher, 1991; King, 1991; Koulaidis & Ogborn, 1989). In a critical review of the attempts undertaken to improve teachers' views of the NOS, Abd-El-Khalick and Lederman (1998) concluded that those attempts were generally not successful in achieving their goal. They noted, however, that a reflective explicit approach to enhancing teachers' views was more "effective" than an implicit approach that utilized hands-on, inquiry-based science activities but lacked any explicit references to various aspects of the NOS.

The present study aimed to assess the influence of a set of activities developed by Lederman and Abd-El-Khalick (1998) on preservice elementary science teachers' conceptions of the NOS. The study also aimed to compare the "effectiveness" of the aforementioned activities when implemented using two approaches. The first was a direct explicit approach while the second included additional reflective components. The reflective components included written and oral discussions of elements of the nature of science throughout the courses in the second cohort.

The specific questions that guided this research were (a) What is the influence, if any, of using a set of specially designed activities on preservice elementary teachers' views of the NOS? (b) Does the addition of a reflective component enhance the "effectiveness," if any, of the activities used?

Before proceeding to describe the methodology undertaken in the present study, it is important to elucidate our definition of the NOS and the aspects of this multifaceted construct that were emphasized in this investigation.

The Nature of Science

Typically, the NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). These characterizations, nevertheless, remain fairly general, and philosophers of science, historians of science, and science educators are quick to disagree on a specific definition for the NOS. It is our view, however, that there is an acceptable level of generality regarding the NOS that is accessible to K-12 students and also relevant to their daily lives. Moreover, at this level of generality virtually no disagreement exists among historians, philosophers, and science educators (Lederman & Abd-El-Khalick, 1998).

In our view, the aspects of the scientific enterprise that fall under this level of generality and that are emphasized in the present study, are that scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional important aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws.

Method

Participants

The present study spanned two semesters. Two preservice elementary teacher cohorts participated in the study. The first cohort comprised 35 undergraduate students enrolled in an elementary science methods course during Fall term in a mid-sized Western state university. The second cohort comprised 50 students enrolled in two sections of the same course during Winter term. Twenty-five undergraduates were enrolled in the first section and 25 graduate students were enrolled in the second. Participants were mostly female (3 males in cohort 1, 5 males in cohort 2, with three graduate and one undergraduate, with the remaining 77 female). Their ages ranged between 23 and 52 with a median of 28 years. Undergraduate students were seeking a BA degree in elementary education while graduate students were working toward a Master in Teaching (MIT) degree in elementary education. The undergraduate students in the first cohort were in their fourth and final year. Both undergraduate and graduate participants in the second cohort were in the first year of their respective programs. Both groups of undergraduates had similar backgrounds in science, with most students (54) having taken between 10 and 16 credits of science. Half of the undergraduate students had taken biological sciences, while only one-third had enrolled in physical science courses. Most of the graduate students had taken between 12 and 15 credits of science, with two having previously received bachelor's degrees in engineering. These latter two students had taken more than 100 credits of science. Thus, with those two exceptions, the science backgrounds of all three groups were similar and comparable to other education students who were at similar levels in their programs.

Procedure

Data collection spanned the entire two semesters during which the study was conducted. Several data sources were used to answer the questions of interest. An open-ended questionnaire (Appendix A) in conjunction with semi-structured interviews was used to assess participants' views of the NOS prior to and at the conclusion of each course. The questionnaire (Abd-El-Khalick et al., 1998; Bell, Lederman, & Abd-El-Khalick, 1998) consisted of seven open-ended items that assessed participants' views of the tentative, empirical, creative, and subjective nature of science; the role of social and cultural contexts in science; observation versus inference; and the functions and relationships of theories and laws.

Semi-structured interviews were used to establish the validity of the questionnaire and generate in-depth profiles of participants' NOS views. Interviews were conducted with 60 randomly selected participants (20 students from each course). Half of these participants were interviewed at the beginning of each course and the other half at its conclusion. During these interviews participants were provided with their pre- or post-instruction questionnaires and asked to explain and elaborate on their responses. All interviews were audio-taped and transcribed for analysis. Additional data sources included student reaction papers, and a researcher log.

The three courses were similar in structure and aimed to prepare preservice elementary teachers to teach science. The courses were held weekly in three-hour blocks each semester, and were all taught by the same instructor. The course goals were to help preservice teachers develop (a) a repertoire of methods for teaching science, (b) favorable attitudes toward teaching science, and (c) deeper understandings of some science content area emphasized in the national *Benchmarks* (1993). The same readings, activities, and assignments were presented and undertaken in each of the investigated courses. These assignments included (a) an in-depth study of a science content area chosen by preservice teachers, (b) an interview with an elementary student to elicit his/her ideas about the science content area chosen by preservice teachers, (c) a presentation of the interview findings to peers, (d) a paper illustrating the content understandings gained by preservice teachers from their study contrasted with the corresponding understandings elucidated by the interviewed elementary student, (e) a series of three lessons designed to address misconceptions elicited during the elementary student interview, (f) weekly reflection papers on assigned readings and tasks, and (g) weekly in-class activities designed to help preservice teachers experience a variety of teaching strategies, develop content knowledge, and become more comfortable with science. The only difference between the courses offered in Fall and Winter terms was related to the NOS instruction that constituted a theme rather than an isolated topic, and the intervention in the present study.

The study featured two different interventions that were respectively implemented during Fall and Winter terms. The first intervention was implemented over the course of six instructional hours. During the first six hours in the course, the instructor (the first author) engaged students in 10 different activities that explicitly addressed the aforementioned aspects of the NOS. Detailed descriptions of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998). Each activity was followed by a whole-class discussion that aimed to involve students in active discourse concerning the presented ideas.

Two of the activities addressed the function of and relationship between scientific theories and laws. Two other activities ("Tricky tracks" and "The hole picture") addressed the difference between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Four other activities ("The aging president," "That's part of life!" "Young? Old?" and "Rabbit? Duck?") targeted the theory-ladenness and the social and cultural embeddedness of science. Finally, two black box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the above NOS aspects and provide them with opportunities to apply these understandings. It is noteworthy that these activities were purposefully selected to be generic (not content-specific) given the participants' limited science content backgrounds. Following this initial NOS instruction, however, the instructor made no further attempts to address the NOS. She consciously avoided explicit references to the NOS and drawing connections between the presented aspects of the NOS and other science content/teaching methods discussed throughout the course.

The second intervention was similar to the first save one major aspect. This aspect related to the extent to which participants were given opportunities to reflect on and articulate their views of the NOS. In addition to the six-hour NOS instruction at the beginning of the course, the instructor made numerous references to the discussed aspects of the NOS throughout the course. Whether students were engaged in learning science content or pedagogy, they were often asked to reflect on how that content or those teaching strategies were related to the NOS. The instructor kept a detailed log of all such references, prompts, and reflective opportunities. These opportunities included a discussion of the *Benchmarks* definition of evolution as a scientific theory (AAAS, 1993, p. 122) and how students in the class interpreted that statement. Children's literature books were often shared with the participants and they were often asked, "What does this book have to do with science?" to prompt discussions about the NOS. In addition to these many verbal discussions, students were assigned to write two papers in reaction to specific readings and videotape presentations related to the NOS. Further description of these reaction papers and course discussions are found in the reflective component section.

Data Analysis

The second and third researchers analyzed the data. This approach was undertaken because the first researcher was the instructor of the investigated courses and consequently she might have perceived such data to be partially evaluative.

The questionnaires and corresponding interview transcripts of the 30 randomly selected participants were used to establish the validity of the open-ended NOS questionnaire. The questionnaires were thoroughly read and searched for initial patterns. The same process was repeated with the corresponding interview transcripts. The patterns that were generated from the independent analysis of the questionnaires and interviews were compared and contrasted. This analysis indicated that the questionnaires generated valid profiles of participants' NOS views as established during the individual interviews.

Next, all NOS questionnaires were analyzed to generate pre-instruction and post-instruction profiles of participants' views of the NOS in the three courses. In this analysis, each participant was treated as a separate case. Data from each questionnaire was used to generate a summary of each participant's views. This process was repeated for all the questionnaires. After this initial round of analysis, the generated summaries were searched for patterns or categories. The generated categories were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data. Moreover, analyses of the second cohort participants' reaction papers were used to corroborate or otherwise modify the views derived from analyzing the NOS questionnaires. Additionally, reaction papers allowed the researchers to generate more in-depth profiles of participants' views. Finally, pre- and post-profiles were compared to assess changes in participants' views. These changes were compared across the investigated courses and the two interventions.

Results

The following sections describe participants' views prior to, and following the interventions. Changes in participants' views are elucidated and comparisons are made across courses to elucidate any differences that were evident between the two Winter courses that included a reflective component and the Fall course that did not. Additionally, a separate section describes the reflective component of the second intervention and elucidates its activities and discussions in relation to the changes that were evident in the second cohort participants' views.

In the following sections, a coding system is used to refer to participants. The codes "C1" and "C2" refer to participants in the first and second cohort respectively. The codes "U" and "G" refer to undergraduate and graduate participants respectively. The number following a "U" or "G" letter refers to an individual participant.

Pre-instruction NOS Views

Participants' pre-instruction views of the NOS were not different across the three courses. Consistent with previous research findings (see Lederman, 1992) participants' views harbored several misconceptions about the NOS.

<u>The empirical and tentative NOS.</u>

Participants in both cohorts held inaccurate ideas of the empirical and tentative nature of science. Participants tended to believe that with technological advances theories might change because we would better be able to view whatever it was we were looking at:

> As new and more powerful (more advanced) equipment becomes available theories can be retested. Our current knowledge is only as good as our current technology. C1U13

> Yes, theories can change after they are developed because of the new technology. An example would be the microscope. Several theories have changed because of high-powered microscopes. (C2U17)

> Theories do change. As technology advances we get more information, and can change the theory. (C2G23)

Students did not speak of the role of evidence as being important as how science differed in relationship to other disciplines. Rather, they spoke more of science being a study of things, while art was subjective, or a way to "prove" something:

> Art is a way to be creative. Science is a way to study things but you have to be objective. You can't be creative. (C1U33)

> Science is an attempt to find the truth. It tests theories and establishes laws. Art expresses feelings. (C1U19)

> Science is done to prove theories. Art is a way to show a picture of the world. (C2G24)

> Scientific theory is just a belief based on data currently available. Scientific law is proven fact, just like the law of gravity. (C1U7)

The view that scientific laws are "proven" and/or not liable to change indicated that participants thought that scientific knowledge is absolute.

The function of and relationship between scientific theories and laws.

All participants explicated inadequate views about the function of and relationship between scientific theories and laws. Many believed that laws are "proven" to be true while theories are not "proven:"

> A theory is a guess or a question that has not been proven or disproven by experiments. A scientific law is a theory that has been proven over and over by different scientist's. (C2G9)
>
> Scientific theory is a best guess about how something happens or works in science. It is based on data. A scientific law has been proven repeatedly and has not changed since it was developed. (C2G10)

Many participants did not seem to realize that theories and laws were different "kinds" of scientific knowledge and that one does not become the other. They believed in a hierarchical relationship between theories and laws whereby theories become laws with the accumulation of supportive experimental evidence:

> Through the method of science a theory is formulated. Before it can become a law it is subject to the world of science to prove or disprove it. If it withstands the tests, it becomes a law. (C2G3)
>
> A theory is an unproven, untested, invalidated hypothesis. A scientific law would be a theory that has been validated, proven, tested, and documented to be true. (C1U33)

One student drew a diagram (see Appendix B) to illustrate the hierarchical nature of the relationship between theories and laws and stated:

> Laws started as theories and eventually became laws after repeated and proven demonstration. A law can still be disproven, but there is ample proof that it is valid. Perhaps the difference between a law and a theory is the degree of proof??? (G15)

The creative, imaginative, and subjective NOS.

The majority of participants did not demonstrate adequate understandings of the role of human inference, imagination and creativity in generating scientific claims, or the subjective (theory-laden) nature of scientific knowledge and investigation. Students thought of creativity in science more in terms of problem solving than in terms of inventing theories and explanations:

> Scientists use creativity to improve their last experiments. This is called advancement, like creating super-glue! (C1U14)

> Scientists use creativity to help them solve problems. Like to build a car that will sell better than another model because people like the design better. (C2U23)

Participants failed to recognize that scientists use their imagination and creativity throughout scientific investigations, especially when interpreting data and inventing explanatory systems to explain those data. Some participants believed that scientists use creativity only in designing experiments. These students noted that it was not acceptable or desired to use creativity or imagination in other phases of scientific investigations such as interpreting data. Such use, they continued, would compromise the objectivity of scientists:

> A good scientist must be creative to design a good experiment. That scientist must keep an open mind to what he/she is observing and not be subjective. The scientist might be imaginative in coming up with a theory, but it must be through the scientific method so they stay objective. (C2G5)

> A scientist only uses imagination in collecting data . . . But there is no creativity after data collection because the scientist has to be objective. (C2G24)

> Data needs to be collected in a very systematic way, should be repeatable, needs to be well-founded and should lack personal opinion and interpretation. Dealing with data should be objective. (C1U12)

Similarly, the majority of participants believed that science was objective as evident in the following representative quotes:

> Art tends to be more subjective. Science is objective. (C2U12)

> Scientists are very objective because they have a set of procedures they use to solve their problems. Artists are more subjective, putting themselves into their work. (C2G17)

The objectivity of scientists, the participants continued, was guaranteed by the use of "The Scientific Method." Indeed, the belief that scientists use a single scientific method or other sets of orderly and logical steps characterized the responses of almost all participants:

> Science is an academic discipline that requires the use of methods to ensure it is without bias. (C1U14)

> Science experiments are planned out ahead of time so there is no way to get the wrong results. (C2U10)

> Science deals with using a good method so we can duplicate our results. That way we know we have the right answer. It is very exacting. (C2G3)

Participants failed to recognize that the scientists' training and disciplinary backgrounds, as well as their theoretical commitments, philosophical assumptions, prejudices and preferences influence their work.

Post–instruction NOS Views

Participants' post-instruction views are reported separately for each cohort. The two cohorts' views are compared and contrasted in a separate section.

Cohort #1 NOS views.

Analyses indicated that participants' views in the first cohort were not appreciably altered as a result of the intervention. Although a few participants expressed more adequate views of some of the addressed aspects of the NOS, the majority maintained their initial views.

The empirical and tentative NOS

In post-instruction questionnaires, participants' responses still indicated difficulties in articulating how science differed from art in relation to the role of evidence (item four on the questionnaire). Only 3 out of 25 students stated that science required data while art did not

Scientists rely on data for their end results and artists do not. (C1U1)

A scientist collects data, interprets it, and reports upon it. (C1U17)

As far as tentativeness is concerned, relatively more students in the first cohort indicated that theories change. This could be taken to indicate that more of these participants adopted the view that scientific knowledge is tentative. However, in distinguishing between theories and laws, the majority still indicated that laws are "proven" and are thus *not* liable to change. As such, participants' responses were more indicative of inaccurate conceptions of the nature of scientific theories than of their commitment to a tentative view of scientific knowledge.

The function of and relationship between scientific theories and laws

As noted in the above section, students in the first cohort continued to have inaccurate ideas about theories and laws. Many students still believed that theories were unproven and laws were "proven." Others held on to a hierarchical view whereby theories would become laws with the accumulation of evidence:

> Scientific law is a theory that has been accepted and proven. Like the Law of Gravity. This theory was proven and became a law. (C1U20)

> Scientific law is a theory which has been proven time and time again. A theory is a guess or question that has not been proven or disproven by experiments. (C1U25)

> A scientific theory is somebody's idea to explain the how and the why of the world around us. A scientific law is a theory that has been proven. (C1U18)

Only one student seemed to have adopted a more accurate view of the relationship between theories and laws. Her statement that "Scientific law states what is observed and theory states the how and why" (C1U6) did not include a hierarchical reference or references to the amount of "proof" or evidence that other students thought differentiated between scientific theory and law.

The creative, imaginative, and subjective NOS

Many participants noted in their post-instruction responses that while art involved creativity and imagination, science was "factual." As evident in the following representative quotes, these students continued to harbor inaccurate understandings of the creative nature of the scientific endeavor:

> Science must be precise to get the best results. Art has more creativity. (C1U33)

> Science is based on facts that the scientists hope to prove. Art is more interested in feelings and emotion. (C1U2)

Only one student expressed more adequate views of this aspect of science. Indeed, she noted that scientists create laws and theories:

> Science and art are similar in that scientists and artists both creatively interpret something within the medium they are given. For example, in science, the medium is the entirety of scientific law. The scientist is creative in visualizing an interpretation of how all scientific laws go together. In so doing, the scientist may create scientific theory. (C1U12)

Moreover, the responses of a majority of students in the first cohort indicated a still-present belief in the existence of a single scientific method:

> In art the creative, subjective approach is valued. In science the objective approach is more important, and you must document your work through the scientific method. (C1U10)

As evident in the above quote, some participants held on to their view of science as an "objective" enterprise. However, significantly more of them noted that scientists' backgrounds, theoretical commitments, and personal views influence the way they interpret data:

> Scientists probably interpret the experiments and data differently, or they may have their own pre-determined theories that causes them to view the data in other ways. (C1U7)

> Data and experiments are interpreted differently for each scientist depending on their own theories. Biases are supposed to be left out, but do at times appear in findings. (C1U32)

> It all comes down to how each scientist takes in and interprets the experiments and data. They take the data and within their minds they see different pictures which lead to different interpretations of what is happening. (C1U27)

It is noteworthy, however, that a few participants attributed negative connotations to this theory-ladenness of science. They viewed the "subjectivity" of scientists less as an aspect inherent to scientific investigation—an aspect that scientists actively attempt to ameliorate—and more as an intentional search for pre-conceived results for the purpose of securing research funds:

> I think it is just a way for scientists to get more funds to find out something that may never be proven. It sounds more like they want their opinions believed than anything else. (C1U5)

> Each one has come up with their own hypothesis even though they are looking at the same data because each is trying to come up with the findings they are seeking. (C1U35)

> When a scientist has an opinion about something they are not going to change their outlook probably because that is how their program is funded and they want to get the expected answers. (C1U31)

Cohort #2 NOS views.

Relatively more participants in the second cohort expressed more adequate post-instruction views. The changes in participants' views due to the reflection-based

> Theories change after new scientific evidence makes the theory into a law by continuous proof of the theory (C2U24).
>
> Yes, theories sometimes do change. It either changes into a law, or it is disproven and is no longer a theory (C2G12).

Four other participants, two graduates and two undergraduates, retained the erroneous views that theories and laws were difference because laws were accepted as "truth," whereas theories lacked verification:

> Theories are still being doubted, or have too many loopholes for absolute acceptance. Scientific laws are accepted as truth. (C2U20)
>
> Scientific laws have been proven time and time again since the recorded history of humankind. They are ALWAYS true within the given sphere. They will remain true unless nature changes. (C2G13)

However, many participants adopted the more adequate view that scientific theories and laws were different kinds of scientific knowledge. These participants noted that while a scientific theory is an inferred explanation for observed phenomenon, a scientific law states, identifies, or describes relationships among observed phenomena:

> Scientific theory is the inferred explanation for observable phenomena. Scientists infer explanations by observing. Scientific law is the statement of what you observe happening (C2U8).
>
> A scientific law <u>describes</u> something that happens in nature. A theory is an attempt by scientists to <u>explain</u> why nature is the way it is (C2G18)

The subjective and creative NOS

Students in both the undergraduate and graduate sections articulated better understandings of the role of creativity and subjectivity in science. Over half of the students in the second cohort believed that science, like art, required creativity and imagination, and both were in many respects subjective:

> Both science and art are subject to interpretation. Differing opinions allow either to approach new methods or ideas with creativity (C2U19).
>
> Both science and art are created by humans' minds. Both reach their fullest expression only when the scientist or artist shares his/her creation with other human beings. However, science is based on evidence, whereas art is not (C2G11).

Fifty percent of the second cohort students no longer believed that creativity was only used in the initial stages of scientific inquiry, but that it was an integral part to all stages of scientific investigation. Additionally, many students used the term creativity in the sense of inventing theories and explanations rather than problem solving or resourcefulness:

> You need to design an experiment which requires creativity and imagination and it takes imagination and interpretation to create a hypothesis and theory. (C2U3)
>
> Scientists use their imaginations in creating theories. Especially when experimenting and investigating there are so many different ways to look at science. Scientists use the knowledge gained from their experiments and observations, but their creativity and imagination are also important in coming up with a conclusion or in developing a theory. (C2U11)

Nonetheless, the view that "creativity" in science was related to solving society's problems such as curing diseases or reducing pollution, rather than the invention of explanations, was expressed by approximately one-fourth of the students in the second cohort in their post-instruction responses:

> Scientists use their creativity and imagination to find cures for diseases like cancer. (C2U12)
>
> Scientists manipulate variables to see if results change. This creativity has led to the discovery of vaccinations for disease. (C2G7)

Three-fourths of participants in each section of the second cohort demonstrated adequate views of the subjective (theory-laden) NOS. For instance, they recognized that scientists' prior knowledge, personal backgrounds and viewpoints influence the ways in which they interpret empirical evidence:

> Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge. (C2U24)
>
> The human element in analyzing and interpreting data leaves much room for varying views. This is the creativity of science showing itself. Individuals will have different natures, mental processes, and backgrounds. The interpretation of data is subject to the human element (C2G23).

Only 3 in each section of 25 students still held fast to the notion that scientists purposively interpret data differently because they seek to support their own theories and secure funding:

> Scientists are interpreting things different to prove what they believe. They may ignore certain facts and pay attention to only the things that support their own ideas (C2U10).
>
> Scientists interpret data to steer towards proving their own hypotheses (C2G13).

Summary of Results

Prior to instruction, most students in both cohorts believed in a single scientific method that guarantees the "objectivity" of scientists and scientific knowledge. All students held either a hierarchical view of the relationship between scientific theories and laws, or believed that laws were well-supported, "proven," or "true" while theories were not. Moreover, participants held inadequate views regarding the role of human inference, imagination, and creativity in generating scientific claims.

Following instruction, three of 35 students in the first cohort expressed more adequate views about the empirical NOS. In comparison, half of the students in the second cohort emphasized the role of evidence in setting science apart from other disciplines of inquiry. Moreover, while many of the first cohort participants held fast to the view that there was a single scientific method through which objectivity was maintained and appropriate conclusions drawn, no participants in the second cohort made similar references. Also, more participants in the second cohort demonstrated better understandings of the explanatory function of scientific theories and their role in guiding research efforts.

Regarding the relationship between scientific theories and laws, only one student in the first cohort abandoned the hierarchical or "laws-as-truths" viewpoint. By contrast, only four students in the second cohort retained the hierarchical view. Nine others expressed more accurate conceptions of the difference between theories and laws. They noted that theories are inferred explanations for natural phenomena while laws were descriptions of observable relationships among phenomena.

Probably the greatest improvement in the views of participants in both cohorts was related to the role of human attributes such as creativity and subjectivity in science. In the first cohort some students noted that scientists interpreted evidence based on their own backgrounds. Substantially more students from the second cohort, however, expressed more accurate post-instruction views in this regard. Half of these latter participants believed that creativity was involved in all stages of scientific investigations, and three-fourths recognized that scientists' background played a role in interpreting data and reaching conclusions.

While participants' views of certain aspects of the NOS improved, particularly for participants in the reflective group, there is still much to be desired. Nonetheless, the results of the present investigation seem to indicate that the addition of a reflective component to explicit NOS instruction resulted in *more* students adopting adequate views of the NOS. We now turn to examine in some length the reflective component of the second intervention.

The Reflective Component in the Second Intervention

Following the initial six-hour NOS instruction and throughout the second cohort's classes, students were asked to reflect, both orally and in writing, upon various aspects of the NOS as they arose during activities or as they related to course readings. The NOS aspects that were common throughout the reflective component of the second intervention were identical to those adopted and emphasized in the present study.

Classroom Discussions

Students were often asked to relate the NOS aspects discussed at the outset of the intervention to other topics discussed in the course. For instance, at about midpoint in the semester, participants were asked how whether NOS was related to the assessment of elementary students' science content knowledge. The ensuing discussion in the graduate section of the course highlighted the distinction between observation and inference as evident in the following excerpt:

> Student 1: Assessment is only a picture of what students might know, not a given of what they actually do know. It is like science. You are looking at pieces of evidence, trying to draw conclusions and then infer what the evidence means about what the students know about a given concept. Just like science your conclusions are tentative because with new evidence your interpretations may change about what the student knows.
>
> Instructor: That is an interesting idea. It does relate to our discussions on the nature of science. Can you say more?
>
> Student 2: Yeah. It is like the "tubes" activity (one of the activities presented in the first two weeks of class). With a lot of variety of assessments you can get a better picture of what the student knows than with only one method of assessment. With the "tubes" activity, if you pull only one string you will have less of an idea of what is inside the tube than if you pull all of the strings and see what happens.

In a related discussion, the reading for the week addressed the assessment of process skills. The instructor raised the following questions, "Do you think there is a scientific method that includes all of those process skills in a particular order? Can we use this scientific method to assess students' mastery of process skills?" The discussion that followed started students thinking about the distinction between the finished products of science as they appear in professional journals and the actual work that scientists engage in their day-to-day activities:

Student 1: That is how all the journal articles are written. Yes, there is definitely a scientific method.

Instructor: Is the "method" actually step-by-step, just as published? When you "do science" do you always ask a question, then observe, then hypothesize, then design your study, then draw your conclusions, etc.?

Student 1: No, not really. It is more mixed up in order when you do it. When you write it up you kind of have to "figure out" a logical way to present what you did and then you can probably get to publish it.

Student 2: Probably you do observations and all those things, but they are in different orders. Then when you write it up is when you put it in the order the magazine [journal] wants.

Another discussion that focused on the notion of unifying themes from *Benchmarks for Science Literacy* (AAAS, 1993). In the undergraduate class, the instructor asked whether this discussion was related in any way to earlier NOS discussions. Students referred to the "Tubes activity" in the attempt to explain how and why "Models" are a unifying theme in science:

Student 1: It is like the tubes activity.

Instructor: How so?

Student 1: You are seeing the evidence when you pulled on the strings of the tube and the evidence showed you how you could build your tube to match the real thing. You don't really know what the real thing is, but can approximate it through the model. If the model works like the real thing, it is a good model.

But you still don't know if it is like the real thing. Still, the model can help explain what you are studying.

The above discussions might help to illustrate the importance of explicit prompts to get students to think about and reflect on different issues related to the NOS. Without such prompts, these discussions were not likely to have taken place. Toward the beginning of the courses, these discussions were almost exclusively dependent on explicit prompts from the instructor. It got students involved in discourse about the NOS. Such involvement, we believe, was crucial in helping students clarify their ideas about the NOS for themselves in the first place, and for other in the second place. However, as the term progressed, it was interesting to note that the students began to recognize on their own what elements of the NOS were relevant to various discussions. At this stage, the instructor's role shifted from prompting discussion about the NOS to facilitating the discussion, providing focus, and helping participants to come to some sort of closure.

For instance, at about the midpoint of each class, the children's book *Earthmobiles as Explained by Professor Xargle* (Willis, 1991) was read to the class. This book discusses transportation on Earth from the viewpoint of aliens. The question was raised "Why would I read this book to you? What does this book have to do with science?" The graduate students noted that the book was talking about the NOS. The instructor capitalized on this opportunity, and as evident in the following excerpt, attempted to focus participants thinking on the distinction between observation and inference:

Student 1: It talks about different viewpoints.

Student 2: Yes, it is like drawing conclusions based on your own viewpoint.

Student 3: It is good for sharing how things can be described and interpreted from different viewpoints.

> Instructor: To me it is like science because the aliens are taking the evidence of what they observe and interpreting through their own lens. They are drawing conclusions and presenting them based on their prior knowledge and their interpretations from that evidence and knowledge. They don't know for certain if their ideas/interpretations are correct, but they are reasonably sure that their conclusions, based on their observations, make sense.

> Student 4:This is another nature of science thing again.

Written Reflections

Students in both classes of the second cohort were required to respond in writing to two reflective prompts that related directly to the NOS, and one that allowed them to reflect on their experiences in the course as a whole. The first paper was related to the prologue of Penrose's (1994) *Shadows of the Mind: A Search for the Missing Science of Consciousness.* Specifically, students were asked:

> How do you see this article does/does not fit with our discussions of the nature of science? Include the elements of tentativeness, creativity, observation versus inference, subjectivity, relationships of theory and law, and social and cultural context in your response.

Student responses to this prompt focused on the social, subjective, and tentative NOS, and the distinction between observation and inference:

> Jessica and her father's theories about the outside world could never be more than tentative because they can never be sure whether they made the right inferences from their observations of the shadows. This is the case in science today. Since we cannot directly see the atom or black holes, our inferences about these concepts are tentative even though they are as reasonable as possible from the evidence. (C2G13).

> Jessica's father said it would be difficult to persuade cave-confined people that their theory of the earth going around the sun is accurate because:
> • Their possible experience and mindsets are so limited as results of their backgrounds in the cave.
> • Their observations could be interpreted in different ways. (C2U8)

> I thought the boulder sealing the people in the cave was a nice metaphor for how much we can see of astronomy from our planet. We can't really see much, so we have to draw tentative conclusions from what we can observe. (C2U23)

> One of the aspects of the nature of science that this story illustrates is subjectivity. We interpret things based on what we know. Because if we were born in a cave we would have to infer what was outside the cave from observations, we might not really know what is there, though it would make sense to us. Much of our scientific knowledge today seems to me to come from observing the "shadows on the wall" and maybe what we think we know is really way off. (C2U19)

> One student chose to illustrate her ideas through a concept map (See Appendix C).

For the second reflection paper, the students watched Bill Nye the Science Guy "Pseudoscience" episode and responded to the following prompt:

> How do you see what Bill Nye shared in the "Pseudoscience" episode fitting with our class discussions of the nature of science? Again, include elements of tentativeness, creativity, observation vs. inference, subjectivity, relationships of theory and law, and social and cultural context in your response.

Again, students focused on the tentative and empirical nature of scientific knowledge and the roles of observation versus inference in the generation of scientific knowledge:

> The episode showed that new evidence can change our view about what we know about science. Bill Nye focused on observation vs. inference, because he pointed out how without direct observation inferences could really be wrong, like with thinking crop circles are created by UFOs. (C2U18)

> The show really discussed the difference between science and pseudoscience. Real science can be tested. Pseudoscience is not testable. (C2G5)

> The thing that struck me is that even when you observe something that doesn't mean you will make a good inference. Like when Bill Nye said he was a ghost, you knew he wasn't even though what was observed made it look like he was a ghost. (C2U25)

In the third reflection paper, students were asked to prepare a "Top Three List" of the most important things they believed they learned in their methods course. Four of the graduate students mentioned the NOS as one of the important things they learned about. None of the undergraduates mentioned NOS. It is possible that the graduate students, who were more reflective in their discussions and written responses, gained a better understanding of the importance of knowing about science itself when becoming teachers:

> My favorite part was learning about science—like the string in the tube, and the cube with one side down. These types of activities are powerful examples of working on scientific ideas without being able to observe actual parts, like atoms. (C2G11)
>
> I learned that creativity is just as important in science as it is in the arts. Scientists must create problems to study, ways to study them, and ways to synthesize the information they learned. The "Prologue" article showed how creative Jessica and her dad had to be when they discussed the cave question.
>
> I learned that in order to be able to effectively TEACH science, I have to have a clear understanding of what IS science. (C2G17)

Implications

The results of the present study are consistent with research on student misconceptions and serve to show the tenacity with which students hold on to their own views. After all, participants' views about the NOS have developed over years of elementary and secondary education. It is unlikely that such views can be undone as a result of six hours of instructional activities even if such activities explicitly address specific aspects of the NOS. It is also the case that the instructor of the course was new at using the activities in the course, and could have become better at presenting the activities in the second semester to the second cohort. Nonetheless, the results of the present study serve to substantiate the view that an explicit approach to teaching students about the NOS, coupled with reflective elements spanning the entire science methods course is more effective than simple direct instruction in an isolated unit.

For participants in the first cohort, six hours of instructional activities designed to illustrate elements of the NOS were only minimally effective in improving their views. Nonetheless, the addition to this six-hour instructional component of a reflective component centered on the theme of NOS throughout the investigated science methods course resulted in changing the views of substantially more participants in the second cohort. Yet, there is still much to be desired. At best, only three-fourths of the second cohort participants held acceptable views of the role of subjectivity and creativity in science, and one half held more acceptable views of the relationship between scientific theories and laws. Many other targeted aspects of the NOS showed no improvement.

So, it can be asked whether the project was successful given that many students in the second cohort still held less than adequate views. The answer would be that many participants made impressive changes in their views of and thinking about the NOS, and that given more time, and more dedicated direct and reflective activities, others could be helped to develop desirable views. However, investing more time in teaching about the NOS in an elementary science methods course may not be feasible. This is especially so given that most elementary preparation programs include only one science methods course in which a plethora of other science and science teaching topics must be covered.

Nonetheless, another route can be taken within the timeframe of an elementary science methods course. Participants in the present study were not made aware of the inadequacy of their ideas at the outset of the course. In other words, these participants did not experience any cognitive dissonance regarding their NOS views and, thus, might have had no incentive or desire to change their ideas. Making students aware of their misconceptions prior to teaching them about the NOS might facilitate changing their ideas toward more current conceptions. In other words, explicit and reflective instruction about the NOS integrated within a complete conceptual change approach might serve to better enhance student views. Indeed, such an approach will be the focus of our next research effort.

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Appendix A
Nature of Science Survey Interview

1. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of atoms? What specific kinds of evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

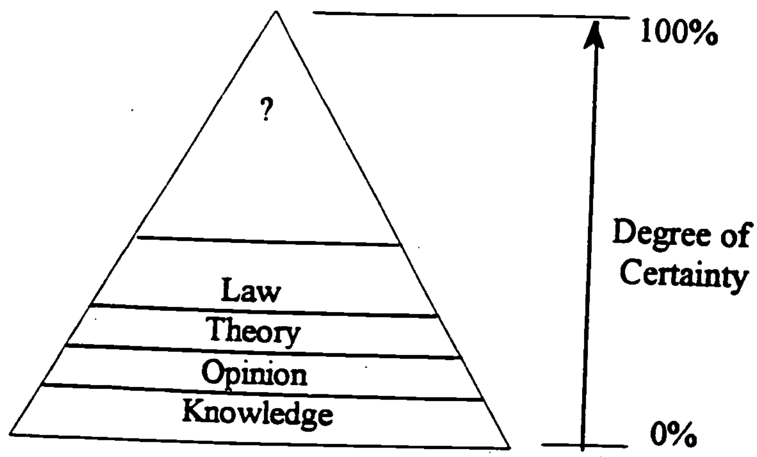
5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

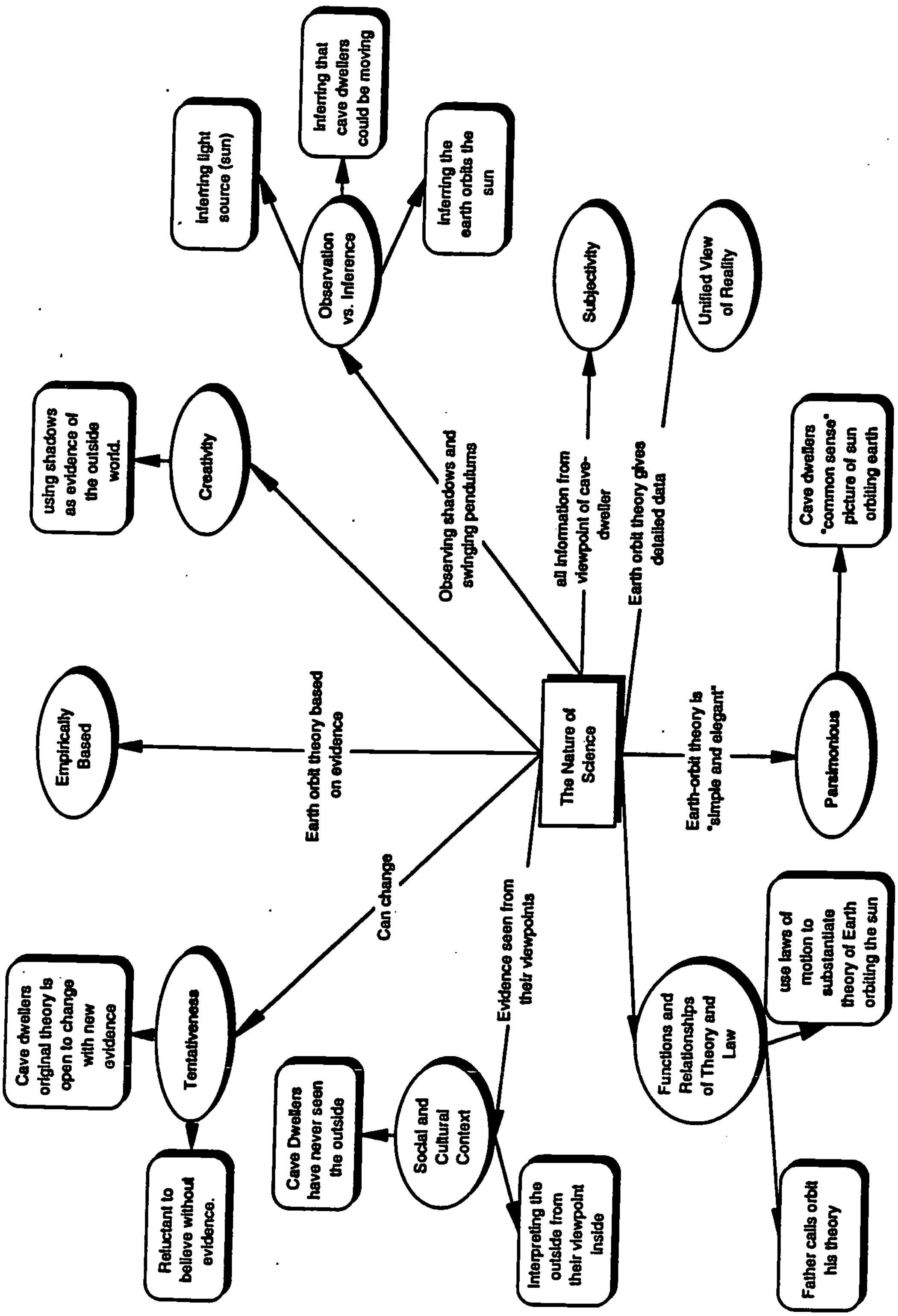
Appendix B

Cohort #2 Pre-Instruction Drawing of the Relationship Between Theory and Law



Appendix C

Student Concept Map as a Reflection Response to the Penrose Article Prompt.



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TEACHING BIOLOGY TO PRESERVICE ELEMENTARY TEACHERS: USING THE K-8 CONTENT STANDARDS AS A FRAMEWORK

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Educators and science professionals have issued the call to improve science education for all students (AAAS, 1990; NRC, 1996). In response, various criteria have been generated for learning such as the Benchmarks (AAAS, 1993), the National Science Education Standards (NRC, 1996), and various state and district level science standards. Now we are faced with the challenge of implementing these standards. Important to consider in this process of implementation of standards are the preservice teachers.

Preservice elementary content courses have been criticized for a variety of reasons. Suggestions have been made that they become more hands-on, more focused on content that the teachers really need, less vocabulary driven, and taught in ways that model good teaching for elementary classrooms (McDevitt, Troyer, Ambrosio, Heikkinen, & Warren, 1995; NRC, 1996; Hammrich, 1998, Mellado, 1998). Revisions in this course were conducted as part of a larger initiative to improve teaching in undergraduate science courses taken by preservice science teachers. The larger initiative was the Rocky Mountain Teacher Education Collaborative (RMTEC), one of the NSF funded Collaboratives for Excellence in Teacher Preparation. RMTEC included Colorado State University, Front Range Community College, Metropolitan State University-Denver, Community College of Denver, University of Northern Colorado, and

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Aims Community College. One of the overall goals of this project was to bring more constructivist teaching and assessment strategies into the university science classroom. Currently it seems evident that beginning teachers also need to be familiar and comfortable with national, and if applicable, state science standards.

This paper describes a course revision of a content biology course for elementary teachers in which content was filtered through the K-8 national and state standards and teaching strategies appropriate for use by elementary teachers was modeled by the instructor.

The Course

The course targeted for revision is a content biology course taken by preservice elementary teachers at a mid-sized western state university. In addition to this course, most also take a physical science course designed for the preservice elementary teacher. There is also an earth science course for elementary teachers offered. Most students who take the biology do not take the earth science. This course also counts toward general education requirements for other students so each semester a few students in the class are not planning on becoming elementary teachers.

Originally the three content courses for prospective elementary teachers were designed because it was believed that these students had different needs than the biology majors or those taking biology for a general education requirement. It was thought that future elementary teachers needed different content from science majors. Biology majors needed content at a level that was unnecessary for elementary teachers but the introductory course for majors, primarily a cell/molecular biology course, failed to cover other material, such as germination of seeds, that elementary teachers could use. The non-major's course did not include a laboratory, and was not content-rich enough to give preservice teachers the confidence to teach biology. Over time, the biology course for elementary teachers evolved into a very traditional biology content course with many of the same content and activities as the course for biology majors. The authors felt that if the course could be revised to be brought in line with national and state content and teaching standards, it would better fill the needs of prospective elementary teachers.

The Students

The students enrolled in this class are primarily females (84%) and freshmen (32%) or sophomores (48%). Enrollment ranges between 30 to 60 students per section. Laboratory sections tend to be small, from 12 to 24 students per section. Most students have not had any previous teacher preparation classes (71%) or college biology (74%). Of the study groups, 84% were seeking licensure, mostly elementary. There were two students seeking secondary licensure and three who were in programs that have K-12 licensure. 90% of the students had taken a high school biology course.

Revision Goals

The goals of the authors in revising this course were as follows.

1. Base the content and processes on National and State science standards.
2. Base the instruction on National teaching, professional development and assessment standards as described by the National Science Education Standards (NRC, 1996).
3. Ensure that sufficient content was presented and assessed so students would be able to teach in accordance with the elementary science standards.

4. Model a variety of teaching and assessment strategies, and discuss these explicitly but briefly.

5. Require that students use the K-8 National and state science standards in a variety of ways to ensure familiarity and increase their comfort level with the standards.

6. Present science in such a way as to increase the students motivation to teach science in the classroom.

Rather than fitting the standards to the content of an existing syllabus, the content was completely revised in light of the elementary standards. The textbooks chosen were *Biology: Discovering Life: Core Concepts* and *Biology: Diversity of Life*, both by J. S. Levine and K. R. Miller (1994). Content was specifically selected which provided necessary background so teachers would feel comfortable with the content contained in the K-8 national and state standards. Because of this, more time was spent on some topics than is usually the case in a content course, and other material was eliminated completely. For instance, the Kreb Cycle was not taught but the overall idea that all cells must respire to have energy was discussed.

Activities and assessments were also designed which modeled practices considered to be good teaching by the NRC teaching and assessment standards (NRC, 1996). A variety of strategies were used including cooperative groups in the labs and classroom, authentic assessment, informal learning assessments to adjust teaching, field trips, long-term experiments and projects, inquiry-based laboratories, and discussion. The instructor made these strategies and methods explicit to the students. For example, a brief discussion of the benefits and drawbacks to field trips were discusses as well as how to plan a field trip that is educational. When the instructor asked for a one-minute paper about a concept, she made it explicit that she was monitoring their understanding so she could go over the concept again if necessary.

Sample Activities

The course began with an activity in which students were asked to describe what items in a plastic bag were living. Included in the bag were pennies, toothpicks, plastic clips, popcorn, pinto beans, rubber stoppers, and freshly pulled weeds. Students were asked to work in groups and decide whether each item was living, had been living but was now dead, or had never been alive. Then the class brainstormed the requirements for life. They added a very damp paper towel, some air (by blowing in the bag), sealed the bag and placed it in the light. One week later they opened the bag and analyzed their results. Most of them did not initially know that the beans and popcorn were living. After discovering their mistakes, it was pointed out to them that one of the first state standards was that students in grades K-4 would be able to distinguish living from non-living items (Colorado Model Content Standards, 1994). The students readily acknowledged that they probably needed to know some biology if they were to teach science effectively.

Some other activities were a field trip to a neighborhood park (see Appendix A), an inquiry-based genetics lab using F_2 corn showing 1:1 and 1:3 ratios (yellow: purple kernels), a population lab and a personal food pyramid. Students also built ecosystems in pop bottles, which were used for all units throughout the semester (Bottle Biology Project, 1993). All content was selected with the K-8 standards as a framework in deciding which content to cover, which concepts to stress, and to what depth a concept should be understood.

Examples of teaching strategies modeled and briefly discussed were inquiry-based laboratories, think-aloud techniques, journaling, confirmatory laboratories, and simulations. A variety of assessments were used. Among those were discussion, journals, take-home authentic assessments, one-minute papers, and traditional paper-and-pencil tests. Cooperative learning and collaboration was used frequently in both the classroom and in the laboratory. Most labs were designed to be performed in groups. Classroom activities included jigsaws, round-robins, small group discussions and debates.

Survey Results and Student Comments

A survey was given at the conclusion of the class to determine whether the students felt a particular strategy or activity helped them learn biology content and whether it helped prepare them to teach. Comments were solicited concerning the activities. In addition, comments offered during informal interviews by the instructor during the course of the semester were collected. The survey used a Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). For each strategy or activity in the survey, students were asked whether the item helped them learn biology, and whether it helped prepare them to teach. Students who were not seeking licensure did not answer the questions concerning teacher preparation.

Activities and strategies which were felt to be most helpful in learning biology included bottle biology and inquiry labs in general. Others ranking high included an activity on the properties of water and one on acids and bases, both including prescriptive and inquiry-based activities. The field trip to a near-by park to study ecology was also felt to be beneficial in helping students learn biology.

The highest ranking item on the survey was using the standards in helping the students prepare to teach (mean =4.52). Other activities and strategies which were considered to be helpful by the students in preparing them for teaching were the bottle biology, observing a variety of teaching methods, using cooperative groups, and the properties of water lab.

Comments made by the students included statements about the course in general such as the following:

> *I've had quite a few biology courses, but in here I finally came to really understand the concepts I've just memorized before.*

> *I never liked science before but this class is fun.*

Remarks about the types of activities include the following:

> *Doing inquiry taught us how to ask good questions and come up with our own answers.*

Not all comments were positive. One student remarked,

> *There aren't enough multiple-choice tests in here. This just isn't what I expect in science classes.*

Many students made comments about using the standards during the course. Representative remarks include the following:

> *It is good to get a head start on what students should know.*

> *It prepared me for the future.*

> *I didn't know anything about them. This will be useful later.*

> *I liked planning with standards.*

> *I'm the only one of my friends in elementary education who knows anything about the standards.*

One student who was not in elementary education and who was not seeking licensure said,

> *I am really tired of these standards.*

Specific activities also elicited comments, such as opinions about the field trip to a park. The remarks included the following:

> *I will definitely use these ideas.*

I learned how to plan a field trip that is educational, cheap, and fun.

Students also remarked about using bottle biology. Comments ranged from general statements about the activity to those about specific content learned, such as:

I learned a lot about biology.

It was a fun and unique activity.

The following remark is an example of one student's excitement about the content:

> *I learned by watching the bottle that if a closed off environment has the components of life to survive, it will grow in its own ecosystem!*

Future Research

The authors maintain that reform of preservice teaching programs is only valuable if it positively impacts teacher behavior and student learning in the elementary classroom. Longitudinal studies should be performed to determine whether these changes take place. The authors propose that studies of teachers' attitudes toward science and science teaching, feelings of self-efficacy, and their use of content and teaching standards in the classroom be surveyed during their second and fifth years of teaching. In addition a survey of the methods used in the classroom, which were modeled in the revised class, will be performed. At the same time, their elementary students' attitudes toward science and their achievement in biology content will be assessed. Results will be compared with those of a cohort group who were not involved in the revised course and their elementary students.

The authors hypothesize that teachers who were enrolled in the revised course will have more positive attitudes toward science and science teaching, will use the standards more in planning and carrying out curriculum, will have stronger feelings of self-efficacy, and will use methods modeled in the revised biology course more than the cohort group. It is also hypothesized that their students will show a more positive attitude toward science and will have higher achievement in science.

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A MODEL AND STRATEGIES FOR REALIZING SECONDARY LEVEL INTERDISCIPLINARY INSTRUCTION

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Educational reform currently advocates a movement towards connecting the disciplines by employing multidisciplinary, interdisciplinary, thematic, or integrated approaches to curriculum and instruction (Lederman & Niess, 1997, Marsh, 1997). Lederman and Ness discuss the "semantics" of the previous terms: They contend that integrated instruction is where the traditional disciplinary boundaries are "dissolved," whereas with interdisciplinary instruction, "the integrity of the various academic disciplines remains clear" (p. 57). In thematic instruction, an overarching concept/topic is provided to interrelate separate disciplines and respective topics, e.g., "food safety" might connect history (the genesis/progression of sanitation, inspection, and labeling laws and regulations), health (food-borne diseases), and science (microbiology, toxins). Marsh (1997) defines multidisciplinary instruction as teaching, over the same time period, lessons from two or more disciplines (e.g., science and social studies) that correspond to the same topic, the latter taking the form of a theme (e.g., global warming) to provide explicit focus. In multidisciplinary instruction, the identity of the separate disciplines is retained.

Irrespective of the semantic issues, attempts to interrelate the disciplines should consider focusing on real world problems or issues (e.g., alternative eating, discrimination) that have relevance to youth. Problem-based learning (Stepien & Gallagher), and guiding questions with "intellectual bite" and "emotive force" (Traver, 1998), can be employed. Relative to the latter, one could pose, "How might the adoption of vegetarianism by developed countries impact our planet (or global warming, world hunger, our society, our economy, and so on)?

Connecting the disciplines for meaningful learning is often accomplished in elementary education. However, this is considerably more difficult at the high school level, and achieving such on a long term basis is confounded by a host of barriers and issues (Miller & Davison, 1998). These may include: (a) a "top down" edict by administration to implement a specific curriculum, (b) a "gung ho" approach to realizing interdisciplinary instruction (i.e., entire courses are overhauled/combined instead of a phased/unit approach), (c) being relatively uncomfortable or unfamiliar with alternative teaching and assessment strategies, (d) insufficient or ineffective inservices on interdisciplinary instruction, (e) lack of a common planning period, (f) no flexibility to schedule different subjects "back to back" or for block scheduling, (g) a need to preserve the integrity of individual disciplines (Lederman & Niess, 1997), and (h) demands (perceived or real) to "cover" an immense number of concepts within each discipline.

This workshop will familiarize participants with an "interdisciplinary" high school curriculum, which employs common themes that can be taught across the curriculum or in a variety of subjects. The themes are related to human nutrition. The workshop also will explore strategies to realize interdisciplinary instruction at the secondary level and discussions about ways the authors have used the curriculum for professional development of secondary teachers, including science teachers who participate in a Health Sciences and Technology Academy (http://nt-hsta/hsc.wvu.edu/health) (Rye, 1998). The curriculum is especially relevant to science educators and science teachers because of the focus on nutrition: a subject matter area that is founded on the principles of biology and chemistry (Guthrie, 1989, Spallholz, 1989) and allows for the learning of science as well as mathematics in authentic contexts (Rye, in press).

Curriculum Development

The *Secondary Level Interdisciplinary Curriculum* (SLIC) (Campbell & Meyers, 1997) is a high school curriculum published by the Pennsylvania Department of Education, Nutrition Education and Training Program (NET). It was developed with funding from the United States Department of Agriculture by a team of curriculum specialists, nutritionists, and secondary teachers from a variety of disciplines (e.g., sciences, mathematics, English, history), and included the pilot testing of lessons by 65 teachers and over 1800 students in Pennsylvania. Additionally, some of the science lessons were pre-pilot tested through instructional settings "beyond the classroom:" extracurricular science clubs and a summer institute that were part of the Health Sciences and Technology Academy at West Virginia University (Rye, 1998).

The 16 lessons in SLIC were developed "by teachers for teachers" in an effort to maximize the chances that the curriculum actually would be used in a variety of disciplines/teachers' courses at the high school level. For example, all high school students in the United States study prohibition in their American history course. SLIC's history lesson on "Prohibition in the U.S. and the Debate Today" can be used by these students to research and debate the alcohol-nutrient issues involved with alcohol consumption.

Curriculum Description and Approach

SLIC is organized around five thematic units that present nutrition issues highly relevant to adolescents: Alternative Eating, Food Safety, Physical Activity, Disordered Eating, and Special Concerns in Nutrition for Teenagers. Each thematic unit is comprised of three to four lessons that are taught through different disciplines, which include algebra, American history, biology, business education/consumer math, chemistry, English, environmental science, family and consumer sciences, and health. Accordingly, SLIC employs a multidisciplinary approach: The integrity of the different secondary level disciplines can be maintained while facilitating understandings of interconnectedness, as advocated by Lederman and Niess (1997).

For any theme, it is recommended that all teachers from the affected disciplines try to teach their lessons within the same 3 to 4 week time period. For example, the theme "Alternative Eating" includes one lesson each from algebra, English, business education/consumer math, and environmental science. The respective lessons, which would all be taught during the same month, would be "DeCarte's Recipe Mania," "Decisions, Decisions," "A Balancing Act: Food, Family, and Fitness," and "What's the Beef About Methane?" These lessons attempt to facilitate understandings about vegetarian lifestyle choices and the effect of these choices on global warming, personal health, restaurant economics, and family food budgets. A common skill that is taught in English class is how to make an informed decision utilizing important criteria. In the lesson, "Decisions, Decisions," students work on this skill by researching different types of alternative eating styles such as low fat, ovolacto vegetarians, vegans, and Mediterranean diet, and develop a decision-making matrix to evaluate these eating styles. This topic is particularly important to examine at this age because high school students now make up the largest group of vegetarians, and many are choosing vegetarian or alternative eating styles based on inadequate information.

Lessons in biology and chemistry include "Hamburger Sizzler," which targets food poisoning, and "Titrating Calcium from Milk Products," which addresses osteoporosis and bioavailability. Through development of the latter concept, students come to understand that nutrient content of the food and the degree to which that nutrient is absorbed need to be considered in accurately determining how much of a given nutrient is available for metabolic processes. For example, only about 5% of the calcium in spinach is absorbed whereas over 60% of the calcium in green cabbage is absorbed (calcium from milk has a bioavailability of about 32%). In addition to global warming, environmental science lessons focus on "Pesticides in our Foods."

Certain lessons that are taught through other disciplines also contain science content and can facilitate science literacy as it relates to human health. For example, the history lesson mentioned above on the Prohibition era includes information on the physiological effects of alcohol. A health lesson entitled "Fat Phobia" helps students "restructure" the alternative conception that the healthiest diet is one with no fat. This lesson develops understandings about the variety of physiological functions of fat (e.g., carries and stores fat soluble vitamins), the amounts of fat needed (at least 15% and up to 30% of total daily calories should come from fat), and how to construct or modify diets to provide for adequate fat intake.

Science teachers who have a special interest or a secondary teaching emphasis in health may find SLIC especially useful. In reference to disease prevention and health promotion, SLIC provides for the integration of nutrition subject matter into the school curriculum far beyond those disciplines--health and family and consumer sciences--that are the traditional vehicles for nutrition education. Accordingly, students who engage in learning experiences through SLIC will have considerably more opportunities for constructing nutrition knowledge. Students should emerge with greater understandings about disordered eating, food safety, special concerns in nutrition for teens (e.g., calcium and iron intake), alternative eating, and physical activity, which ideally will translate to lifestyle behaviors that promote health. Students who complete the experiences from this curriculum also will possess a higher level of citizenship nutrition literacy, which should enhance their ability to discern "fact from fiction" in the popular press.

SLIC is designed to address state and national standards for science, math, language arts, and allied arts. For example, the subject matter presented is central to "personal and community health" within the "Science in Personal and Social Perspectives" content standard of the National Science Education Standards (National Research Council, 1996). The curriculum incorporates a variety of instructional strategies and tools, such as graphic organizers, the Expert Jigsaw, PMI charts, and the Internet, which facilitate an experiential approach to learning. Example uses of the previous include: a Venn diagram to contrast students' conceptions with a nutrition expert's conceptions of what constitutes "normal eating;" and an Expert Jigsaw where students teach each other what they learned from readings that pertain to methane production. The curriculum also embeds a host of alternatives to traditional methods of assessing learning outcomes. Such assessments include the use of rubrics and range from student-constructed products (e.g., portfolios, journals, and simulations) to student performances (e.g., demonstrations, oral presentations, and debates). A robust example of a product is the preparation of an environmental impact statement that surrounds beef and rice production and consumption, which is assigned near the end of the lesson on "What's the Beef About Methane?" SLIC also provides an appropriate balance of performance-based assessment methods across content areas. An example performance assessment utilized near the end of the American history lesson, "Prohibition in the U.S. and the Debate Today," is a structured debate that addresses the question, "Should alcohol consumption remain illegal for teens?"

Dissemination, Impact, and Implications

The Pennsylvania Department of Education has distributed a copy of SLIC to every public high school and many non-public high schools in Pennsylvania, and the NET Program offices in all 50 states. Teachers or other professionals (e.g., Cooperative Extension staff and teacher educators at post-secondary institutions) interested in the topics presented by the curriculum can obtain SLIC for preview from their state NET office, and can make a copy of it. In addition, SLIC is listed in the National Agriculture Library Food and Nutrition Information Center catalog: Teachers and other professionals from anywhere in the United States can request SLIC for preview from the National Agriculture Library via their local or school library. SLIC also can be ordered from Creative Enterprises (see Campbell & Meyers, 1997).

Approximately 1200 teachers in Pennsylvania have been reached through training programs on SLIC. For the 1999-2000 school year, the Pennsylvania Department of Education plans to provide start-up grants to high schools in Pennsylvania to implement SLIC in an interdisciplinary manner. A comprehensive evaluation of the degree to which (and how) the curriculum has been implemented in Pennsylvania has not yet been conducted. Evaluations of SLIC training attended by 32 teacher-participants of the Health Sciences and Technology Academy (HSTA) were very impressive, with the majority of teachers responding that they planned to use the lessons "a great deal" in HSTA or their regular school classrooms. Various open-ended responses provided by HSTA teachers corresponded directly to intended features of the curriculum, e.g., "Nutrition information will provide [a] great activity-based learning project," "The entire nutrition program could be used as a starting point to develop a [HSTA] club project and/or individual student projects," and "All of the 4's and 5's [high ratings] are directly related to the interests of all teenager[s], not just HSTA kids."

The innovative nature and potential contribution of SLIC recently was recognized by the American Dietetic Association: The curriculum received the 1998 President's Circle Nutrition Education Award. Instruction from SLIC can promote a greater degree of citizenship scientific literacy amongst students relative to understanding their own body and discerning "fact from fiction" about health information in the popular press. Further, teachers who utilize the curriculum have the opportunity to learn new concepts in human nutrition as well as increase their familiarity with a diversity of teaching and assessment strategies. The curriculum also can impact school specialists in curriculum and instruction and teacher education faculty because it can serve as a model for multidisciplinary instruction at the secondary level.

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METAPHOR: A TOOL FOR MONITORING PROSPECTIVE ELEMENTARY TEACHERS' DEVELOPING METACOGNITIVE AWARENESS OF LEARNING AND TEACHING SCIENCE

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Learning to Teach Science

This study of learning to teach elementary science emerged from a concern in teacher education that prospective teachers do not find their teacher preparation courses particularly helpful in their development as teachers (Calderhead & Robson, 1991; Kagan, 1992; Zeichner & Gore, 1990). Prospective teachers typically enter a teacher education program with at least 15 years of experience as science learners in classroom settings where *learner as absorber of knowledge* with *teacher as transmitter of information* were dominant metaphors for learning and teaching (Northfield, Gunstone, & Erickson, 1996).

Before one can change her or his beliefs, one has to realize what those beliefs are. In 1968, Asubel stated, "The most important single factor influencing learning is what the learner already knows" (cited in Treagust, Duit, Fraser, 1996, p.1). Since learning is strongly influenced by prior knowledge, instruction must begin by helping the learner articulate what he or she already understands and believes. Kagan (1992) concluded that a problem with many teacher education programs is they do not encourage novices or preservice teachers to make their personal beliefs explicit. Previous studies have suggested that until extant beliefs about learning and teaching science are made explicit, it is unlikely that they will mature within a prospective teachers' preparation program (Kagan, 1992; Treagust, Duit, Fraser, 1996).

Some of the common beliefs of elementary teacher candidates that need to be made explicit and changed are the primarily resistant conceptions of how science is learned and consequently should be taught (Stofflett, 1994). Teachers tend to teach as they were taught and a large number of preservice teachers have, for the most part, experienced a didactic model of science teaching. That often does not include an explicit goal of student learning with understanding. For preservice teachers to move from short-term, rote learning to a longer-term and deeper understanding of science concepts, they need to undergo a conceptual change themselves (Stofflett, 1994).

Specifically, Prawat (1992) noted some predominant beliefs among teachers that often get in the way of adopting a constructive approach to teaching and learning. First, when the learner and content are viewed as static, non-interactive entities, more time and attention is spent on delivery or teaching than on student learning. This is typically where preservice teachers remain for possibly years into their practice until they may eventually begin to consider the meanings learners are constructing. Second, there is a tendency toward "naive constructivism" (Prawat, 1992, p. 357) which results in equating activity with learning. Dewey (1938) argued that student engagement should not be used as the best measure of educational value.

The conceptual change model, developed by Posner and later modified by Hewson, is a way of thinking about science learning from a constructivist viewpoint (Hewson & Hewson, 1988). In this model, learning begins for the individual at a point based on what the student already knows. Teachers cannot be constructivist teachers when they have not been constructivist learners (Stofflett, 1994). If preservice teachers experience conceptual change content learning experiences themselves, they might become dissatisfied with how they were taught science and seek more constructivist models of teaching science (Thorley & Stofflett, 1996). If they understand the new model (intelligibility), find it consistent with their new beliefs about learning (plausibility), and experience its usefulness as teachers (fruitfulness), preservice teachers may undergo a pedagogical conceptual change and adopt this model as a way of approaching instruction (Martens & Crosier, 1994).

Conceptual change is accelerated when students are conscious of their thinking (Martens & Crosier, 1994). One element to promote this sort of consciousness is collaborative, self-reflective inquiry (Tabachnick & Zeichner, 1994). Beliefs and ideas about science teaching and learning can be made explicit through reflection. Dewey (1933) called reflection the hallmark of intelligent action and suggested we learn more from reflection on our experiences than we do from the actual experience. In this sense, reflection is more than just talking about ideas; it leads to doing something about them in a classroom. Student teachers need to become reflective practitioners to metacognitively improve their understanding of their practice (Gunstone, Slattery, Baird, & Northfield, 1993). It is through this metacognitive activity that the focus moves from self or teacher behaviors to students and learning (Stofflett & Stefanon, 1996). This shift may not be as developmental as once thought, suggesting that teacher education programs that help develop reflective practitioners could have an impact on shifting the focus of prospective teachers from self and teaching to students and learning.

One vehicle to prompt and assist reflection is metaphor. The term metaphor comes from a Greek word meaning "to carry across" (Schon, 1979). This implies the rich vocabulary developed for one experience can be used to describe another. Lakoff and Johnson (1980) have concluded that the value of metaphor is understanding and connecting a new experience in terms of a more familiar one. They argue the human conceptual system is defined and structured metaphorically, and human thought processes are largely metaphorical. In other words, humans make sense of new information by directly relating it to personal experiences and prior knowledge.

To learn, one needs to make sense of an unfamiliar situation. Through metaphor, one personalizes one's understanding by relating new information directly to personal experience and knowledge, and thus offers a path or vehicle for learning about one's thinking. In this way, metaphor is both a product – a way of looking at things – and a process by which new perspectives are constructed (Schon, 1979). It can be either, but in this study, the focus is on product and how reflection through metaphor indicates conceptual change and conceptual growth. Reflection through metaphor might prove an interesting way to study changes in teacher conceptions of science, learning, and teaching, and also facilitate the sorts of changes in thinking that science educators hope to see within prospective teachers over the course of a teacher preparation program.

Several studies have indicated that reflection through metaphor can be a means by which preservice teachers come to terms with experience (Bullough & Stokes, 1994; Shapiro, 1991; Tobin, Tippins, & Hook, 1994). All new knowledge is filtered through a teacher's framework of beliefs which have developed over a lifetime of experiences, both in and out of the classroom (Briscoe, 1991). Personal theories are formed by teachers as related to practice; however, much of this pedagogical knowledge is tacit. From a constructivist view of learning, the impact of typical teacher education is questioned because teacher educators typically ignore the novice's prior knowledge about teaching (Bullough, 1991). Here, metaphors can be used during reflection as prospective teachers assign language to these otherwise nonlinguistic constructs.

Within a teacher education program, prospective teachers should be encouraged to interact in increasingly more effective ways with their learners. Through observation of learning environments and then through their own practice and reflection, prospective teachers can perhaps better understand their own teaching beliefs and roles through the metaphors they craft to identify their part within a particular situation (Tobin, 1990). Each individual has beliefs about roles for herself or himself (Lorsbach, 1995). These beliefs may govern how an individual acts in a special situation and also the meanings assigned to the actions of others. If reflection through metaphor accompanies changes in action within practice, then reflection through metaphor can serve as a foundation for teachers to better understand conflicts in embedded beliefs and classroom practices, and perhaps better identify where change is needed and why.

Using metaphors represents an explicit comparison and interaction among conceptual representations of content, pedagogy, students, self, and classroom actions (Tobin & LaMaster, 1996). Keeping metaphors in mind before and during a lesson could help the prospective teacher remain focused on teacher behaviors and actions necessary to encourage student learning. After a lesson and during reflection, the prospective teacher can become more metacognitively aware of her or his own beliefs and actions through examining metaphors for functionality. Being accountable for functional or nonfunctional metaphors is empowering. Being empowered is taking responsibility for one's own learning, one's own lifelong learning. Reflection through metaphor could provide a new vision for some prospective teachers to do just that.

Given that beliefs of learning and teaching science held by prospective teachers need to be made explicit before they can be changed and that reflection through metaphor is a way of looking at a situation or problem differently helping to make implicit beliefs explicit, a purpose started to emerge. The purpose of this study became to explore metacognition in preservice teachers of science through reflection featuring metaphor generation and analysis. This purpose led to the following research questions: (1) How do beliefs about learning and teaching science in prospective elementary teachers change, as reflected through metaphor, over their yearlong field experiences? (a) How do they view the role of hands-on experience or activity within a science curriculum? (b) Do they distinguish between rote science learning and meaningful learning? (c) What is their understanding of the relationships between student learning and their teaching? (2) In what ways do prospective elementary teachers' metacognitive awareness of learning about teaching science change over their yearlong field experiences as reflected through metaphor? (a) How does reflection through metaphor make beliefs about teaching and learning explicit? (b) How does reflection through metaphor change? (c) How does reflection through metaphor capture alternative beliefs?

This interpretive case study of the processes of four participants' developing and changing beliefs was guided by phenomenological inquiry. Participants who enjoyed crafting metaphors were selected. Data were collected over the Fall 1997 and the Spring 1998 semesters as participants progressed through their pre-student and student teaching field experiences. Primary data sources included transcripts of formal and informal interviews with participants, reflective journals, and documents such as lesson reflections and philosophy statements produced for university course work. Secondary data sources included a researcher's journal, field notes of observed lessons, and videotaped teaching episodes.

The data were analyzed inductively to develop grounded theory by way of assertion building. Two levels of data analysis were used. The first was a within-case analysis of each individual participant followed by a cross-case analysis of all four participants.

Nancy: An Awakening

As Nancy completed the last year of her formal process of learning to teach, she crafted a metaphor for *learning to teach*. She felt it was *an awakening* as she became more aware of both perspectives of the student and the teacher: "There are just things you never realize a teacher has to do! I didn't think it was this hard. I didn't realize how much work goes into it" (Interview 6, 5/7/98). She began her pre-student teaching with a negative attitude toward learning and teaching science.

However, after experiencing and crafting metaphors for each phase of the conceptual change model used within a conceptual change lesson in her elementary science methods class, Nancy came to realize some of her implicit beliefs about learning. She believed learners needed a safe, risk free environment for learning. Through *learner as blank slate*, she explained how her anxiety prevented her from thinking and learning: "When you asked us to apply it, I feel I didn't know. My mind just went blank. . .I'm not used to having to apply what I learned. . .I'm just not used to it" (Interview 1, 10/17/97). Along with being free from anxiety, Nancy also realized that for her to learn, she had to use and apply the concepts.

Within her pre-student teaching field experience, Nancy used hands-on activities as the teacher and focused on questioning skills to encourage thinking. Through *teacher as facilitator of thinking*, Nancy encouraged independent thinking within her learners. Upon reflection, Nancy changed her metaphor to *teacher as connection maker* as she began to concentrate more on the outcome of thinking, that of the students building connections. As Nancy became more aware of individual students with individual differences, she saw a larger, more encompassing role, *teacher as quilt*. To her, the different patches represented the various roles teachers needed to be depending on the individual needs of the students.

Nancy entered her student teaching with the confidence to teach science. That diminished as she also entered into a personality conflict with her cooperating teacher. Called into question was who Nancy was as a person and a teacher and resulted in Nancy entering a depression. It also resulted in her being moved to a second placement in another school district with a more traditional cooperating teacher who was supportive of Nancy. However, depressed from her experience, Nancy became *teacher as self-centered* as her learning shut down and she withdrew.

She realized her attitude after reading a vignette of her pre-student teaching experience: "I started really getting upset because you know, I really am not thinking about anybody but myself and that's not what a teacher can do. A teacher can't be *self-centered.* Teaching is almost like a selfless service" (Interview 2, 3/4/98). Nancy focused on herself surviving her field experience and graduating. She realized her egocentrism and the effect it was having on the students. She was not encouraging meaningful learning. As she tried to see the students' perspective, she was *teacher as student*, but this sensitivity alone was not enough to help her become the science teacher she was in pre-student teaching.

As her student teaching became a full time experience, Nancy experienced challenges with classroom management and called herself, *teacher as disciplinarian* or *drill sergeant*, originating from her military background. She was disappointed that the students did not automatically respect her as the teacher. Nancy herself was respectful of authority, to the point of modeling her teaching after that of her cooperating teacher even though she did not believe her actions would lead to meaningful learning within her students.

It was toward the end of this field experience that Nancy crafted her metaphor for *learning to teach, an awakening*. Nancy started to realize the teacher had to do more than she realized. Nancy felt she, like her students, was egocentric. As a result, she did not want to put the students first, even though she felt she would have to if she wanted to be an effective teacher. Though she tried as the *quilt,* she also realized a teacher cannot reach all students and attempting was very tiring.

Overall, Nancy's progress in learning to teach was impaired by a personality conflict with her cooperating teacher in her first placement. While Nancy had some idea of meaningful learning, her experiences in her teacher education program did not seem to be adequate or sufficient to stimulate a significant conceptual change within her as she learned to teach. She had motivation to complete her degree but not necessarily to learn to teach. Perhaps this was due, in part, to Nancy not entering classroom practice upon graduation, but rather a military assignment.

Nancy had reflected in-depth about learning to teach but her depression had led her to self-preservation and survival by following the rules of her cooperating teacher rather than risk creating any more conflict. Without a safe, risk free environment, Nancy was not free to grow, be creative, experiment, and learn. Without a lasting conceptual change, Nancy was teaching as she was taught when she was in elementary school. It is not impossible but is unlikely that if she ever teaches, she will remember the few positive experiences she once had with learning and teaching science, and teach from a constructivist perspective.

Placement with a supportive cooperating teacher for her student teaching was not enough to allow Nancy to feel safe enough to try hands-on activities or any other innovations that were not part of the classroom in her second, more traditional placement. Instead, Nancy tried to please her cooperating teacher to the point of using strategies and techniques that she did not really believe in. Her confidence in her beliefs was second to completing her tour of duty, student teaching ending with graduation.

Kris: Sink or Swim

Kris entered his last year of formal teacher education with certain beliefs and goals for learning and teaching science that were part of his philosophy of being a teacher. First, from his early childhood experiences, it was evident he enjoyed science and viewed science more as a process or a way of thinking. Second, he viewed hands-on activities and thinking as essential to science learning and teaching. As a result, Kris approached learning to teach as a hands-on experience or process.

Kris also believed in cooperative learning because of the opportunities for learning from each other leading to independent learning. Even before his last year of formal teacher preparation, Kris had crafted a metaphor for teacher when he first learned of this tool in an educational psychology course. He was *teacher as one of the students* because he wanted to create a student-centered classroom that encouraged independent learning, his ultimate goal for a learner.

Within his pre-student teaching field experience, Kris crafted the metaphor, *teacher as business executive*, as he focused on creating a safe, risk free environment for learning. Just as every department is needed within a business, so is every student's opinion and voice valued in the knowledge construction within a classroom. The students in Kris' pre-student teaching classroom were motivated to learn and the classroom was well managed because Kris felt students were focused on thinking.

Kris entered a different classroom for his student teaching experience. Kris felt the students in this new context were less motivated to learn and were not as used to thinking independently. To achieve his philosophy, Kris had to change his metaphors. Kris had to go to the bottom of his metaphor hierarchy to become *teacher as tour guide*: "This group is unable to handle a large amount of independent thought. My [pre-student teaching classroom] was quite capable of such and was frequently excited by the opportunity to think and figure things out for themselves" (Journal Entry, 1/26/98). Through this metaphor, Kris guided his learners to develop critical thinking skills. Once they could learn more independently, Kris became *teacher as business executive* where he could give them more independence to learn together. Ultimately his goal as teacher was the metaphor he created before his field experience, *teacher as one of the students*. Here, the students could reach Kris' goal for them of more independent learning within the student-centered classroom he provided. Being student-centered, Kris handled any problems or constraints that arose in this classroom with the students' needs first in mind.

Kris' metaphors reflected a hierarchy of teaching styles that Kris viewed as being used depending on the type of students in the classroom that he would enter. Foremost, Kris realized the importance of his students developing and applying those critical thinking skills through hands-on activities. After all: "If children are proficient in their use, any and all science content will be available to them" (Post-philosophy, 12/10/97). Similarly, this is how Kris viewed his own learning process. He felt strongly that in order to learn to teach, one must have many opportunities to do so and discover for one's self how to approach problems or constraints that would inevitably arise. His metacognitive approach to teaching reflected his process view of science.

Integral to Kris' growth at this point were his cooperating teacher and supervisor who allowed him to learn in this way. Both gave him free reign to be in charge, experiment, learn, and grow. Kris in turn crafted the metaphor for *learning to teach* as a *sink or swim* experience. Prospective teachers would *sink* if they did not learn from their experiences and *swim* if they did. Within his student teaching placement, Kris felt his opinions were valued and he never seemed to doubt that he could figure out problems. By developing his own critical thinking skills, Kris grew confident to teach as he finished his formal education program. With three metaphors in hand, Kris felt ready to be the teacher he had to be depending on the students placed in his responsible care. He had learned how to swim capably and confidently by realizing the learning process for him would be ongoing. As a teacher, he would always be *one of the learners*; in other words, one of the lifelong learners.

Matt: A Kid in a Candy Shop

Early in his last year of formal teacher preparation within his elementary science methods course, Matt experienced a conceptual change lesson on density. He himself began to undergo a conceptual change in how science should be learned and therefore, taught. His new beliefs about science learning were evident in the metaphors he crafted for phases of the conceptual change model used in the lesson.

Matt was *learner as excited child* to express the safe, risk free environment he felt he had and needed in order to learn: "I felt like a kid in a candy store. . .for one time in my life, I was allowed the freedom to test materials in my own way and wasn't embarrassed to show my excitement or enthusiasm" (Instrument Tool 1, 9/26/97). Next, he crafted *learner as light bulb*: "During this phase of the lesson, I could feel the light bulb going off in my head. I was making the connections. . .I learn a lot from other people. . .somebody made a comment and the light bulb went off" (Instrument Tool 1, 9/26/97). Here, Matt expressed how he and other learners make connections through hands-on experiences and through social interactions with others. Third, he was *learner as amazed* to emphasize that learning happens when one experiences a concept instead of just hearing about it: "I was amazed at this because although I heard about this separating many times, I had never experienced it" (Instrument Tool 1, 9/26/97). In summary, when Matt was able to feel safe about taking risks and experiencing a concept through hands-on activities, he was able to learn on his own and through others, and he felt more confident to continue learning.

As Matt created and implemented a conceptual change teaching project within his pre-student teaching, he reinforced these new beliefs and began to see how useful they were in action. Because Matt felt the teacher needed to provide support, guidance, and direction for learners, he crafted *teacher as runway*: "I think of myself as the base. I think a lot of teachers would think, 'Well, I'm the plane; I fly the students'. . .I prefer to be the *runway*. They'll use me to go to other places" (Interview 1, 10/24/97). With this metaphor, Matt created a safe atmosphere where learners felt free to take risks and learn. Matt also felt the positive encouragement was important to learners in providing a safe atmosphere where they would feel motivated to learn. He crafted *teacher as proud father* to express that and the joy he experienced as a teacher in watching his students experience their own learning.

As a learner within his pre-student teaching experience, Matt did not feel he was in a safe environment for learning and taking risks in the classroom as a way to explore his ideas about teaching. Personality conflicts with both his cooperating teacher and supervisor created a restrictive environment from Matt's perspective. His confidence in teaching suffered, but as he moved into student teaching, that changed. Matt's new cooperating teacher was supportive and respectful of his ability to learn to teach and she provided that safe, risk free environment that he needed. He crafted a metaphor for *learning to teach, like a kid in a candy shop*, and commented on the atmosphere his cooperating teacher created for him: "I love the freedom [cooperating teacher] is giving me in the classroom. She really makes me feel comfortable. She shows me how she can learn from me as well" (Journal Entry, 1/15/98).

Matt's cooperating teacher encouraged him to try all his ideas and learn from the experiences. Because of an upcoming medical leave on the part of the cooperating teacher, Matt became a full time student teacher early in his student teaching field experience. With a renewed feeling of confidence and the opportunity to experience teaching, Matt progressed in the development of his beliefs as evident through his metaphors. In general, he became much more student-centered in his approach to teaching and learning.

First, he expanded *teacher as runway* to *teacher as foundation* as he considered the depth of support the teacher provides for students to feel free to learn. He also expanded *runway* to *teacher as stagehand* as he realized some students need to have the stage set for meaningful learning to occur from hands-on experiences. He continued to believe in the power of positive encouragement and crafted three metaphors to explain. Through *teacher as open book*, Matt shared with the students so they would feel more comfortable relating to him. *Teacher as breakfast cereal* expressed Matt's goal of creating a friendly, family atmosphere in the classroom conducive to learning. Matt was *teacher as emotional* when he shared his emotions in hopes of students feeling more free to express their feelings and opinions.

While Matt felt behavioral problems were largely prevented in a student-centered classroom, he did have to be *teacher as teacher* when he had to discipline students. The origin of this metaphor lay in Matt's early perceptions of a teacher. As Matt progressed in the creation of a student-centered classroom, he felt that he became more flexible and able to think on his feet. He crafted *teacher as gear shifter* to express that growing flexibility. As he completed his student teaching, Matt crafted *teacher as one of the students* as he came to perceive teaching as lifelong learning. In learning to teach, Matt had really learned how to learn.

Carrie: An Open Canvas

Early in her pre-student teaching field experience when she created and implemented a conceptual change teaching project, Carrie realized one of the most important beliefs for her of learning and teaching, the power of experience through hands-on activities in learning science. To express this, she crafted the metaphor *teacher as trunk or branches of a tree* which she also referred to as *provider of experiences*. She also realized the importance of the teacher in providing those experiences individual students needed to learn which she commented on after a lesson on pumpkins: "A lot of them, this was the day before Halloween and they didn't even have jack-o-lanterns, didn't even have pumpkins at their houses. . .a lot of them never had felt one before" (Interview 1, 10/22/97). Carrie realized what those students were missing: "They never realized it has ridges, or it's kind of heavy but when you knock on it, it still sounds a little hollow inside. . . That was an important revelation for me, to know that not everybody received this opportunity" (Interview 1, 10/22/97). At the end of her pre-student teaching experience, Carrie still felt this experience was a revelation for her: "I left the school that day with a new view on life and teaching. I can see that providing students with meaningful, hands-on experiences is the most valuable gift I can give to my students" (Lesson Reflections, 11/26/97).

Carrie also placed importance on determining the prior knowledge of the learners because she felt this was where learning began. She expressed this belief through her metaphor, *teacher as roots of a tree*. Also important to learning was a safe, supportive environment, which she created through her metaphors. With *teacher as sun, rain, and air*, Carrie provided the necessary support for individual learners and through, *teacher as state park*, she provided that safe learning environment.

As Carrie entered her student teaching experience, she crafted a metaphor for *learning to teach as an open canvas*: "People in your lives paint on you; the students, your coop, your supervisor, your professors. . .parents. . .it's all in how you look at that canvas and perceive everything. . .and develop on your own what you want from that" (Interview 5, 4/14/98). Here, she expressed that all her experiences, represented by the different paints on her *canvas*, blended to form the teacher that she perceived she was at any given point. Her *canvas* changed during her student teaching as Carrie developed a more student-centered approach to teaching and learning.

As Carrie progressed through her student teaching, she modified her existing metaphors accordingly and added several new ones, some from her own independent reflection. To emphasize the importance of helping students learn to develop critical thinking skills, Carrie was *teacher as stage crew*. One of her goals for her students was to help them become independent learners. By this, she meant learning individually and from others with the teacher available as needed for support.

Teacher as state park became more like the metaphor, *learning community as state park*. Carrie began to realize the importance of involving parents in the emotional and academic well being of the individual learner and crafted a metaphor for them, *parents as park committee*.

Through this position of higher authority, Carrie emphasized the need for parents and teachers to support and trust each other to provide the best learning environment possible for the children. As needed, she became *teacher as security guard* or *police officer* to ensure that every child had the opportunity to learn and not be inhibited or distracted by others. To provide that necessary support and positive encouragement, Carrie was *teacher as park ranger* or *gardener*.

Carrie became more student-centered in her approach not only to teaching, but also to learning. She learned more about learning for her students and herself, and felt a teacher needed to become a lifelong learner. She used metaphor to reflect both in collaboration but also independently. One aspect about herself that Carrie learned was what she did not want to be in teaching. Early in her student teaching, she crafted a metaphor for *teaching, VCR,* where she described her routinization of certain processes and procedures in teaching. Later in her experience, she felt the effects of too much routine in the classroom. If her teaching was the metaphor, *teaching as VCR*, she felt she was in a monotonous routine, harmful to the learning of her students and to her teaching. From this, she further developed a metaphor for the role of a teacher she did not want to be, *teacher as ruler,* indicating her desire to be flexible and open minded.

Throughout her yearlong field experience, Carrie embraced metaphor as a personal vehicle for making sense of new experiences and deriving her beliefs from her actions. She enjoyed the process enough to begin using it independently. She began developing metaphors in her personal reflective journal entries, which were not required for her coursework or this project. It seemed as if Carrie had found a tool that might help her continue to learn about her growing and changing beliefs throughout her teaching and learning career.

Learning to Teach Science: A Human Construction

The purpose of this study was to determine, through reflection including metaphor, the ways in which four prospective elementary teachers changed their metacognitive awareness about learning to teach science. It was centered around an interpretive case study design of four participants who were purposefully selected. Data were collected over the last year of their formal teacher preparation. This time period was the most intense in their process of learning to teach and included their pre-student teaching and student teaching field experiences as well as a set of coordinated methods courses.

During the first half of this study which took place while the prospective teachers were in methods courses (including courses in teaching and learning social studies, mathematics, and science), this study focused on learning to teach science. Once the prospective teachers entered their student teaching placements, the context for interviews continued to focus on science teaching. However, because there was little control over how much or if science was taught in the student teaching placement classrooms, the context of responses to interview questions was different for each participant. Only Matt entered a classroom where the cooperating teacher was teaching science almost daily and shared the science teaching and learning philosophy of the university. Nancy and Kris entered classrooms where science was being taught from a more didactic orientation, while Carrie entered a classroom where science was not being taught at all.

Despite varied student teaching contexts, each participant seemed to shift her or his thinking about learning to teach science to learning to teach, in general. Kris seemed to sum up what all participants were expressing when he was asked about a revelation he had experienced over the course of student teaching: "The things that stick in their minds is when they do the hands-on, get involved, and it's not coming from the book or me just talking to them for half an hour. . . It's true. That's what they remember" (Interview 6, 5/6/98). Whether for science or another subject, if students were involved in a relevant, meaningful activity, students seemed to remember the lesson. This comment was important to Kris as it mirrored his thinking that hands-on makes good teaching, no matter what the subject matter is.

The focus of the participants on being generalists and educators more than a content specialists was also expressed by Matt: "No, I just think we need better. . .well-rounded teachers who are going to [teach] everything. That's what it comes down to" (Interview 5, 4/16/98). For Matt, teaching science seemed to be a small part of teaching, in general. He felt it was good to be a generalist, and saw no need to be a science-specific educator. This was true for all four participants as their last year of formal teacher preparation came to a close.

While the goal of the last year of formal teacher preparation was the same for all four participants, that of learning to teach, the process was unique to each of the participants. The process of learning to teach resembled a human constructivist view of learning. Novak has synthesized a comprehensive view of meaning that encompasses a psychological model of human learning and knowledge restructuring together with the analytical and explanatory potential within a unique philosophical perspective on conceptual change (Mintzes & Wandersee, 1998a).

This view is summarized in three assertions. First, humans are meaning makers and do so by forming connections between new concepts and those that are part of an existing framework of prior knowledge (Mintzes & Wandersee, 1998a). The human constructivist would assert that no two humans would construct the same meaning from identical phenomenon. Second, knowledge is a dynamic construction of human beings. Third, the construction of shared meanings can be facilitated by the active intervention of well-prepared teachers.

The participants constructed their own meanings of the phenomenon of learning to teach science specifically and learning to teach in general through their pre-student teaching and student teaching field experiences. The prospective teachers constructed those meanings through varying amounts of reflection, both individual and with cooperating teachers, supervisors, university instructors, parents, other prospective teachers, and me (first author) as instructor / researcher / collaborator. Also, facilitating their meaning constructions was the use of metaphor in reflection both with me and individually.

Table 1 shows the summary of the predominant uses of concept codes in the cross-case analysis of the participants over the yearlong field experience. The ideas were demonstrated by all four participants unless a name appears in parentheses beside a particular use of the concept code. In that case, that use of the code was unique to that prospective teacher. From an analysis of the concept codes, a main assertion emerged. It was 'prospective teachers' reflections through metaphor indicated a focus on student-centered beliefs about science teaching and learning, but the extent of learning to teach science and putting those beliefs into action depended on their personal histories as science learners and on their perceptions of the learning-to-teach environment as influenced by their cooperating teachers.'

While prospective teachers held student-centered beliefs, they did not always put those beliefs into action. It seemed that how safe the prospective teachers felt to experiment and try new ideas and also to put those student-centered beliefs into action was determined by how they perceived their own learning environment which included where they learned to teach science and other disciplines. While the learning environment contained students, the supervisor, the school district, and the curriculum, it was perceived by the prospective teachers to be influenced for the most part by the cooperating teacher. Thus, how the prospective teachers perceived their cooperating teachers greatly impacted if, how, and what kinds of risks the prospective teachers took in the areas of teaching and learning. For example, this largely determined the extent to which the prospective teachers used hands-on activities with their learners even though all felt this was the key to meaningful learning of science and other concepts.

There was also an historical element present, which affected the prospective teachers' process of learning to teach science and learning to teach in general. If the prospective teacher were a successful rote learner, one would tend to not be as concerned with finding meaning in the learning process. Instead, one would tend to find an alternate way of completing the process if necessary. Nancy was a successful rote learner of science. When confronted with adversity, she learned to play the game to complete her experience. After her conflict, she took very few risks and only focused on completing the minimum requirements for her field experience in non-controversial ways.

Table 1
Summary of Use of Concept Codes in Cross-case Analysis

Concept Code	Beginning of Pre-Student Teaching	End of Pre-Student Teaching	End of Student Teaching
Learning to Teach Science?		Yes	• Yes (Kris, Matt) • Not beyond pre-student teaching (Nancy, Carrie)
Attitude Toward Science	• Negative • Positive (Kris)	Positive	Positive
View of Science	• Facts (Nancy) • Process (Kris)	Process	• Process • Facts / Process (Nancy)
Learning Science	• Meaningful, hands-on • Rote (Nancy)	Meaningful, hands-on	• Meaningful, hands-on • Rote (Nancy)
Focus - Beliefs into Action	• Student-centered • Teacher-centered (Nancy)	Student-centered	• Student-centered • Teacher-centered (Nancy)
Perceived Learning-to-Teach Environment		• Safe • Not safe (Matt)	• Safe • Not safe (Nancy)
Cooperating Teacher		• Supportive • Personality Conflict (Matt)	• Supportive • Personality Conflict (Nancy)
Reflection with Metaphor	Make beliefs explicit (Kris)	Make beliefs explicit	• Beliefs into action • Recognized need to change (Nancy)
Revelations		• Safe (Nancy) • Conceptual change (Matt) • Experience (Carrie)	• Constraints (Nancy) • Student motivation (Kris) • Foundation (Matt) • Role of parents (Carrie)

Overall, how the prospective teacher perceived the cooperating teacher and the rest of the learning-to-teach environment impacted how safe the prospective teacher felt to take risks and learn to teach. In an environment perceived to be safe by the prospective teachers, he or she could take the opportunity to try new ideas and learn to teach. In an opportunity perceived not to be safe, the prospective teacher would compromise her or his beliefs. As a result, actions seemed to be dependent on how the prospective teacher perceived he or she could successfully complete the experience for the sake of completing it, not for the sake of meaningful learning.

Nancy identified student-centered beliefs through the metaphors she crafted during her pre-student teaching where she was in a classroom with a cooperating teacher who shared her philosophy and put those student-centered beliefs into action teaching science and other disciplines. However, Nancy entered her student teaching and immediately had a personality conflict with her cooperating teacher. Her process of learning to teach shut down as she started to focus on herself and her own survival of the field experience.

As Nancy entered her second student teaching placement, she was still *self-centered*. While her cooperating teacher was supportive, Nancy did not perceive of her learning environment as a safe place to take risks and try many new things. Instead, she chose to rely on what had worked for her in the past to be a successful learner. After all, she had boasted to teachers that she could get an 'A' in the class because she could successfully rote memorize and pass a test of that nature. In her placement, Nancy perceived that if she could please her cooperating teacher, she could complete student teaching without any further problems. She learned to play the game as she modeled her teaching behaviors after her cooperating teacher's. While her beliefs remained student-centered, her actions were largely determined by what she perceived would please her cooperating teacher and how unsafe she perceived her own learning environment to be.

Carrie also crafted student-centered beliefs during her pre-student teaching experience. She perceived of her learning-to-teach environment both in her pre-student teaching and student teaching experiences as safe and supportive. Both of her cooperating teachers encouraged and supported her. However, Carrie did not progress much in learning to teach science beyond her pre-student teaching experience because she did not have a cooperating teacher who has able to reinforce and further develop her understandings of how children learn science. However, she did progress in learning to teach in general during her student teaching experience because she was given the feeling of respect. This helped Carrie develop her confidence to learn and put her student-centered metaphors for teacher into action. The confidence in learning that Carrie developed led her to become a lifelong learner. Because she grew as a learner and teacher, it seems if she were given the opportunity to grow in her development as a science teacher, Carrie would probably continue to become a learner of teaching science.

Like Carrie, Matt also progressed in his process of learning to teach as he moved from his pre-student teaching into his student teaching placement. This was evident through his metaphor development. However, unlike Carrie, he also progressed in his process of learning to teach science. His cooperating teacher was unique in that she taught science almost daily and shared Matt's constructivist philosophy of learning. Since Matt's conceptual development of constructivism was new, he benefited from a cooperating teacher who supported, encouraged, and helped him grow and develop. Unlike his pre-student teaching placement, Matt perceived that his student teaching environment for learning to teach was safe. Consequently, he took risks and tried new ideas. The more he experienced teaching and tried new ideas, the more he was able to generate creative ways to help his students learn science and other disciplines. Like Carrie, Matt, too, was on his way to becoming an independent learner of teaching. In addition, he was also further along in his development of becoming a learner of teaching science.

Kris entered his last year of formal teacher preparation with a clear idea of how science should be learned and taught. He immediately developed student-centered metaphors, and he crafted *teacher as one of the students* even before he began his field experiences. During both of his field experiences, Kris had supportive cooperating teachers who provided safe, risk free environments for him to learn to teach science and other disciplines. As an independent learner, Kris tackled obstacles as problems to be solved. Confident in himself as a learner of science, he was also confident in his ability to learn to teach science and other disciplines. He approached his field experience as another hands-on experience for him to learn from as he tried to construct an understanding of how to help children learn science. Individual reflection and also talking with others such as his parents, supervisor, and me helped Kris to make sense of his own learning process.

Implications

Several implications for science teacher education emerged from this study. First, if science teacher education is viewed as a personal process of conceptual change, the importance of providing experiences that promote and support conceptual change within teacher education cannot be understated. When prospective teachers of science experience learning science content through a conceptual change approach and are aware of the process of their learning during the science experiences, they are more likely to view science learning as a process of conceptual change. Their experiences as learners in those settings seem to influence their orientations toward teaching science. In other words, if they have experienced conceptual change themselves in how science is learned and should be taught, they will more likely provide similar meaningful learning experiences for their students as well.

While experiencing the conceptual change approach as a learner in a methods course is a beginning for conceptual change within a prospective teacher, it alone is not sufficient. Prospective elementary teachers of science should reinforce and develop their growing beliefs of learning and teaching within field experiences with cooperating teachers who share their constructivist philosophy of learning and teaching. In addition to sharing a constructivist philosophy, the cooperating teachers also should be putting their beliefs into practice within their classrooms. For the prospective teacher to grow and develop in the process of learning to teach science, he or she also should be nurtured along by a cooperating teacher who is knowledgeable in how students learn science. Without this reinforcement, the prospective teacher is left to grow on her or his own. For some, the growth will never progress and eventually digress as their personal histories of learning science move in to replace any new but temporary ideas.

In reality, it is unlikely that all prospective elementary teachers of science will be placed with cooperating teachers who are themselves able to nurture another along in the process of understanding how children learn science, especially when large numbers of prospective teachers enter and leave teacher preparation programs, as was the case in this study. To put that into practice requires a more intensive instructional relationship between the cooperating teacher and the prospective teacher, as well as among the university professors, cooperating teacher, and prospective teacher. To focus on quality over quantity, science teacher educators may need to prepare fewer, more qualified teachers. With fewer prospective teachers in a program, a more personalized approach to learning to teach science and other disciplines is possible.

An understanding of learning to teach science develops with personal experiences in teaching science from various orientations, professional development that includes the conceptual change approach, and collaboration with other science teachers committed to the same conceptual development. However, as with learning to teach in general, learning to teach science begins within a safe, risk free environment created by the cooperating teacher where prospective teachers can experience teaching, construct meanings from their experiences, and apply those beliefs to their classroom practice. They need to feel safe to be creative, to experiment, and to develop the confidence to become an independent, lifelong learner of learning and teaching.

From this study, it cannot be overstated that the role of the cooperating teacher seems crucial to the extent that the prospective teacher learns to teach science. If the prospective teacher perceives the cooperating teacher has created a supportive learning environment for trying new ideas and experimenting with teaching, the prospective teacher grows confident to learn. Consequently, the teacher also grows toward becoming a lifelong learner. If the prospective teacher perceives the environment is not safe, she or he will follow a course of action designed for survival of the immediate experience rather than for making meaning of the greater phenomenon of learning to teach. This points to the need for developing a consistent cadre of committed cooperating teachers. By educating teachers in the variables that impact prospective teachers, cooperating teachers will better understand their role as well as the teaching and learning philosophy of the university teacher education program.

Experience alone is not enough, but is essential along with deep, metacognitive reflection both individually and with another whether that be a collaborator, supervisor, cooperating teacher, instructor, or peer who will encourage the individual to think more deeply about an idea. Purposeful reflection can be encouraged through a vehicle such as metaphor that helps prospective teachers make their implicit beliefs explicit in the form of a concrete image. Once prospective teachers are aware of their beliefs, they can then match them up with their actions; in other words, put their beliefs into action. Reflection through metaphor seems to provide a way of helping prospective teachers recognize their teacher-centered actions and focus on teaching from a more student-centered perspective. By preparing fewer numbers of prospective teachers, science teacher educators provide a more personalized approach to teacher preparation.

This reflection can occur between a non-evaluative collaborator such as the researcher's role in this study, but more realistically within a cohort of student teachers who typically meet weekly with a supervisor. All of the prospective teachers in this study felt that if their supervision group had been more of an opportunity for them to share and challenge their ideas about learning and teaching, they would have better spent their time. At least two of the participants independently contacted me following the study to tell me they felt the experience of this project had helped them realize and articulate their thoughts. As a result, they were better prepared for their job interviews. Both had obtained employment shortly after the completion of this study.

All in all, prospective teachers of science need to be given the opportunity to experience conceptual change as learners. Since learning to teach is a conceptual change itself, the prospective teachers as learners need to first realize their prior knowledge or beliefs they hold about learning and teaching. The use of metaphor can serve as a tool for helping to make those implicit beliefs explicit. They also need to reinforce these developing beliefs as teachers within learning-to-teach environments supported by cooperating teachers who share the constructivist philosophy and who will encourage the conceptual development of the prospective teacher in learning to teach science.

Either way, it is essential that prospective teachers feel safe within their learning-to-teach environment so they can experience and experiment with putting their beliefs into action. Constantly reflecting both individually and in conversation with others through a tool such as metaphor can help prospective teachers align their beliefs and actions, monitor their changing beliefs, and construct their own meanings about this phenomenon of learning to teach science. If they leave the field experience with the confidence to learn, they will be on their way to becoming lifelong learners of teaching and learning.

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A PROFESSIONAL DEVELOPMENT MODEL FOR LEARNING TO USE THE NATIONAL SCIENCE EDUCATION STANDARDS

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The report, *What Matters Most: Teaching for America's Future*, recommends that those involved with education "get serious about standards for both students and teachers" and make teachers and teaching the linchpins of school improvement (1996, p. vii). But the standards-driven reform movement has generated a general wave of uneasiness within the K-16 educational community as its members struggle with the attendant implications on teaching practice and curriculum content.

Because the final fate of most educational reform initiatives rests squarely among teachers who serve as the ultimate agents of classroom change (Bybee, 1997), we propose that for standards to become the cornerstone of their professional lives, teachers must first develop a keen understanding of the history and philosophy underlying standards, then gain a working familiarity with standards documents, and finally, engage in sense-making experiences that lead to personal meaning or internalization of the standards.

This paper describes a professional development workshop framework for assisting both preservice and inservice audiences to gain confidence integrating the National Science Education Standards (NSES) into their teaching practice. Through a knowing in action approach (Schon, 1983) participants develop a practical understanding of the history, goals, and instructional ramifications of the NSES. The methods that we apply are consistent with effective professional development (Loucks-Horsley, Hewson, Love, & Stiles, 1998) and actively model the elements of instruction promulgated by the

NSES. We believe that the workshop's combination and sequence of activities has broad applicability and is readily adaptable for considering standards in other disciplines or at the state and local level.

Workshop Description

Our premise is that direct experience within the context of a widely practiced instructional model creates an optimal environment for learning how to incorporate standards into teaching, assessment, and curriculum decision-making. Hammrich (1998) used a similar approach to give teachers the opportunity to learn, reflect, apply new knowledge, and demonstrate proficiency. To establish a backdrop for the workshop we begin by listing our assumptions about educational standards: that standards are here to stay; that every teacher needs to grasp the implications of standards to their professional lives; that understanding standards based education is not easy or automatic; and that the most effective way to learn about standards is to use them. The workshop applies a five stage, activity-based Learning Cycle based on the Biological Sciences Curriculum Study (1993) model. (See Appendix A).

Engagement

Every participant receives a puzzle piece in their workshop package that consists of a laminated color copy section from the cover of a major standards document. One of four different color dots is affixed to the back of each piece. To begin the workshop, participants locate the three other people having pieces needed to assemble their complete puzzle. This randomized grouping activity defines the work team and the color dot code assigns individual task responsibilities.

As groups display their assembled covers, the workshop leader discusses the chronological development of the standards driven reform movement. The engagement activity quickly and effectively organizes groups, delegates team roles, creates a working atmosphere, a produces a genuine context for reviewing the history of standards.

Exploration

In the exploratory phase, a scavenger hunt provides the learning tool for completing an overview of the NSES (See Appendix B). The scavenger hunt is a participant centered activity that introduces the principal features of the NSES document and website (www.nap.edu/readingroom/books.nses). Fifteen tasks/questions divided among separate work teams encourage small group interaction. This simple exercise activates prior knowledge of standards, gives teachers a comprehensive overview of the NSES, and serves as an advance organizer for the more focused activities that follow.

Explanation

Conceptual development occurs during phase three as teachers analyze existing curriculum materials and videotaped examples of instruction to identify points of alignment with the NSES Content and Teaching Standards. The goal of having teachers gain a working familiarity with the NSES is anchored in an activity in which they assume the role of curriculum consultants. Their task is to complete a standards-based assessment that measures the congruence of representative curricula with the content standards. Teachers use a Curriculum Review Instrument developed by the National Association of Biology Teachers (1996) because the tool is clear, concise, and informative.

Following this curriculum analysis, workshop participants examine video case studies of teaching. A scoring rubric grounded in the Standards for Teaching Science is applied to evaluate pedagogical practices (See Appendix C). Only standards for which evidence is directly observable are referenced. Teachers report that videotapes provide a valuable and safe atmosphere for evaluative discussions about teaching methodologies. A similar instrument described by Ingle and Cory (1999) could readily be adapted to stimulate reflection upon classroom practice.

Expansion

An important purpose of defining standards is to assure that important concepts are introduced at appropriate moments in a student's career and that science teaching is approached in a style that is consistent with the way that children learn. Many high quality traditional instructional materials exist that are clearly inconsistent with the standards for inquiry. We introduce a viable and professionally productive alternative to discarding these activities that applies a technique for making laboratory activities more open ended (McComas, 1997). Teachers use an analytic scale to rate existing curriculum materials according to how the problem is defined, the ways and means of solving the problem, and whether solutions are given or left open to discovery (See Appendix D).

This activity gives teachers an opportunity to apply their growing understanding of standards driven instruction under familiar conditions. The approach respects present practice but emphasizes the importance of inquiry based learning. Participants discover that current instructional approaches and curriculum materials may require only slight redirection or reconfiguration to become more closely aligned with guidelines provided in the standards.

Evaluation

Posner (1996) contends that experience plus reflection equals growth. But is the end of a four hour session an ideal time for reflection? We ask teachers to complete the "I hereby resolve..." activity developed by Silberman (1996). In this self assessment, teachers compose a letter to themselves in which they identify the salient points gained through the workshop. Workshop leaders collect these letters and mail them to the writers after sufficient time has elapsed for participants to have processed the workshop experience. Some teachers report that reading these letters reaffirmed their commitment to lessons learned and helped them make these practices part of their everyday teaching.

Conclusion

Many among the present generation of practicing teachers developed their craft under a very different set of guiding instructional and curricular principles than are espoused by the NSES. The reluctance of some teachers to implement standards driven reform may be associated with the tenacity of established beliefs and practices, the difficulty of making direct connections between standards and the day-to-day job of teaching, and misunderstanding the full implications of a standards-based educational system. The concerns raised by Lynch (1997) bear consideration in this regard. She contends that, "a major reason for the difficulties of science education reform is that many educators simply do not understand its principles and implications, rather than not buying into the goals of reform. Further, the apprehension is not so much because of a lack of intelligence or motivation as that this reform is complex or has been able to produce few, if any concrete examples of what reformed classrooms, school, K-12 curriculum or science activities look like." (Lynch, 1997, p.3)

These workshop experiences described above have helped preservice and inservice teachers overcome these issues and to conceptually integrate the NSES into their professional practice. Demystification of standards enables these frameworks to serve as beacons...dynamic guides representing the collective wisdom of teachers, scientists, and science educators that direct the way towards better science teaching and learning.

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Appendix A
Five Stage Learning Cycle

ENGAGEMENT

Goals: to establish an interactive environment for learning the NSES and create a context for reviewing the history of science standards.
Activity: use "puzzles" to kick off NSES workshop, form groups, and assign roles.
Grouping strategy: make color Xeroxes of major Standards documents cover pages. Laminate copies and cut into 3-5 pieces to create a jigsaw puzzle. Randomly distribute pieces. Have participants mingle and form groups by completing the puzzle. Color dots on back side of pieces designate group member roles.
Performance objective: participants will be able to identify some of the major Standards documents and describe the history of the Standards movement..

EXPLORATION

Goals: to activate prior <u>general</u> knowledge of NSES and to become familiar with the NSES text and website
Activity: participants conduct an active learning exercise (the NSES Scavenge Hunt).Performance objective: participants will be able to use the NSES text and navigate the NSES website to know the content and organizational features of the Standards.

EXPLANATION (CONCEPT DEVELOPMENT)

Goals: to gain knowledge of Content and Teaching Standards by analyzing examples of practice and to use the Standards as a tool to evaluate curriculum and instruction
<u>Content Standards Activity</u>: participants use an adaptation of the NABT or AAAS Content Evaluation Instruments to evaluate selected science materials for their alignment with the content standards.
<u>Teaching Standards Activity</u>: participants apply a scoring rubric to evaluate a classroom videotape focusing on the teaching standards.
Performance Objective: participants will be able to use their knowledge of the NSES Content and Teaching Standards to evaluate curriculum materials and instruction.

EXTENSION (CONCEPT APPLICATION)

Goal: to gain a working understanding of the inquiry standards by analyzing and adapting traditional lab activities.
Activity: participants take traditionally formatted labs and modify them into activities that apply inquiry based approaches.
Performance objective: participants will be able to apply their knowledge of the Science as Inquiry Standard to create open-ended lab activities.

EVALUATION

Goals: to reflect upon the NSES workshop, to self assess knowledge of the NSES, and to affirm commitment to what was gained through the workshop experience
Activity: participants write an "I hereby resolve" letter to themselves.
Performance objective: participants will be able to describe the potential impact of the Science Content and Teaching Standards on their professional lives.

Appendix B
National Science Education Standards and Internet Scavenger Hunt

Purpose: to help educators ......

- become familiar with the content and organization of the NSES book and website;
- develop a personal understanding of the NSES;
- appreciate the impact of the NSES on teaching practices.

References

- *National Science Education Standards* (1996). National Research Council. Washington, DC: National Academy Press
- NSES website: www.nap.edu/readingroom/books/nses

Instructions for Completing the NSES Scavenger Hunt

Each group will be given five questions to answer or tasks to complete. After you finish each item please make note of your specific sources of information.

Group I

1. What exactly are the National Science Education Standards? (Source: _____)
2. What are the eight different Content Areas for which Standards are developed? (Source: _____)
3. What does "scientific literacy" mean and how is this issue related to equity for students? (Source: _____)
4. What does the *NSES* say about "authentic assessment"? (Source: _____)
5. What are the Physical Science Content Standards for grades K-4? (Source: _____)

Bonus: What is the relationship between a Standard and a Performance Indicator? (Source: _____)

Group II

1. Who participated in developing the NSES? (Source: _____)
2. What are the grade clusters into which the Content Standards are grouped? (Source: _____)
3. What is the meaning of the expression "inquiry based instruction"? (Source: _____)
4. What does the *NSES* say about the important issue of lab safety? (Source: _____)
5. What are the Earth and Space Science Content Standards for grades K-4 ? (Source: _____)

Bonus: What is the relationship between the AAAS *Benchmarks for Science Literacy* and the *National Science Education Standards* document? (Source: _____)

Group III

1. What are the six different categories of Science Standards? (Source: _____)
2. Are the NSES the same as a science curriculum? Explain. (Source: _____)
3. Give two examples of how the NSES will change science teaching? (Source: _____)
4. What does the *NSES* say about computer use in the classroom? (Source: _____)
5. What are the Life Science Content Standards for grades K-4? (Source: _____)

Bonus: What is the percent correlation between the *Benchmarks for Science Literacy* and the *NSES*? (Source: _____)

Appendix C: NSES TEACHING STANDARDS: CLASSROOM/VIDEOTAPE OBSERVATION TOOL

STANDARDS IN ACTION	EXEMPLARY	GOOD	COMPETENT	NOT EVIDENT	NOT APPLICABLE
A.2 Selects content that addresses diverse student interests and abilities					
A.3 Uses approaches that develop student understanding					
A.3 Applies strategies that build a community of science learners					
B.2 Focuses and supports inquiry					
B.3 Orchestrates science talk among students					
B.3 Challenges students to be responsible for their learning					
B.4 Responds to student diversity					
B.4 Encourages all students to participate					
B. 5/E.5 Encourages and models skills, values, and attitudes of scientific					
B.5 Encourages and models curiosity, openness, and skepticism					
C.1 Uses multiple methods to gather data about student understanding/ability					
C.2 Analyzes assessment data to guide teaching					
C.3 Guides student in self-assessment					
D.2 Creates classroom setting that is flexible and supports inquiry					
D.3 Ensures a safe working environment					
D.4 Makes tools, materials, media, and technology accessible to students					
E.1 Respects diverse ideas, skills, and experiences					
E.2 Requires students to be responsible for the learning of all class members					
E.3 Encourages collaboration among students					
E.4 Structures class discussion to reflect rules of scientific discourse					

Appendix D: Levels of Laboratory Openness

Level	Problem	Ways and Means	Answers
0	Given	Given	Given
1	Given	Given	Open
2	Given	Open	Open
3	Open	Open	Open

JUST DO IT? THE EFFECT OF A SCIENCE APPRENTICESHIP PROGRAM ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE AND SCIENTIFIC INQUIRY

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Recent reforms in science education have increasingly emphasized the importance of students developing current understandings of the nature of science and scientific inquiry (e.g., American Association for the Advancement of Science, 1989; National Research Council [NRC], 1996). However, research studies have consistently shown that students' views are not in line with the more recent conceptions of either the nature of science (Aikenhead, 1973; Bady, 1979; Broadhurst, 1970; Mackay, 1971; Miller, 1963; Rubba, Horner & Smith, 1981), or scientific inquiry (Welch, 1979). A common recommendation among these and other studies has been for educators to provide students with opportunities to "do science" through in-class science projects or extra-curricular work with scientists (Gallagher, 1991; NRC, 1996; Schmidt, 1967; Tobin & Gallagher, 1987). After all, it seems reasonable that students who are actively engaged in scientific inquiry should develop more accurate understandings of science and the construction of scientific knowledge.

Involvement in scientific inquiry can range from brief classroom laboratories to lengthy projects in research laboratories. The assumption has been repeatedly made that the more authentic the research experience, such as an apprenticeship guided by science professional, the more likely students will learn about aspects of scientific inquiry (Ritchie & Rigano, 1996). Hodson (1993) stated that: "The only effective way to learn to do science is by doing science, alongside a skilled and experienced practitioner who can provide on-the-job support, criticism, and advice." (p. 120) Programs have sought to place students in research laboratories or special programs to develop a broader and more complete understanding of science (Cooley & Bassett, 1961).

But is this approach as reasonable as it first appears? The suggestion that simply engaging students in scientific inquiry will improve their views of the nature of science and scientific inquiry is ultimately based on the assumption that students' can learn these complex constructs implicitly through "doing science." This assumption, while intuitive, has not been validated. In fact, a review of research on improving college students' understandings of the nature of science has recently concluded that students are unlikely to gain the desired understandings through implicit instruction alone (Abd-El-Khalick & Lederman, 1998).

The purpose of this study was to explicate the impact of an 8-week science apprenticeship program on a group of high-ability secondary students' understandings of the nature of science and scientific inquiry. The main questions of the investigation were (a) What are the student's understandings of the nature of science before entering an apprenticeship program? (b) What are the student's understandings of scientific inquiry before entering an apprenticeship program? (c) What impact (if any) did the apprenticeship program have on the student's conceptions of the nature of science? (d) What impact (if any) did the apprenticeship program have on the student's conceptions of scientific inquiry?

The Apprenticeship

The apprenticeship program has a seven-year history of placing students in science laboratories throughout a Pacific Northwest state. Apprentices worked in laboratories for an eight-week period during the summer, usually between their junior and senior years in high school. Interested students underwent a rigorous application process that involved an extensive written application and interviews with the research mentors. Participation required active involvement in a research project and presenting research results at a conference at the conclusion of the apprenticeship. Typically, the apprenticeships began with the apprentices reading literature pertaining to the research conducted in their laboratories. The mentors, who were university research faculty, introduced the apprentices to other members of the research team and the current research projects. The apprentices then participated in aspects of the on-going projects, or conducted a spin-off research project of interest. The mentors and the laboratory workers provided guidance throughout the apprenticeship experience.

One of the primary goals of the apprenticeship program was to provide high school students with authentic science research experience that would assist them in making choices about science careers. Mentors were encouraged to engage the apprentices in all aspects of research, and not merely the "grunt work" often assigned to temporary laboratory employees. Several of the science inquiry skills outlined in the National Science Education Standards (1996) were components of the apprenticeships, particularly dealing with data, constructing and testing explanations, and communicating results. A few students were given the freedom to investigate their own research questions. Research within the apprenticeships generally covered a breadth of life and physical science topics, most requiring apprentices to learn a significant number of procedures and skills. Sample apprenticeships are described in Appendix A.

Method

Ten volunteers (grades 10-11) were purposely selected from the 18 high school students participating in a science and engineering apprenticeship at a Northwest university. These apprentices participated in apprenticeships previously identified as providing opportunities for a high level of inquiry (Bell & Blair, 1997). Each high school apprentice worked within a laboratory full-time for 8 weeks during the summer, with exposure to research design, data collection, and data analysis.

Prior to the first week of their apprenticeship, the apprentices were administered an open-ended questionnaire to assess their conceptions of the nature of science and scientific inquiry. The questionnaire focused on eight aspects of the nature of science considered appropriate for secondary students (Abd-El-Kalick, Bell, & Lederman,1998; Smith et. al., 1997). The aspects of the nature of science assessed were the tentative and empirical nature of science; subjectivity, creativity, and the role of social and cultural contexts in science; observation versus inference; and the functions of and relationships among theories, hypotheses, and laws. Additionally, the questionnaire assessed students understandings of scientific inquiry gleaned from Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996): six aspects of doing inquiry (formulating questions; designing investigations; dealing with data; constructing explanations; testing explanations against current scientific knowledge; and communicating results) and four aspects about inquiry (scientists use varied methods; scientists test ideas; scientists use logic, higher-order thinking, and current knowledge; and investigations may lead to more questions). The same questionnaire was administered as a posttest at the end of the 8-week apprenticeship in order to determine whether the students' conceptions of science changed during their apprenticeship experiences (See Appendix B).

Semi-structured exit interviews provided the apprentices with an opportunity to describe the nature of their apprenticeship experiences and to elaborate on their written questionnaire responses (see Appendix C). The interviews provided insight into students' conceptions of the nature of science and scientific inquiry. Additionally, the interviews provided the researchers with the opportunity to explore the role of the research experiences in shaping the apprentices' concepts of science.

Exit interviews were conducted with the scientists who served as mentors for each of the science apprentices. The mentors were interviewed at the conclusion of the 8 weeks to provide additional information about the apprenticeships and the degree of explicit instruction related to the nature of science and scientific inquiry. The mentors were asked a series of questions (See Appendix D).

Follow-up questions were used to obtain more detailed responses during both apprentice and mentor interviews. The interviews were audiotaped and transcribed. All four researchers analyzed the questionnaire responses and interview transcripts. Prior to analyzing the entire data set, three identical, randomly selected samples of each of the data sources were independently analyzed by each of the researchers. Results of these three analyses were compared in order to establish inter-rater agreement on the categorization of the apprentices' beliefs regarding the nature of science and scientific inquiry. Better than 95% agreement among the three researchers was achieved. The transcriptions and questionnaire responses were coded, read and reread to search for categories pertaining to the nature of science and scientific inquiry.

The analysis focused on generating in-depth profiles of the participants' views and the aspects of scientific inquiry experienced during their apprenticeships. Each participant was treated as a separate case. Questionnaire and interview data were used to generate a summary of the participants' understandings of the previously discussed aspects of the nature of science and scientific inquiry. Finally, the researchers compared each participant's pretest and posttest summaries to determine the degree of change that occurred during the apprenticeship.

Results

The results are presented in three sections. The first section focuses on understandings of the nature of science and the second section focuses on understandings of scientific inquiry. In each of these sections, changes in the apprentices' views during the apprenticeship program and the origins of their views are elucidated. The third section describes the mentors' views of their role in the development of the apprentices' understandings.

The Nature of Science

Changes in the Apprentices' Understandings

Comparison of the 10 apprentices' responses to the pretest and posttest questionnaires and posttest interviews indicated few changes in their understandings of the nature of science over the course of the eight-week apprenticeship program. In fact, the views of only three apprentices changed appreciably, and only one of these attributed her change in view to the apprenticeship program. This particular apprentice developed an understanding of how common it is for multiple theories to co-exist:

Researcher:

So, did your views of theories change over the course of your apprenticeship?

Apprentice:

Yeah. I think so. I just realized through my apprenticeship how often multiple theories are in existence at the same time...I think at any one time in any field there are multiple theories, multiple ways of explaining why things occur. If one group of people interpret current knowledge to mean one thing, and another group interpreted the same knowledge to mean something else, then they could develop very different theories. No new knowledge is necessary. (2)

Researcher:

That's a pretty interesting idea-where did you learn that?

Apprentice:

My apprenticeship itself, that definitely contributed to the answer I just gave, because you see it in real life. I went out once to do some field work with some guy who was an influential scientist in the herpetology world. He did a lot of work regarding the mutated frogs. While I was out with him looking at these mutated frogs, he was talking about the different theories of what was causing the mutations. Some thought it could be an increased concentration of pollutants; others were still holding on to the UV ray theory. He was just trying to explore both of those ideas at the same time. I guess that was one time when I saw new theories and old without any groundbreaking experiments. (2)

It should be noted that this apprentice stood out from the other apprentices in that she was extraordinarily reflective, as indicated by her many references to her apprenticeship as a source for examples during the interview. She even jokingly referred to the fact that her friends at school called her "the Thinker".

A second apprentice changed his view of the relationship of theories and laws over the course of the summer. In the following interview excerpt, he describes a shift from a hierarchical view, where theories become laws when proven, to a view that theories and laws are different types of knowledge:

Researcher:

On the posttest you said," there is a difference, but I don't know what it is..."

Apprentice:

Yeah, Well, I have read about it in a science book since then.

Researcher:

Oh, in the last week or two?

Apprentice:

Yeah. Well, the difference is that a scientific law is something that happens, you know. If you drop something, it is going to fall. And a scientific theory is explaining why the object falls.

Researcher:

OK- so... you didn't really know that before you took your chemistry class this fall?

Apprentice:

No, I just realized that. I thought that a law, a scientific theory is that they were not quite sure about it. Like about 99% sure. And I thought that a scientific law was that they were absolutely sure.

Researcher:

O.K. So now, do you think that theories turn into laws?

Apprentice:

Ah, no. Because the theory is the explanation of why something happens, and a law is that something happens.

The apprentice made it very clear that his change in views concerning the relationship between theories and laws came from reading his chemistry textbook, rather than his apprenticeship experience.

The third change in understandings of the nature of science came from an apprentice whose views appeared to shift from an absolute to a more tentative view in regard to atomic theory. In her response to the second item of the pretest questionnaire, she stated:

> Scientists are very sure about the structure of the atom... they probably did a lot of research using strong microscopes to determine the structure of the atom. (3)

This answer describes the atomic model as something that can be viewed directly and appears to confuse the model, which is based on inferential evidence, with reality. In her posttest questionnaire response, the apprentice speaks more of indirect evidence:

> Scientists are pretty certain that they have discovered all aspects of the atomic structure, but new evidence could always come up. Scientists relate the actions of the atom to the location of certain things in the structure. For example, scientists think the electrons are in fields around the nucleus because they are accessible enough there to cause static electricity. (3)

When asked during the interview to elaborate on this apparent change, the apprentice explained:

> I did kind of change my opinion. The first answer I gave about the atom, I don't think anyone really knows or has seen an atom, because it's not something you can see. My second answer was trying to explain certain ways that they can prove that it looks that way without really knowing what it looks like. So, they're doing experiments with static electricity and things that involve atoms and electrons and stuff. (3)

When queried about the source of this change, however, the apprentice clearly indicated that the change in her responses was the result of reflection on the pretest, rather than any implicit or explicit instruction she experienced during her apprenticeship:

> Researcher:
>
> Is that change something that occurred because of your apprenticeship, or something else?
>
> Apprentice:
>
> It's wasn't something that changed because of my apprenticeship. I think I just kind of rethought it in my brain, because after I took that questionnaire I started thinking about the answers more and trying to decide if that was right. (3)

In conclusion, the only change of apprentices' understandings of the nature of science that can be attributed to the apprenticeship experience is the view that Apprentice 2 developed concerning the coexistence of multiple competing theories. No other apprentice experienced any changes in their understandings of the nature of science attributable to their participation in the intensive and authentic eight-week apprenticeships.

Views of the Nature of Science

Following are descriptions of the apprentices' views of the nature of science with representative excerpts from their pre-and posttest questionnaires and interview responses.

The Empirical Basis and Tentativeness of Science

All of the participants expressed the belief that science is empirically based. For example, in response to the interviewer's question about the difference between an idea and a scientific theory, one apprentice stated:

> An idea is just what something thinks, and a theory actually has evidence to back it up. The Theory of Evolution has lots of physical evidence to back it up-the fossil record and I guess similarities between different organisms. (7)

Other expressions of the empirical nature of scientific knowledge were in conjunction with explanations for the tentative nature of scientific theories. Specifically, all the apprentices noted that theories change in light of new evidence. The following are representative of the apprentices' comments:

> Theories change because we have new technologies that allow us to see farther into space or to see smaller particles. (10)

> Theories do continually change. As more experiments are done and more results and conclusions are drawn, most theories are modified or updated. Although it is uncommon, some theories are greatly altered or proven wrong. (9)

Only 2 of the 10 apprentices cited new ways of looking at existing evidence as a reason that theories change:

> Theories change because of new evidence and new ways of looking at the evidence that's already there. This is part of the normal scientific process. (1)

> I don't think new knowledge is the only thing that would make a theory change. ..I think at any one time in any field there are multiple theories, multiple ways of explaining why things occur...If one group of people interpret current knowledge to mean one thing, and another group interpreted the same knowledge to mean something else, then they could develop very different theories. You know, it's the second group of people that come along and look at the knowledge and come up with a theory that seems to make a lot of sense to other people in the field, then it could be that the theory is changed and the new one would be accepted. No new knowledge is necessary. (2)

Finally, while two apprentices believed that laws, as well as theories, are tentative:

> Many situations in physics can be explained with the laws of physics (gravity, thermodynamics, etc.), but there is also quantum mechanics where some of the theories and laws are not useful anymore. (8)

> ...a law might be still proven wrong in the long run. (5)

the majority of the apprentices believed laws in science to be absolute:

> Theories can change, or else they would be laws. (7)

> Laws, as I understand them, would only change if something in our nature, like our environment, changed. As far as I know, laws don't change because they're facts. (2)

> A scientific law is definite, and nothing is named a law unless scientists agree that there is no question to its being true. For example, scientists are open to finding new information about the atomic theory, but Newton's Law of motion has been tested enough times that scientists are certain it is true. (3)

The Relationship Between Theory and Law

In addition to the misconception that scientific laws represent absolute knowledge, many of the apprentices expressed the misconception that theories and laws are the same kind of knowledge, separated only by the degree of certainty ascribed to them. In the apprentices' views, theories become laws over time as enough evidence is collected for them to be proven:

> OK, um, I think I decided that a scientific law would represent something that had been a theory. It had been proven so many times and under so many circumstances and conditions that it had elevated into a law, something that, I guess, has withstood the test of history. And a scientific theory would be something that had been more recently proposed and may hold up, still, to our tests, but has not been around long enough to be proven as a law. (5)

From my understanding, an hypothesis is sort of, the lowest down on the level...a theory has been proven more, with less fault. It is just more concrete than an hypothesis, and a law is even more so than a theory. It is something, such as gravity, that is proven everyday. It has never been proven wrong, so it has become a law. (9)

A theory turns into a law, but most of the time it will remain a theory. It will turn into a law when they are positive that is what is right. (7)

This hierarchical view of the relationship between laws was not held by all of the apprentices, however. Four of the apprentices demonstrated understandings that laws are statements or descriptions of patterns in observable phenomena, while theories provide explanations for those phenomena.

Theories are ways science explains the world around us. From what I understand, laws just describe what is happening. So, the law of gravity describes that an apple falls down, but it doesn't explain why. (1)

Laws describe what happens. A theory tries to give a reason for what happens and a law just describes it. (4)

However, being able to state a particular view did not necessarily mean that they were able to apply it. For example, one of the apprentices was able to describe the relationship between laws and theories. However, when she applied it to her apprenticeship project, she incorrectly labeled the relationship that she developed between a snake's mass per unit length and its gravity as a theory:

What I've been taught, at least, is that laws are all observable or immediately obvious. And I'm not sure whether that's true or not, but that's what I've been taught. The effect of gravity is immediately obvious; it's always there. The theory that we developed about garter snakes was that a snake's mass per unit length will determine the likelihood that it will reproduce in a given year. And that's got a lot of exceptions. Like, some very unhealthy snakes will reproduce in a given year. And that happens. It can't be a law. At least the theory that we developed can't. It can't be a law because it's not consistent. It's consistently broken, actually. I think our theory is correct, but it's not like a given... As far as I know, laws don't change because they're facts. They're not really explanations. That's what theories are. Theories are more explanations, laws are facts. (2)

Observation and Inference

The second item on the open-ended questionnaire was concerned with the model of the atom, how certain scientists are about that model, and what kinds of evidence they use to support it. The primary focus of this item was the difference between observation and inference. A common response to this item is that scientists have viewed the structure of atoms directly using powerful microscopes. This reference to direct evidence reflects a misunderstanding of the inferential nature of scientific models. Only 2 of the 10 apprentices expressed this view:

I believe that scientists have very little doubt about what the nucleus looks like because they can detect them with different microscopes. (6)

Scientists probably did a lot of research using strong microscopes to determine the structure of an atom. (3)

It should be kept in mind that apprentice 3 changed her response on the posttest and interview to reflect a more tentative view, i.e., that atomic models are based on inference, rather than observation. As described earlier, she explained this change as the result of her reflecting on the questionnaire, rather than her experiences in the apprenticeship program.

Most of the apprentices, however, demonstrated some understanding of the inferential nature of the atomic model:

> There are different ways to diagram atoms, like the Bohr model, or models showing the shapes of different orbits in the electron cloud. Of course, these are just representations. (6)

> As far as I know, it's still not possible to actually see an atom. I think [the structure] is mostly determined by how atoms behave--how they combine, or how they don't combine. As far as I understand, there's a lot of theory, too. And I would imagine that would be the case anytime you can't actually see what you're studying. (2)

> Scientists are never certain that any one particular model can last. A lot of it is based on evidence that we can't really see, like in Rutherford's investigation. I think that scientists developed the current quantum model by using an array of instruments...to develop a probability field. (7)

Creativity and Subjectivity

All of the participants ascribed some role for creativity in the construction of scientific ideas. For example, while all of the apprentices saw experimental design and developing methodology as creative endeavors, some believed that creativity should be avoided during data interpretation:

Apprentice:

I think that scientists should not use their imagination in some circumstances. In interpreting the data, they should go strictly with what's in the data. If they sorta try to make it slant one way or the other, or you get two people doing the same experiments, and they have the same data and they get different conclusions, I think that that is because they sorta have creative answers to what their data is showing.

Researcher:

So what about that? Is that O.K.?

Apprentice:

No. If you have data, you should go with what the data says. You could create a new hypothesis... They could use their creativity and imagination in that. (10)

Clearly, this apprentice expressed an absolutist/positivistic view of data interpretation. Most apprentices, however, were willing to ascribe a role for creativity and imagination in the interpretation of data:

Apprentice:

If there wasn't creativity, you wouldn't be able to come up with anything at all. If you have creativity, you look at the data and if you think you see something in it, then you investigate it further. (7)

I think that [creativity] is a big part of science, because, I think, that actual discoveries have been made, not because scientists follow the scientific method, but because they are creative... they have to look beyond what is right in front of them. (5)

Creativity and imagination is definitely needed during data collection in overcoming unforeseen practical problems. Creativity and imagination is also extremely helpful and possibly necessary during the analysis of the data collected. In my experiment this summer, my data did not at first appear to be conclusive. Neither snake length nor mass was associated with reproduction, but when I analyzed length and mass together (mass per unit length), I found a clear conclusion that this measure of body condition was indeed associated with whether or not female red-sided garter snakes chose to reproduce.

Researcher:

Would you say that you discovered this conclusion, or did you create this conclusion?

Apprentice:

Creativity in my mind means something, I don't know, looking at something from a different point of view. Working in new ways with your materials, or with your data. So, I guess you could say I created it, if you use that definition. (2)

One important aspect of the apprenticeship experience was the conference at the end of the summer where each apprentice shared the results of his/her project with the other apprentices and mentors. An important consideration for the apprentices at this time was how best to present and display their project results. Consequently, a few of the apprentices cited presenting data as a place in a science investigation where creativity plays an important role:

Apprentice:

I think, probably, communication is where it comes in a lot. What is the best way to communicate to the public? You have to be really creative to get your point across. (4)

Researcher:

Is it possible to use creativity in other aspects of the investigation?

Apprentice:

Oh, yeah. That's another place that creativity is used is in displaying the data. (3)

While there certainly is a place for creativity in communicating the results of an investigation, this is generally not considered part of the scientific process itself. Additionally, there can be a real danger if students take this idea too far, since one has to be careful that the creativity involved in communicating the results does not distort or detract from the results themselves.

The apprentices also suggested that subjectivity contributes to the tentative nature of science. Most dismissed the view that science as completely rational and objective:

Every human has their own way of looking at things, it's subjective. They see the world a certain way. They get this information, they interpret it the way they see it.

These different conclusions are possible because the world is viewed differently by different people. I believe there is an entirely right answer in this case, but I don't know what it is. (1)

Once you develop an idea you tend to be biased. Everybody's mind functions differently. So you are going to look at it differently, So they are going to think that this is their idea, and it is going to be pretty hard to convince them otherwise, if they are sure about it. I mean, scientists are human. (7)

A few students , however, held on to a more objective view. Some apprentices directly stated their belief that science should be objective:

Apprentice:

I could look at a picture and think that it is beautiful, and you could look at a picture and think that it is ugly. You know, even though it is still the same picture. And I think that scientists still do that, even though they are not supposed to.

Researcher:

Are scientists supposed to be objective?

Apprentice:

They are. but I think it is really hard to be completely objective. I mean we all have our views. If the data were more accurate, I don't think we would have as much debate about whether it was expanding or not. (10)

Others indicated an objective view by emphasizing that the different interpretations were the result of looking at different data:

Apprentice:

I guess it could be conflicting data, like one astronomer looks at stars that are spreading out and another astronomer looks at planets getting closer... (4)

The universe is huge. It's so big that we can't see most of it or comprehend where the end is, and because of this, different people, or what they call theoretical physicists, I guess, don't observe it the same way. They can observe parts of it, but they obviously don't come to the same conclusion. (2)

Researcher:

How can they infer different things if they are looking at the same data?

Apprentice:

I'm not sure...I guess they could look at microcosms and see what is happening in, like, smaller models. I suppose they could see different things if they were looking at different galaxies or solar systems. (9)

A few indicated that the different interpretations were due incomplete or inaccurate data:

The data is inconclusive or misinterpreted. More studies should be done. (10)

If we had all the data, then we would know. But it is clear that we are missing something. (6)

Still others suggested that some of the scientists were misinformed or even dishonest:

Researcher:

What about a person's background might cause him/her to interpret something differently?

Apprentice:

Well, perhaps one scientist does not have as strong of a background in astronomy as the other, and so they didn't really know what they were looking at. So, they just interpreted the results differently than someone who had been studying astronomy all their life and knew exactly what the numbers meant. (3)

I think people can distort data in many ways. What if the universe is expanding during some part of a year, shrinking during others, or even remaining constant during some time period. Depending on what the scientists want to believe, they can strategically choose only certain time periods to reflect their data (distorting the facts) instead of looking at the whole picture. (8)

The Social and Cultural Embeddedness of Science

The effects of the social and cultural contexts in which scientific investigations are embedded were almost entirely overlooked by the apprentices in this study. As previously demonstrated, many of the apprentices cited "different interpretations" as the reason that the astronomers in item seven of the questionnaire came up with different conclusions about the ultimate fate of the universe. When probed about the source of these different interpretations, all of the apprentices cited personal beliefs/bias. Only one apprentice volunteered that influence outside the individual might play a role in data interpretation:

> I think it's because sometimes their company wants it to be a certain way, they want to have this theory proved, or whatever their personal agenda is. Let's see, if someone is really religious they'll think creationism is right, if someone is an atheist, they'll think evolution is right. So, personal belief or the company's agenda. (4)

In summary, despite participation in an authentic, inquiry-oriented science apprenticeship program, none of the 10 participants were found to have mastered all seven aspects of the nature of science described at the beginning of this paper. In particular, no single apprentice appeared to possess "acceptable" understandings of any more than four of these seven aspects. In general, the apprentices appeared to understand the empirical basis for scientific knowledge, the tentative nature of hypotheses and theories, and the role of creativity in scientific investigation. A few appeared to posses an instrumentalist view of the atomic model. Fewer still were able to articulate the differences between scientific theories and laws, and almost none attributed a significant role for social and cultural influences in the development of scientific knowledge.

When the participants were asked about the sources of their understandings (whether "acceptable" or not), references to their apprenticeships were conspicuously absent. Instead, the apprentices referred to their science classes, personal reading, and parents as the primary sources of their understandings. The following response is both typical and salient:

> Working in the ASE program changed my views of the specific field I was working in, because before I thought, it's just wood, you know? What can you do with it? Now I know a lot more about that specific field, but things such as these [nature of

science questions], it didn't do a lot to change my opinion of them... Nobody ever really discussed any of these topics with me. (8)

Scientific Inquiry

Changes in the Apprentices' Understandings

Apprentices noted that they learned more about doing science due to participation in their apprenticeships, as discussed in detail below. However, few apprentices exhibited changes in their knowledge about scientific inquiry, despite involvement in laboratory investigations over a sustained length of time.

The interviews of a few apprentices provided evidence of the beginnings of change in thinking about the real work of scientists. For example, Apprentice 2's view of the scientific method remained intact following her apprenticeship, but she appeared to be wavering in this belief. Early in the interview this apprentice appeared to believe in a single scientific method. However, later she indicated that her view of science had changed over the summer to a more general view.

> Yeah, I think that my concept of what science is has changed. I kind a think that I have a more general view of science than I would have, if you had asked that question before my apprenticeship... I know have a more general view because science is about the real world. It is not just what goes on in labs. (2)

As stated in the previous section, this apprentice acknowledged that she was particularly thoughtful. Her exceptional ability to reflect, combined with the observational nature of her field work, contributed to her ideas of a more general view of science.

In most cases, the apprentices' previous understandings of scientific inquiry were reinforced by their work with their mentors. Some apprentices stated they acquired an in depth understanding of lab safety, following procedures, and the need to be careful in collecting data.

> Probably the biggest thing I learned was how to work in a lab, lab safety, how important it is to do things the right way, and to know what you're doing when you're doing it. (3)

> What hit me most was that everything needed to be recorded in detail. I didn't really think about how meticulous scientists had to be. I definitely got a clearer idea of the scientific process over the summer. (1)

One might predict that apprentices involved in descriptive work and correlation studies, versus experimentation, would more likely change their views of inquiry. However, this was not the case. For example, apprentice 1 maintained his belief in a single scientific method. "As far as I know all scientific investigations include controlling variables." This idea of a single scientific method was substantiated in his response to the birdhouse question, "This is following the scientific method. I'm controlling variables...I'm doing experiments."

Yet, this same student participated in a descriptive study of a beetle in an old growth forest. Although his apprenticeship experience involved finding patterns, Apprentice 1 held onto his earlier beliefs. Apprentice 1 viewed his apprenticeship study as a precursor to the real scientific investigation and something less than science, "In my experiment we were mostly describing what we found. We did not have much of a chance to put controls on different things."

Acquiring Abilities to Do Inquiry

Apprentices and mentors reported that the apprentices learned many new ways of doing science. Apprentices were actively engaged in research, particularly data manipulation, construction of explanations, testing of explanations, and communicating results.

> I did the actual data collection, and then kind of looked at that, trying to figure out what it might mean, then went deeper into it. (2)

> I set up experiments, I ran the experiments. I did some research on it. I was pretty much in charge of almost everything. I would talk with the professor every once in a while about where he wanted me to go with this, and then (it) was pretty much up to me, how I got there. (10)

> So in my experiment, I had the title, and I had my objectives, what I was trying to accomplish, looking at the effect of wood species and the different solutions on the growth of the fungus...then I made graphs and I analyzed the data and made conclusions about it. So, I basically followed the method. (8)

Some of the apprentices had the opportunity to test their explanations, primarily in response to emerging "problems:"

> We had to do a quick save to figure out how to salvage the experiment and explain the data (4).

Apprentices learned about making sense of their data, and using evidence to construct explanations.

> We tried to explain why we got the results that we did and we both had ideas about that (5)

Additionally, several of the apprentices reported that they acquired abilities to do various aspects of science inquiry as a result of their participation in the program.

> I have learned more about the nature of conducting experiments and running tests than I ever would in a science class. (7)

Fewer references were made to formulating research questions or designing investigations. This is not surprising in that most of the apprentices joined research already in progress, missing the design portion of the project.

> It was a small project (the effect of different treatments inhibiting fungal growth in different woods) that I totally worked on. I started on it when I got there, and finished by the time I left. I didn't design the experiment. They did it for me. (8)

Apprentices modified existing experiments as illustrated by this comment.

> My role in this research was to see if the different substrates would affect the performance of them. The particular bacteria that I worked with was Pseudomonas. It breaks down butane I modified the experiment to test if it breaks down pentane as well. (7)

The apprentices had rich experiences in carrying out the scientist-designed experiments. However, the summer apprenticeship generally afforded few opportunities to participate in the creative work missing in many high school science laboratories-- the work of formulating broad and ill-structured questions, refining and refocusing these research questions, and designing the studies.

Developing Knowledge About Scientific Inquiry

While the apprenticeship experience appeared to reinforce and enhance students' abilities to do scientific inquiry, it did little to improve their knowledge about scientific inquiry. This is well-illustrated by the apprentices' adherence to the single scientific method misconception. Seven of the 10 apprentices referred to a single scientific method in their questionnaire and interview responses:

> The scientific method is a step-by-step process to solving a problem...scientific investigations should follow the scientific method. (10)

> All good scientific investigations should follow the scientific method, which is a specific process by which a hypothesis is made, then tested, and either proven correct or incorrect. If the method is not followed (even to a certain degree), then there may be holes in the argument. (5)

Many of the apprentices worked on experimental projects, where variables were controlled and manipulated in order to test hypotheses. For example, apprentice 8 investigated the effect of adding various concentrations of glucose and ammonium nitrate solutions on the growth of a particular wood stain-inhibiting fungus. Not surprisingly, students who participated in such experimental work often indicated that their apprenticeship experiences reinforced their views of a single scientific method. What is surprising is that even students who participated in observational studies typically adhered to the misconception of a single scientific method. For example apprentice 3 worked in a germ plasm repository collecting observational data on the growth and development of cloned plants. Despite the fact that she participated for 8 weeks in non-experimental scientific work, she believed that the only valid scientific methodology was experimentation:

> Researcher:
>
> Do all scientific investigations follow the scientific method?

> Apprentice:
>
> I'm sure that there are some experiments that do not follow the scientific method, because there's some steps in there that they can't do or some reason. But that wouldn't really be considered a scientific experiment, because it's not following the method completely.
>
> Researcher:
>
> Is there any other science besides science experiments? Is there anything that a scientist might do that does not follow the scientific method, but is still considered science?
>
> Apprentice:
>
> I've never thought about that before. It seems if you think about it, if a scientist was trying to determine something, then they would always use the scientific method, because that's the way you find a conclusion. (3)

Another apprentice, whose description of the scientific method included testing hypotheses and controlling variables, stated that her apprenticeship reinforced her understanding of a single scientific method:

> (My apprenticeship) is where I became, like, really familiar with the scientific method. I probably still can't list all the steps, because that's not what we were doing. But, we were using the scientific method actively and so that's why I think I have an idea of what it is. Because, I know that you always aim to follow the scientific method. (2)

Amazingly, this apprentice's work did not involve experimentation. Rather, she was participating in a correlational study that sought to link physical characteristics of garter snakes to their gravity.

While most apprentices identified valid science with experimentation, a few recognized that there are many ways to do science. None of these apprentices associated this knowledge with their apprenticeship experience, however.

> Theoretical physicists, they don't do experiments. They derive proofs and stuff like that. Astronomers, they don't, and I guess, biologists. People that work with space a lot, the stars, they don't actually run experiments. (7)

> Not all scientific investigations follow the exact same method. Some do not lend themselves well to experimentation...there is no one set scientific method. (9)

> The scientific method can mean one of two things. First, there is the six-step process that school children are taught. Second, there is the more fluid method that scientists actually use. (6)

Another aspect of knowledge about scientific inquiry emphasized in the current reforms is the notion that science involves testing ideas. The understanding that doing science involves testing ideas was evident in all of the apprentices' responses to the pre- and posttest questionnaires and interviews. Many of these were in response to the last item on the questionnaire that asked respondents to design an investigation.

Researcher:

What do you mean by "experiment" on the last question?

Apprentice:

You know, like a test to see if one factor seems to be making a huge difference. I think it's a matter of finding that factor or factors. (2)

I would first develop a hypothesis...after this, I would observe each one of the bird houses and compare its characteristics to my hypothesis. I would then re-evaluate my hypothesis as needed. (7)

If I see some differences between the occupied and unoccupied birdhouses, [I would] research that area more to see if that is really the cause of it. For instance, If I found out that the 14 birdhouses that were occupied had a close food source, I might take half of the unnested birdhouses and put some more feeders by them and see if the birds would come. (8)

It is important to note that the apprentices' pretest responses were no more complete or elaborate than their posttest responses regarding their understandings of testing ideas. Thus, the apprentices apparently learned what they knew about this aspect of scientific inquiry prior to their entering the apprenticeship program.

None of the apprentices indicated that it would be important to consider existing knowledge when designing their birdhouse investigations (question 8). This is surprising, because most of the mentors required their apprentices to review existing literature prior to beginning their apprenticeship work. Additionally, few of the apprentices mentioned that scientific research typically results in new questions. It is unclear from the existing data whether their failure to mention this reflected a belief that new questions are not a primary outcome of scientific investigation. Finally, the apprentices' responses to the questionnaires and interviews did not allow for assessment of the concept that scientists use logic, and higher-order thinking in their investigations.

In summary, apprentices' understandings of the six aspects of doing inquiry (formulating questions, designing investigations, dealing with data, constructing explanations, testing explanations against current scientific knowledge, and communicating results) appeared enhanced by their work with scientists. This finding is not unexpected. However, there appeared little, if any change, in their understandings of the four aspects about inquiry (scientists use varied methods; scientists test ideas; scientists use logic, higher-order thinking, and current knowledge; and investigations may lead to more questions). In fact, the apprenticeship appeared to have reinforced inaccurate understandings of these ideas in some cases.

Impacts on Conceptions of Scientific Inquiry

Most apprentices' views of scientific inquiry appeared to stem from science classes, reading science books, and from parents who happened to be scientists. The misconception that scientists use a single scientific method appeared to originate from middle school and high school science classes and school textbooks.

> Apprentice:
>
> Scientific method is a process used to find answers to questions and experimentation. And we have six basic steps to find your answer. There is forming an hypothesis, researching and experimenting, ah...collecting data. analyzing data...um

Researcher:

Where did you hear that there were six steps?

Apprentice:

Oh, science books always have them. I have seen books that have six. I have seen books that have seven. They have different ones, but basically the same thing. (10)

I did not answer the questionnaire from my apprenticeship, so much as from the science classes I have taken. (5)

From what I read in school about science, I always had the impression that science is a very official sort of business, very much like following a checklist of the scientific method. (2)

One apprentice noted a difference between what is taught in school science and real science.

First there is a six-step process that school children are taught. Second, there is the more fluid, but similar method that scientists actually use. (6)

One apprentice who articulated a more accurate view of conducting scientific investigations appeared to gain his knowledge from his parent. When asked, Is it good to follow all the steps? Apprentice 7 responded,

Well it is a good idea, but most scientists don't pull out a sheet, and say, This is the scientific method--I have to follow that. My dad is a physicist, and that is pretty much how they do it. And I know a lot of this stuff because he talks about it a lot.

Although Apprentice 2 connected her ideas of listing the steps of the scientific method to school science classes, she appeared on the verge of changing her views. Her summer field experience of catching snakes may have influenced her thinking about the ways some scientists gather and interpret data.

> I probably still can't list all the steps, because that is not what we were doing. I think being in the middle of it, and using it, showed you what it was. I still never looked at a chart and followed any flow chart, you know, that is step one, that is step two. Like with the native snakes we were making observations on, we have absolutely no way of monitoring their environment at all. So then what we are looking at is similarities between them.

In most cases, apprentices stated that answers to the questionnaire did not reflect discussions during the summer. Instead, they stated that talk during the apprenticeship centered mainly on immediate tasks.

> We mostly just talked about planning experiments. (5)

On the positive side, some apprentices did gain an understanding of the unpredictability of laboratory life.

> Before, I thought that experimentation was done in kinda rigid manner. You do this at ten oclock in the morning. And then you do something else at 1:30 in the afternoon. But when I was working this summer, my day always changed, it was never the same. In school we actually followed the scientific method.. What we think is going to happen…It is good for school, it is not great for other research, because it is too strict. Research really needs to be done in a flexible environment. (7)

In summary, except for formulating questions, apprentices' understandings of the six aspects of doing inquiry (formulating questions; designing investigations; dealing with data; constructing explanations; testing explanations against current scientific knowledge; and communicating results) appeared enhanced by their work with scientists. This finding is not unexpected. However, there appeared little, if any change, in their understandings of the four aspects about inquiry (scientists use varied methods; scientists test ideas; scientists use logic, higher-order thinking, and current knowledge; and investigations may lead to more questions.). In fact, the apprenticeship may have reinforced inaccurate understandings in some cases. Almost all apprentices appeared entrenched in their prior belief in a single scientific method, and many apprentices credited their apprenticeships as supporting this belief. At most, a few apprenticeships appeared to stir up the beginnings of change in thinking that scientists use diverse methods.

Mentors

Mentors were responsible for providing the research framework for the apprenticeships and guidance to the apprentices. When asked what they believed the apprentices learned about science, the mentors provided many responses, mostly pertaining to aspects of inquiry.

> He learned how to do experiments, how to design an experiment, and what an experiment is...These aren't the two-hour labs they are used to doing in school. (Mentor 10)

> (Apprentice 1) gained an appreciation for experimental approach and hypothesis testing, including what hypotheses are and why they are important. He understood

the importance of good experimental design, and how it enables us to do what we want to do. (Mentor 1)

Mentors made far fewer comments about the apprentices learning aspects of the nature of science. Only one mentor focused on multiple aspects of the nature of scientific knowledge, including tentativeness and objectivity.

> There is no real right or wrong, which sometimes makes this (research) look like a series of mistakes. The students learn that the truth is not out there. Science is not just a march towards goals, the process is more like an adventure. You never really know where you are headed.
>
> (Mentor 2)

Additional comments focused on the impact of society on science and the culture of scientific research.

> It is also important for them to understand how research is impacted by societal needs....For example, with our research there is underlying societal importance. (Mentor 1)

> I think she experienced the dynamics of how a research group works together. I think she did not know the human element of science. (Mentor 6)

When asked whether they explicitly taught their apprentices about science, the mentors stressed that the way to learn about science is to do science. They also stressed that this was the way scientists learned about science, by actively participating in the research process.

Most of these things are learned by osmosis. This is the way I did it, and this is the way others have done it. This is an environment in which to flourish of flounder. (Mentor 7)

You learn about science from participating, she learned science for herself. (Mentor 6)

Meetings between mentors and apprentices focused on problem solving related to the projects, and little time was spent on explicitly discussing general attributes of science.

We spent a lot of time explaining the basics needed to complete the projects. (Mentor 3)

Overall, the mentors stressed the importance of the apprentices learning to do science and, as a result of this process, developing knowledge about aspects of inquiry. The mentors perceived that knowledge of inquiry and the nature of science is developed through participation in research. The mentors spent the majority of their time with the apprentices addressing problems with experimental design, and did not seek to explicitly instruct the apprentices in other aspects of science not directly related to the projects.

Analysis of the mentor interviews indicated that few provided any explicit instruction regarding either the nature of science or scientific inquiry. The small amount of direct instruction provided by the mentors dealt primarily with science processes directly related to the projects the apprentices were working on. Discussions between mentors and apprentices usually centered on immediate concerns with the data collection and procedures of the project.

Discussion and Implications

An adequate understanding of scientific inquiry and the nature of science is a perennial instructional objective of science education. This investigation assessed the effects of an authentic science experience on secondary students' knowledge. The influence of the experience will be described in terms of data collected from research mentors and students. Prior to any discussion of individual perspectives it is important to note that no changes in conceptions were noted in students' conceptions from pre to posttest.

According to the mentor scientists, students were exposed to a full range of scientific investigation experiences. In particular, students were engaged in the development of research methods, data collection, and data interpretation. In general, however, students were not given the opportunity to develop research questions for these investigations. Further, it was assumed by the scientist mentors that students would come to understand science by doing science. This is not surprising, as it is generally assumed that students will learn how to do science as well as learn about science by doing science. In short, it was believed that implicit instruction on these topics would accomplish the desired educational objectives. Unfortunately, students exhibited no changes with few exceptions, in either their understanding of the nature of science or their understanding of scientific inquiry.

With respect to the nature of science, students believed (on both pre and posttests) that scientific knowledge is tentative, based on empirical evidence, and involves creativity and subjectivity. However, these beliefs tended to be superficial, as students ascribed tentativeness to the lack of information and they did not exhibit an in-depth understanding that it is possible for different interpretations of the same data to be valid. Furthermore, students still possessed the misunderstanding that theories eventually turn into laws with more evidence and there was still some misunderstanding about the role of creativity in the analysis of data.

With respect to scientific inquiry, students clearly exhibited the ability to do inquiry, but they also exhibited a strong belief in a single scientific method. Again, there was virtually no change in students' views from pre to posttest. Overall, students' understandings of the nature of science and scientific inquiry did not change. It is especially important to note that the sample of students for this investigation were not representative of the population of secondary students. Students involved in the ASE program are recognized as high ability science students by any criterion. Still, the lack of any change in views clearly indicates the lack of any discernible influence of the program.

Unfortunately, the results of this investigation do not support the intuitive assumption that students will learn about science simply by doing science. Although there is virtually no research to support this assumption, science educators have assumed that students will learn about scientific inquiry and the nature of science simply by doing science. It is quite clear, and substantiated here, that students only learn how to do science, by doing science. Indeed, even this claim must be qualified, as the typical experience is one in which students are provided with questions and, at best, develop an approach to answer the question. The result, as was true in this investigation, is only support for the view that a single scientific method exists. Although this was not the intent of the scientist mentors, students were actually only relegated responsibility for the more menial aspects of scientific inquiry. In effect, they were technicians attempting to answer a question that was already posed and focused. It is not surprising that students' views about the existence of a singular scientific method were reinforced.

With virtually no exceptions, the scientist mentors believed students would learn about science by doing science. Learning about a way of knowing requires reflection on one's actions, not just doing (Bell, Lederman, & Abd-El-Khalick, 1998; Lederman, 1995). As would be expected, students did not learn much about what they had done, they only learned how to perform certain physical skills. How much more data will it take for the science education community to accept that students should not be expected to master what they have not been given an opportunity to learn?

This investigation represents a direct test of the assumption that experience with an authentic scientific experience will translate to increased knowledge about science and scientific inquiry. The results are not surprising and further emphasize the importance of systematic reflection upon one's actions. It is not enough to include such experiences within teacher education programs and undergraduate science experiences. Experiences in authentic science are necessary, but not sufficient. Teacher educators will need to provide opportunities for preservice teachers to explicitly reflect on their actions in such a manner that the nature of science and scientific inquiry are brought to the forefront (Abd-El-Khalick, Bell, & Lederman, 1998). Students do not learn about the nature of science and scientific inquiry by osmosis, as one mentor scientist stated, they learn those ideas and skills that are explicitly addressed. When students only do science, it is the doing, and only the doing, that is explicitly addressed and learned. Teacher education programs should require that all preservice teachers participate in authentic scientific inquiries as well as participate in courses or experiences that explicitly debrief these experiences in terms of the nature of science and scientific inquiry.

Assuming the aforementioned is addressed, our task is not complete. Teachers will then need to develop those skills necessary to translate and communicate the knowledge they have to K-12 students. This translation will need to be both concrete and useable. An effort to develop K-12 teachers' pedagogical content knowledge (PCK) for nature of science and scientific inquiry is needed. The development of this PCK will not occur through osmosis. It will need to be developed and systematically addressed through explicit and context-based science instruction.

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Appendix A
Sample Apprenticeship Profiles

Sample Apprenticeship Profile 1

The apprentice worked in a zoology laboratory studying reproductive biology of snakes. The apprentice's project focused on the relationship between body condition and reproductive capability. This research was part of a larger study investigating natural influences on snake population size, with possible implications for control of invasive snake species. The apprentice assisted in collecting snakes, and maintaining them in captivity (feeding and general animal husbandry). In order to draw connections between physical characteristics and reproduction, the apprentice marked the snakes and collected data on weight, length, temperature, and number (of births). The apprentice conducted radioimmunoassays to monitor endocrine changes and kept a research journal. During the project, the apprentice repeatedly analyzed data and discussed results with the research team. Modifications were continually made based on the apprentices observations and inferences.

The apprentice also volunteered to assist with a separate amphibian project, and worked with graduate students conducting a variety of research projects. In addition to presentation at the conference concluding the apprenticeship, it is anticipated that results of this project will be presented at a national science meeting and published in a science journal.

Sample Apprenticeship Profile 1

The apprentice worked in a plant pathology laboratory investigating how bacteria can degrade harmful chlorinated pollutants into less toxic compounds. This was part of a larger study investigating the aerobic metabolism of chlorinated aliphatic hydrocarbons by butane-utilizing microbes. The apprentice conducted experiments on degradation rates utilizing a variety of different media. To study degradation of the pollutants, the apprentice grew bacterial cultures, assessed their growth using a spectrophotometer, and prepared the cultures for the degradation assays using an ultracentrifuge. The apprentice then prepared buffer solutions for the degradation assays and performed the assays using electron capture and flame ionization detector gas chromatographs. This was followed by a protein assay to roughly estimate culture size.

The apprentice then entered and plotted data on computer, and analyzed the data to make alterations in the experimental design. Results were reported at a bi-weekly research group meeting and at the conference at the end of the apprenticeship. It is anticipated that results of these experiments will be published in a science journal.

Appendix B
Apprentice Questionnaires
Nature of Science Questionnaire

1. After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.
2. What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?
3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.
4. What is the scientific method? Do all scientific investigations follow the scientific method? Defend your answer.
5. Scientists perform experiments/investigations when trying to solve problems. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments/investigations? Please explain your answer and provide appropriate examples.
6. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers if all of these scientists are looking at the same experiments and data?

7. A person interested in botany collected specimens from the Andes mountains of Venezuela and the volcanoes of the Canary Islands. Based on these specimens and his extensive field notes, he developed the concept of altitudinal zonation, which describes how plant species found at sea level differ significantly from those found at high elevations. Would you describe this person's work as science? Please explain.
8. You decide to inventory the bird-houses in your neighborhood as an after-school project. During this inventory, you locate a total of 34 birdhouses, only 14 of which are being used by nesting birds. The others are currently unoccupied. You decide that you would like to know why some of the birdhouses are occupied and others are not. How would you conduct this study?

Appendix C
Apprentice Interview Questions

1. Please describe what you did in your apprenticeship.
2. Did you have an opportunity to conduct your own research project?
3. What did you mean by your response to question number (refers to a specific question on the questionnaire)?
4. Did your views about science change as a result of your apprenticeship experience? In what way? or Why not?
5. What kinds of things did you and your mentor talk about?
6. Did your mentor ever talk to you about the kinds of things on this questionnaire? Please explain.
7. What did you learn from your apprenticeship experience?

Appendix D
Mentor Interview Questions

1. Briefly describe the apprenticeship.
2. During the apprenticeship, did you modify your original plans? If so, in what way? Why?
3. What do you think the apprentices learned about science by completing this apprenticeship?
4. Did you explicitly teach your apprentice anything about science during the apprenticeship? If so, what? How?

MAKING CONNECTIONS BETWEEN SCIENCE AND MATHEMATICS IN A SCIENCE METHODS COURSE: ASSERTIONS AND REFLECTIONS OF THE PARTICIPANTS

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Overview and Rationale

This study interprets the efforts made by one elementary science methods professor to make connections between mathematics and science in an elementary science methods course. There is currently considerable interest in preparing science teachers to make connections with mathematics; however, there is a dearth of empirical studies that systematically study the implementation of this teaching innovation. The focus of this report is not to document the innovation in teaching practice but to present researcher assertions and reflections concerning the innovation. Participants in this study include the professor and his coresearcher and the thirty teacher candidates in the course. Special focus is on six teacher candidates participating in a special National Science Foundation funded undergraduate teacher preparation program (the Maryland Collaborative for Teacher Preparation, MCTP) and on a comparison non-MCTP group consisting of three elementary education majors with concentrations in mathematics or science.

Context of the Study

The MCTP is a NSF funded statewide undergraduate program for teacher candidates who plan to become specialist mathematics and science upper elementary or middle level teachers. The goal of the MCTP is to promote the development of teachers who are confident teaching mathematics and science, who can make connections between and among the disciplines, and who can provide an exciting and challenging learning environment for students of diverse backgrounds (University of Maryland System, 1993). The program has sought to: (a) introduce future teachers to standards-based models of mathematics and science instruction; (b) provide courses and field experiences that integrate mathematics and science; (c) provide internships that involve genuine research activities; (d) develop the participants' ability to use computers as standard tools for research and problem solving, as well as for imaginative classroom instruction (through training on how to incorporate calculators, microcomputer-based laboratories, and the Internet into their instructional practices); (e) prepare prospective teachers to deal effectively with the diversity of students in public schools today; (f) provide graduates with placement assistance and sustained support during the critical first years of their teaching careers. This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities. In practice, the MCTP undergraduate classes are taught by faculty in mathematics, science, and education, who strive to diminish faculty lecture while emphasizing student-based problem-solving in cross-disciplinary mathematical and scientific applications.

Theoretical Assumption and Research Methodological Approaches

A fundamental assumption of the MCTP is that changes in pre-secondary level mathematics and science educational practices require reform within the undergraduate mathematics and science subject matter *and* education classes teacher candidates take throughout their teacher preparation programs (NSF, 1993). To test this assumption, an empirical study using an action research approach (Collins, 1995) with an N of one (a case study) was designed. A common focus of action research is to promote a self-reflective analysis that can improve teaching practice and our understanding of practices (O'Hair, 1995). This study also takes a symbolic interaction theoretical stance (Blumer, 1969; Denzin, 1978). Symbolic interactionism makes the assumption that meanings are constructed by humans through interaction. A central premise is that inquiry must be grounded in the empirical environment under study.

Research Questions

As a result of the teacher candidates' participation in the MCTP reform-based science and mathematics courses, the following research questions were investigated:

1. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the science content knowledge they bring to their science methods course?

2. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions they bring to their science methods course concerning: (a) preparedness to teach science content to elementary students; (b) an appropriate science learning environment for elementary students; (c) the rationale for and intent to make connections between science and mathematics in elementary teaching; (d) the role of science methods in their teacher preparation program?

3. Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions upon completion of the science methods course concerning: (a) an appropriate science learning environment for elementary students; (b) the extent to which their science methods professor modeled good teaching of science; (c) the extent to which they observed their science methods professor making connections to mathematics in his teaching; (d) the rationale for and intent to make connections between science and mathematics in elementary teaching?

Data Collection Strategies

Observations

A coresearcher regularly observed and videotaped the science methods class.

Interviews

A coresearcher conducted semi-structured interviews (taped and transcribed) with the six MCTP teacher candidates and three non-MCTP teacher candidates as a comparison group. The interviews were conducted at the beginning and the end of the semester in groups of two or three. Each of the interviews lasted approximately 30 minutes. In addition to the semi-structured interviews, the professor of the class conducted an open-ended, videotaped group discussion with the MCTP teacher candidates in the science methods class. The group discussion focused on ideas about integrating mathematics and science in teaching and learning.

Journals

Both the professor and the teacher candidates in the class keep journals in which they regularly reflected on the pedagogy of the science methods class.

Content Instruments

We used two instruments to assess the prior science knowledge of the teacher candidates enrolled in the science methods course. The GALT was used to assess process skills; a 75-item "Science Content Diagnostic" was crafted by the researchers from existing items in the literature (Gega, 1986) that aligned with recommendations made in the *National Science Education Standards* (National Research Council, 1996).

Findings

Question 1

To answer our first research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the science content knowledge they bring to their science methods class?") we administered two instruments at the beginning of the semester. In analyzing these data we performed the Mann-Whitney U Test using the SPSS version 6.0 statistical analysis software package. The Mann-Whitney U Test is commonly used in place of a *t*-test for the equality of two means when sample sizes are small and correspondingly the assumption of normality is questionable (McGhee, 1985). This test is regarded as "one of the most powerful of the nonparametric tests for comparing two populations" (McGhee, 1985, p. 509).

In determining our two groups, we compared the MCTP teacher candidates with the following groups: (1) all of the other teacher candidates in the class; (2) the teacher candidates who had a science concentration; and (3) the teacher candidates who had a mathematics concentration.

The results from the Mann-Whitney U analysis of the GALT scores are shown in Table 1 (Note: a higher rank signifies a better score.)

Table 1
Mann-Whitney U Analysis of GALT Scores

Groups Compared	Cases	Mean Rank	U Value	2-Tailed P
1. MCTP and	7[1]	20.43	46.0	0.08
The Other Classmates	23	14.00		
2. MCTP and	7	8.43	18.0	0.40
Science Concentration	7	6.57		

(Table 1 continued, next page)

3. MCTP and	7	6.93	7.5	0.21
Math Concentration	4	4.38		
4. MCTP and	7	12.43	32.0	0.27
Science and Math Concentrations	11	9.46		

Note: At the end of the semester, seven the teacher candidates were identified as MCTP teacher candidates as determined by their meeting all requirements to enter student teaching as an MCTP teacher candidate. Thus, we determined that these seven teacher candidates comprised our group of MCTP teacher candidates for research purposes as well. One of the seven was not included in the semi-structured interviews during the semester since she was accepted as an MCTP teacher candidate during the middle of the study semester.

The results show that the MCTP teacher candidates performed significantly better than the other teacher candidates in the class on the GALT at the 0.10 level of significance ($p = 0.08$). While the MCTP scores, as a group, were better than the other sub-groups (i.e., science and or mathematics concentration) a significant difference did not exist between the MCTP teacher candidates scores and any of the sub-groups. Thus, the MCTP teacher candidates performed as well as either the mathematics concentration or the science concentration teacher candidates, and the MCTP teacher candidates performed better than the other teacher candidates as a whole.
The Science Diagnostic Instrument scores were analyzed as follows: (a) total score; (b) physical science score; (c) life science score; (d) earth and space science score. The results from the Mann-Whitney U analysis for these scores and for the various groups described above are shown in Table 2.

Table 2

Mann-Whitney U Analysis of Science Diagnostic Instrument Scores

Total Score

Groups Compared	Cases	Mean Rank	U Value	2-Tailed P
1.) MCTP and	7	20.07	48.5.0	0.11
The Other Classmates	23	14.11		
2.) MCTP and	7	7.64	23.5	0.90
Science Concentration	7	7.36		
3.) MCTP and	7	7.29	5.0	0.09
Math Concentration	4	3.75		

Physical Science

Groups Compared	Cases	Mean Rank	U Value	2-Tailed P
1.) MCTP and	7	18.79	57.5	0.26
The Other Classmates	23	14.50		
2.) MCTP and	7	7.71	23.0	0.85
Science Concentration	7	7.29		
3.) MCTP and	7	6.93	7.5	0.22
Math Concentration	4	4.38		

Life Science

Groups Compared				
1.) MCTP and	7	18.14	62.0	0.36
The Other Classmates	23	14.70		
2.) MCTP and	7	7.07	21.5	0.70
Science Concentration	7	7.93		
3.) MCTP and	7	7.43	4.0	0.06
Math Concentration	4	3.50		

(Table 2 continued, next page)

Earth and Space Science

Groups Compared	Cases	Mean Rank	U Value	2-Tailed P
1.) MCTP and	7	20.43	46.0	0.09
The Other Classmates	23	14.00		
2.) MCTP and	7	7.14	22.0	0.75
Science Concentration	7	7.86		
3.) MCTP and	7	7.29	5.0	0.09
Math Concentration	4	3.75		

The MCTP teacher candidates' total scores were significantly higher than the mathematics concentration teacher candidates' scores ($p = 0.09$). In comparison with the science concentration teacher candidates' scores, the results show that the MCTP scores are quite consistent with the science concentration scores.

In examining the sub-scores in the areas of physical, life, and earth and space science, we see that the MCTP teacher candidates' scores are significantly higher than the mathematics concentration teacher candidates for both the life ($p = 0.06$) and the earth and space sciences ($p = 0.09$) sub-scores. In addition, the MCTP teacher candidates performed better than their classmates as a whole on the earth and space science section of the instrument ($p = 0.09$). For the remaining sub-score comparisons, the MCTP teacher candidates' scores were not significantly different.

Given that the MCTP teacher candidates were prepared with a focus on both mathematics and science content areas, these results indicated to us that the dual focus and the MCTP content professors commitment to a more problem-centered, student-centered pedagogy did not diminish the scientific knowledge gained as compared to the teacher candidates who focused only on science in more traditionally taught science content classes. Moreover, the MCTP teacher candidates appear to have a stronger scientific knowledge base than the other teacher candidates who focused only on mathematics, and also stronger than the teacher candidates who focused on neither mathematics nor science.

Question 2

To answer our second research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions they bring to their science methods course concerning a spectrum of areas, we analyzed the data we collected from the beginning of the semester teacher candidate interview. What follows are assertions we generated from a careful reading and comparison of all the participants' responses to the interview questions. These assertions are presented in the order of the sub-sections of the second research question. Included in each are exemplar comments from the participants that support the claims made by our assertions.

Content Preparedness to Teach Elementary Students

The MCTP teacher candidates were distinguished from the other teacher candidates by expressing that preparedness to teach young students science content required their being taught content in a manner that modeled good practices. However, as a result of being taught science content by MCTP faculty in a constructivist manner, the MCTP teacher candidates recognized that a high level of comfort with science content was required. Consequently, the MCTP teacher candidates tended to express they felt less prepared as compared with the responses of the non-MCTP teacher candidates who were taught content in a lecture-based manner. The non-MCTP teacher candidates expressed a somewhat naive confidence of their content preparedness.

MCTP Teacher Candidate Beliefs and Perceptions

The distinguishable feature of the MCTP teacher candidates' comments on content preparedness was that they believed their MCTP professors taught content in a manner that modeled good pedagogy, and they could emulate this approach with young learners. They believed this approach promoted lifelong retention of content.

> Mary:
> I think absolutely, totally my Physics 117 was incredible. I think to this day I still have a pretty good knowledge base of what happened in that class and can explain things with some, you know, some level of knowledge and confidence. But I just finished [non-MCTP] chemistry this summer, two sessions, and I probably couldn't pass any of the exams if they were given to me right now, and that was only about a month ago. (Interview, September)

> Mark:
> I'm not completely confident in math. The content in science, I do not know. I just wonder if I remember what I should and how difficult it will be when I get to doing a lesson plan or a unit. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions

A distinguishable feature of the non-MCTP teacher candidates' comments on content was a perception that while they believed that they had gained a sufficient body of science content knowledge, it had been learned in isolation from a good model of how to teach young students.

> Margaret:
> Science, I would say I am pretty prepared for the elementary level, yes. Middle school, the courses I took are enough--enough I think to probably prepare for middle school. I don't know how much I have retained to be able to just go in there right now. I mean, I would definitely have to review. (Interview, September)

> Joseph:
> I had always felt that we had gone through and learned the science content, but that I was never taught how to teach until I got into these classes [method block]. Now I feel quite assured that I will know strategies and ways to deal with teaching that I had felt was really not touched on at all in previous content courses. (Interview, September)

> Molly:
> I would agree that I am okay with the science content, but how to teach it up until right now I am not at all confident. (Interview, September)

A Vision of an Appropriate Science Learning Environment For Elementary Students

The MCTP teacher candidates expressed a vision of an elementary science learning environment in alignment with the reform movement (student-centered and problem-based, with an emphasis on students' prior knowledge) that they believed was modeled by their MCTP science content professors. They also could contrast this reform-based vision with a traditional, lecture and textbook-based science content environment. The non-MCTP teacher candidates expressed dissatisfaction with a traditional learning environment based on teacher lecture but could not express an alternative vision of good teaching for elementary science students except for the increased use of labs involving equipment and manipulatives. Moreover, when they referred to using equipment and manipulatives, the non-MCTP teacher candidates did not indicate that they had developed a vision for how they would use these things or for what purpose.

MCTP Teacher Candidate Beliefs and Perceptions

Drawing on their recent undergraduate experience learning science content in MCTP classes, the MCTP teacher candidates expressed a well-developed vision of an elementary science learning with specific examples of their vision. The learning environment that they described included inquiry, cooperative learning, a concern for students prior knowledge, the teacher as a facilitator, and a commitment to achieving equity between males and females. Furthermore, they indicated they had developed personal theories/rationales for why these modes of learning are appropriate for young learners.

> Laura:
> I guess I kind of imagine a classroom setting with the students in groups of four or five; lots of manipulatives at least in the beginning part of the lesson, like an introduction to geometry with the cubes or something like that. And what I've learned, and am finding more and more important, is the discussion taking part in mathematics and science. That it helps the kids understand the concepts more clearly, and it also gives the teacher a chance to assess that way rather than as a quiz with multiplication tables and that kind of stuff. You can hear what they're talking about and see what kind of level they're at, so I definitely would like to emphasize discussion. "How did you get that answer?" Or if two people got the same answer but they did it differently, "Show how you did it," you know, more like a process than just having the right answer. (Interview, September)

Mark:
I guess I envision a classroom where the students are having so much fun and are so interested that they can't help but learn from each other, and share. I guess my ideal is, I'm somehow gonna be able to make that happen and make it so interesting that they'll want to know about probability, or division, or whatever it is. And I think by doing that, you allow the students to have fun with manipulatives, and interact with each other. I think of the way I am now. Just the way I learned science and mathematics, it was not the right way to apply it. It was more memorization and stuff. I hope to be able to keep that in my mind as I teach. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions

In the context of their recent undergraduate experiences of learning content in a lecture-based manner that they believed was inappropriate for young learners, the non-MCTP teacher candidates' alternative vision of good pedagogy for young learners was one based on instances of good teaching in their own K-12 educational histories or on brief field-based education experiences observing young students. These alternative visions were not thoroughly developed.

Lisa:
As an elementary student, I always liked the practical experiments. Like, when I was in second through fourth grade I didn't speak much English, and with the experiments and laboratory work, I'd learn through observing the lab, the experiment, the actual experiment. I couldn't read or understand, so I only learned through observation. (Interview, September)

Molly:
That the kids are using manipulatives, that they're actually doing the work. Often, now I see teachers writing on the board, and the children are copying. (Interview, September)

Rationale for and Intent to Make Connections Between Science and Mathematics in Elementary Teaching

The MCTP teacher candidates evidenced considerable reflection based on the firsthand MCTP experience of learning science and mathematics in a connected manner for a rationale making connections between science and mathematics. They intended to make extensive connections between the disciplines in their future practices. The non-MCTP teacher candidates were characterized by not having reflected on a rationale for making connections between the disciplines nor having experienced learning the disciplines in that manner except in cases where mathematics was used as a tool in science. They expressed a willingness to make connections between mathematics and science but based that connection solely on the use of mathematics as a tool. In addition, while both the MCTP and the non-MCTP groups seem to discuss mathematics as a tool for science when discussing what mathematics as a discipline brings to science, the MCTP group seems to recognize common processes of the disciplines (unlike non-MCTP group).

MCTP Teacher Candidate Beliefs and Perceptions

The MCTP teacher candidates' brought to their science methods course the ability to articulate a rationale for making connections between science and mathematics based on extensive prior experience of learning the disciplines in that manner. Through their MCTP experiences, they perceived mathematics and science to be so intrinsically connected that they had difficulty conceiving teaching them as separate subjects. Their rationale included the belief that both disciplines could contribute, and in the case of mathematics, assist the other, in developing a better holistic understanding of an area of interest. They professed a shared intent to make extensive connections between the two disciplines in their future teaching practices.

> Susan:
> Well, I pretty much think that mathematics and science are interconnected. I mean, if you think about the formulas in science, you're learning all that in math, also.(Interview, September)

> Katie:
> I think that one of the reasons Susan might think that and that I might think that, too, is just because we've been learning it that way, for the past 4 years (I know I have anyway). And so I say, "Oh yeah, math just fits in with science, and science just fits in with math naturally. How would they not?" And maybe some people don't see that and don't emphasize it. I don't know if it's something that we have to emphasize so much and try and make a point of doing it because we're just so used to doing it anyway, and it's just going to naturally kind of fit in. (Interview, September)

> Mary:
> I think mathematics and science can be connected largely by not calling it a math lesson or a science lesson. I think dealing with the topics and letting them flow into the different subjects sort of leads to an integration without forcing it. And questioning, open-ended questions, and probing questions that would lead them to kind of make those discoveries in their minds and draw their experiences from both together. I want to set up things so, like, if my units are more interdisciplinary, so then the connections, hopefully become obvious at least in a way that the kids are gonna feel like they can go home and say, "Mom, I did this today. This was math, but you know what? It was also science and it was really fun and important. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions

The non-MCTP teacher candidates brought to the science methods course a restricted rationale for making connections between mathematics and science. While they voiced a willingness toward attempting to make connections between science and mathematics, they based the connection fundamentally between science and mathematics on mathematics use as a tool in science.

> Margaret:
> Oh, this one I'll have to think about....I'm sure I could come up with lots of ways to tie them together, I just can't think of any right now. (Interview, September)

> Joseph:
> I think it is important to make connections between mathematics and science. . There's quite a large connection between the two of 'em. You can always figure out science properties by doing the experiment, but then its usually the math that's used to prove them.... Hopefully I'll learn how to connect mathematics and science this semester [during the methods block]. (Interview, September)

> Molly:
> Well, I think it would be easier to show the connections going from science to math for me. To show that how--I can't think of an example--but when they've done an experiment and they had to, like, say write the results down, and they've made a graph or something and then you can connect that to the math. (Interview, September)

The Role of Science Methods in Their Teacher Preparation Program

The MCTP teacher candidates brought to the science methods class an inclusive vision of teacher preparation program composed of a seamless linkage between their undergraduate content courses and their science methods course. As a result of being taught content in a manner that modeled good pedagogy, they had a vision of how they wanted to teach. However, they recognized that the science methods course was essential to teach them the skills and knowledge base to enact that vision of teaching. The non-MCTP teacher candidates brought to science methods a vision of content classes taught in a manner that they believed was inappropriate for young learners. They saw the science methods as their first opportunity to gain skills in teaching science appropriately.

MCTP Teacher Candidate Beliefs and Perceptions

The MCTP teacher candidates held the vision of science methods as performing an important next step role in their teacher preparation program by assisting them in enacting their vision of teaching content to young learners appropriately. They believed the primary purpose of science methods was to give them the opportunity to develop the strategies and knowledge necessary to create learning opportunities and environments similar to what they previously experienced in their MCTP content classes

> Susan:
> I'm hoping to actually learn how to tie everything together....We're gonna be learning about the different methods of teaching. That's what I'm hoping to gain from it. (Interview, September)

> Katie:
> I was thinking I would learn in science methods how I am going to use what I learned, take it to a classroom and fill up the day teaching what I know. What I will actually have to do to get across the things that I need to get across the students without having to tell them these things directly. (Interview, September)

Mark:
It's the preparation, getting lesson plans together, knowing where you're gonna go with it. I'm hoping to learn all of that... I guess in methods I'm hoping to learn planning and organization, and how to present the material and all of that lesson plan type thing. That's where we're stuck. (Interview, September)

Non- MCTP Teacher Candidate Beliefs and Perceptions

The non-MCTP teacher candidates saw the science methods course as their first opportunity in their undergraduate program to focus on the teaching of science to young learners in an effective and appropriate manner. They expressed interest in learning the strategies to teach science as if they were content independent.

Molly:
Oh, what I hope to gain in science methods is knowledge of the strategies to teach. This is the first time that they've come up. (Interview, September)

Lisa:
How to come up with questions to ask, because if I was just to give a lesson right now, I would not go too deep with the details to ask how would they get that. So I guess so far I've learned I need more to learn. (Interview, September)

Joseph:
Just the different strategies, the different ways of looking at certain topics which are associated with difficulties for children to learn certain topics. How to get around them, how to set them up with different features, and things like that. (Interview, September)

<u>Question 3</u>

To answer our third research question ("Are the MCTP teacher candidates distinguished from the non-MCTP teacher candidates in the beliefs and perceptions upon completion of the science methods course concerning a spectrum of issues)," we analyzed the data we collected throughout the semester. This included the end of the semester teacher candidate interview. Once again, what follows are assertions we generated from a careful analysis of the extensive data set we collected. For heuristic purposes, these assertions are presented in the order of the sub-sections of the third research question. Included in each are exemplar comments from the participants that support our assertions.

An Appropriate Science Learning Environment for Elementary Students

The MCTP teacher candidates thought young learners should learn science through inquiry characterized by being connected to other subjects and requiring active student participation. The non-MCTP teacher candidates expressed a vision of an appropriate learning environment for young students characterized as being teacher-centered with engaging hands-on activities.

MCTP Teacher Candidates

The MCTP teacher candidates believed that young students should learn science through inquiry characterized by the use of manipulatives, relevant to their lives, cooperative groups, and connected to other subjects.

> Mary:
> Okay. Providing experiences that the students can use hands-on manipulatives to kind of explore how they think about something and question their own ideas.... Well, for science I think that students should go through the inquiry process where they predict, and test, and then, you know, reflect and stuff at the end. (Interview, December)

Laura:
It could connect to other subjects. It makes it more authentic I guess.... I think that it's important not to just, you know, find your right answer or the wrong answer, maybe find out how it's applicable, or, you know, how it fits into their lives. (Interview, December)

Katie:
Okay. Well, hands-on, group work, teacher as facilitator and learning. (Interview, December)

Blanche:
Hands-on, minds on. (Interview, December)

Non-MCTP Teacher Candidates

The non-MCTP teacher candidates believed that young students should learn science in a hands-on manner in which the teacher played a prominent role as a demonstrator of activities.

Lisa:
I thinking, like, the hands-on things that that they actively engage the student in actually doing. (Interview, December)

Molly:
Hands on, minds on. (Interview, December)

<u>Extent to Which Their Science Methods Professor Modeled Good Teaching Of Science</u>

The MCTP teacher candidates were able to describe the teaching of their methods professor in a rich manner, which identified many teaching practices that they believed were effective. These practices included the use of small cooperative learning groups, student-centered activities, making connections between science and mathematics, and an emphasis on classroom discourse. His use of experimentation and on the personal construction of knowledge rather than on the memorization of facts were perceived as in alignment with the instruction they experienced in their MCTP science content classes. In contrast, the non-MCTP teacher candidates evaluated the science methods professor as modeling good teaching practices such as the use of student-centered activities but were not able to link his practices with previous science teachers they had experienced.

MCTP Teacher Candidates

The MCTP teacher candidates identified their MCTP science methods professor as modeling good teaching by the use of small cooperative groups, of engaging student-centered activities, of demonstrating various instructional strategies (including making connections between mathematics and science), of an emphasis placed on questioning and discussion, and a concern for creating a classroom environment characterized by respect for all. His focus on conducting experiments and discussing personal constructions rather than on memorization of facts were perceived as in alignment with the instruction they experienced in their MCTP science content classes.

> Mark:
> I'm thinking of one, using peer--small groups--peers, and we did a lot of that in his class, when we did our, you know, lesson plans and then our peers would evaluate it, and that was really good. (Interview, December)
>
> Mary:
> And also, like, the simulation type lessons--the ear and the pencil. You know, there were a lot of things that truly we could transfer into our classes and use and have, you know, confidence in how that's going to play out. I would also say the investigation, the

questioning, not being focused on the answer, and that maybe there are many answers to one question.
(Interview, December)

Non-MCTP Teacher Candidates

The non-MCTP teacher candidates identified their science methods professor as modeling good teaching by making class engaging through the use of activities and demonstrations in which he made them predict outcomes.

Molly:
We did incredible activities, yeah. He also did demonstrations. (Interview, December)

Margaret:
As he was doing demonstrations, he would, you know, have us think, "What's gonna happen next?" So we did a lot or prediction. It was fun. (Interview, December)

<u>Extent to Which They Observed Their Science Methods Professor Making Connections to Mathematics in his Teaching</u>

Both the MCTP teacher candidates and the other teacher candidates readily identified multiple instances in which the science methods professor sought to make connections between science and mathematics. The MCTP teacher candidates were distinguished in the greater number of instances which they identified as fulfilling this curricular innovation.

MCTP Teacher Candidates

The MCTP teacher candidates identified their science methods professor making connections between science and mathematics throughout the semester. They recognized that specific activities (including the MCTP module) were used by the professor to achieve that goal. They also identified the complete weekly lesson on making connections between science and other subjects as supporting this innovation. It was also recognized that he encouraged them to make connections with mathematics in all their class assignments.

> Laura:
> Well, with the ear lesson, that was kind of, it went hand and hand--math and science--and then he made connections to language arts with the...the (Oh, I can't think of it.)...the bus, the "Magic School Bus" book and, then the Science, Technology, and Society topic. ...We did the investigation with the ear. Oh, with our lessons we prepared in science methods we were encouraged to integrate mathematics. I now think that in so many aspects of science you are using math to either solve the problem or analyze the data or, you know, somehow relate it. (Interview, December)

> Susan:
> For Science Investigation I was permitted to integrate mathematics. I did area and circumference of a pizza. (Interview, December)

Non-MCTP Teacher Candidates

The non-MCTP teacher candidates recognized that their science methods professor sought to make connections between mathematics and science. They identified a few classroom activities that accomplished this innovation, including the MCTP module.

> Margaret:
> To what extent did he seek to make connections between science and mathematics ? I would say, like, all the time. For example, the bouncing balls where we had to count how many bounces from different heights. We made graphs. And he even asked how would we tie in the science activities he taught us with math or how could...if this was a math class, how could we tie it to a science? For example, when we talked about gravity. (Interview, December)

Molly:
That last ear thing we did, the ratios. (Interview, December)

The Rationale For And Intent To Make Connections Between Science And Mathematics In Elementary Teaching

The MCTP teacher candidates were distinguished from the non-MCTP teacher candidates in the advanced manner in which they could articulate a rationale for and intent to make connections between science and mathematics. The MCTP teacher candidates supported the curricular innovation to make connection between science and mathematics whenever it was appropriate in order to more accurately portray a holistic vision of knowledge. The non-MCTP teacher candidates were more wary of making connections between science and mathematics and more likely to portray mathematics as a tool when connections were attempted.

MCTP Teacher Candidates

The MCTP teacher candidates believed that the rationale for making connections between mathematics and science was to more accurately portray a holistic vision of knowledge. Through this portrayal of the world, a deeper understanding was possible. They expressed a commitment to extensively make connections between mathematics and science in their practices. They believed, however, that the two disciplines should only be connected when it was natural, or appropriate, in the context of a topic under study. They believed that mathematics could be connected to science more frequently, and appropriately, than science to mathematics.

Mark:
That's the way our world is. Science and mathematics aren't separate. It should be balanced and that they should be dependent on each other if it's possible. It's hard to do, but they really should be dependent, so you couldn't really do one without the other, or it would make it difficult to do one without the other. (Interview, December)

Mary:
And it kind of gives you, like, a well-rounded look at things, not from just one perspective or another, more well rounded. It should flow. It should kinda be, like, a subtle integration. I wouldn't say, "Okay. Here's the science part, now this kind of has something to do with it. Let's do some math." We had to do this unit for our reading methods class, and she wanted us to integrate, and she said, "Every lesson has to be integrated." And after eight or nine of them, you know, we were gettin' to the end of the wire. We were just forcing the stuff... So I think it has to kind of really flow and the science and mathematics have to be a real part of each other and not just forced. I think you should always try to because it just makes it that more meaningful, but if you can't, don't force it, you know. That might just turn students off. [In my future teaching] I think I will start off, maybe using some of the examples that we've been given in our classes, the kinds of lessons that they done, and then possibly moving, you know, more into it as I get more comfortable with it. (Interview, December)

Laura: Well, with the flow I think that making connections between science and mathematics needs to be meaningful...for it to be true integration, for it to be meaningful, it needs to be more into the content or the processes of that subject. I definitely like to make connections in my future teaching, but it's not as easy as it sounds, and I think it'll take a lot of more practice. (Interview, December)

Blanche:
For me, I would prefer to integrate science and mathematics naturally. I would put the connections in an introduction to a lesson. I mean, I do think that the students should be able to decipher between mathematics and science. (Interview, December)

Non-MCTP Teacher Candidates

The Non-MCTP teacher candidates believed that science and mathematics were connected by requiring the same sort of thinking processes. While they expressed support for making connections between mathematics and science, they were particularly hesitant to make what they perceived as inappropriate curricular connections. Examples provided by them on making connections between the disciplines portrayed mathematics as a tool in science.

> Molly:
> Mathematics and science use the same kind of thinking, I mean, use the same kind of thinking processes. However, they should only be integrated in those types of lessons where they reinforce each other. (Interview, December)

> Lisa:
> I think not all science lessons are gonna have some math in them, so if a teacher just throws the math in there, then it wouldn't be appropriate in all cases. This semester, I did a lesson in my field placement that connected mathematics and science. My cooperating teacher wanted me to think of a lesson which connects the two, the math and the science. So my lesson was on, taking the temperature during different times of the day to see when it would be hottest, and then they were supposed to look at the thermometer and know the difference in temperature, temperature trends. Like when was it the hottest.... But they do need some subtraction skills in order to do that, so...so my teacher wanted me to do it after she taught the subtraction lesson. (Interview, December)

Researcher Reflections

McGinnis

In my planning for this curricular innovation in teacher preparation, I based much of my thinking on an extensive literature review Roth-McDuffie and I conducted on making connections between science and mathematics. In particular, two areas were examined: professional associations' call for mathematics and science integration and theoreticians' conceptualization of mathematics and science integration. While I was heartened that professional associations had historically supported the MCTP's program's goal to make connections between mathematics and science in teacher preparation, I found scant intellectual guidance until I read Steen's (1994) theoretical piece. What follows for the reader's inspection is what I constructed Steen was promoting and what I found compatible with my personal notion of curricular connections.

Steen (1994) discusses possible ways to integrate mathematics and science. These methods include: (a) using mathematical methods in science; (b) using science examples and methods in math instruction; (c) teaching math entirely as a part of science; (d) teaching science entirely as a part of mathematics; (e) employing math methods in science and science methods in math, coordinating both subjects. Steen describes each of these options and uses this description to make the point that while mathematics and science can contribute to each other, the two disciplines are "fundamentally different enterprises" (p. 9). He states that "science seeks to understand nature, [and] mathematics reveals order and pattern" (p. 9). He concludes, therefore, that an effective educational program must teach students the ways not only in which mathematics and science are similar, but also the ways they are different. Steen questions whether it is possible "to teach an entire curriculum that integrates science and mathematics" (p. 10). He believes that it is not possible because science and mathematics teachers are not sufficiently prepared to understand mathematics and the multiple sciences within science (e.g., physics, biology, chemistry). To avoid this overwhelming constraint to successfully integrating mathematics and science, Steen suggests that instead of attempting to integrating content, practitioners should integrate instructional methodologies (e.g., exploratory, investigative, and discovery learning).

Taking Steen's suggestion as my organizational principle, I worked throughout the semester to make connections between science and mathematics by seeking linkages among instructional methodologies. I was pleased that from my observations throughout the semester of my teacher candidates in the course that my efforts were met with their approval. From the analysis of the teacher candidate interview data, I have learned that a one course concerted attempt to make connections between science and mathematics can result in positive outcomes. I also have learned that teacher candidates who come to the science methods with prior experience in learning science in a connected manner with mathematics are better able to conceptualize the innovation and to resist the tendency to portray the use of mathematics in science contexts simply as a tool. I am left, however, with the conviction that this form of innovation requires an extremely high level of planning and commitment on the methods professor's part to lessen the occurrence of teacher candidates constructing inappropriate visions of the use of mathematics in science contexts which may disturb mathematicians and mathematics educators. Therefore, while recommending continued explorations in this effort to make connections in teacher preparation between science and mathematics, I offer a cautionary note for science teacher educators to proceed in a manner that is informed by the concerns many mathematics (and science) educators hold in this endeavor.

Roth-McDuffie

At the end of the semester, Roth-McDuffie recorded her thoughts and perceptions about the teaching and learning in the course and the students' reactions to the course. In reflecting on the semester, Roth-McDuffie referred to her field notes to make some more global observations. First, Roth-McDuffie considered McGinnis' efforts to achieve his goal of making connections between mathematics and science in this science methods course. Roth-McDuffie wrote,

> Throughout the semester, I observed several instances of Dr. McGinnis making a deliberate effort to make connections between mathematics and science in his class. In planning his lessons, he thought about the mathematics involved in the lesson, [especially the mathematics] that might be taken for granted by a person with his level of expertise [as a scientist] (Field notes, 10/8/97). In addition, he directly discussed these connections with the students; rather than leaving it to the students to realize (or perhaps not realize) that connections were being made (Observation, 10/27/97). (Field notes, December)

The evidence seemed to indicate that McGinnis was achieving the goal of helping the teacher candidates to see the connections between mathematics and science. In interviewing the teacher candidates, Roth-McDuffie perceived that they all had developed a greater sense of the relationship between mathematics and science during the semester. Roth-McDuffie recorded the following observations,

> In teaching their own students, the teacher candidates [desire to] strive to make "natural connections" (Interview, Katie, 12/96) between mathematics and science without their students having to think about whether they are studying mathematics or science. Moreover, in preparing to teach this way, the teacher candidates seemed to benefit from

> opportunities to be aware of and to understand Dr. McGinnis's efforts to make connections. (field notes, December)

Roth-McDuffie also reflected on the extent to which others might achieve what McGinnis had achieved in his classroom, helping teacher candidates to understand the connections between mathematics and science (both in terms of content and pedagogy). Below are her reflections on this challenge:

> While we may endeavor to make "seamless" (a word used by faculty in the MCTP working sessions) connections between mathematics and science for the MCTP teacher candidates, the connections cannot necessarily be made without concerted effort on the part of the professors. Earlier research conducted by Watanabe and McGinnis (1996) showed that MCTP science professors tend to view mathematics only in term of how it serves their own discipline. Watanabe and McGinnis (1996) found that scientists tend to view mathematics as a tool for doing science. However, to achieve integration in teaching and to help teacher candidates see commonalties and connections between the disciplines of mathematics and science, science professors need to step outside of their own discipline and examine how one from mathematics might view the problem. This action requires thought and planning beyond saying, "I am going to have students graph the data to bring in some mathematics." As stated earlier, I observed this more preferable type of thought and planning in Dr. McGinnis's science methods course. However, based on the observations with the teacher candidates in the methods class, I caution anyone who is intending to attempt an integrated approach to a science methods course. Such a challenge should only be attempted when it can be made a priority (for the semester or even for a particular lesson). Without careful thought, the danger is that the connection made is only superficial and may result in reinforcing notions of mathematics only as a tool. In this study, the ideas that the MCTP students developed of mathematics and science being inextricably linked by common processes and approaches came about by a carefully conducted and highly focused teaching innovation. (field notes, December)

Parker

A year after the study, Parker (a doctoral level science education student who had two years experience with the MCTP) read a draft of the manuscript and gave the following reaction.

Having had the opportunity to teach in a variety of settings, I understand and have reflected upon the complexity of helping not only younger students, but also teacher candidates make connections between mathematics and science. Given the objectives of the Maryland Collaborative for Teacher Preparation and its attempt to create a seamless fusion of mathematics and science, the statements recorded by the Collaborative students are provocative, but I was not surprised by both the breadth and depth of the group's responses.

The teacher candidates' rationale for and intent to make connections between science and mathematics in elementary teaching is particularly thought provoking. In particular, the following two comments demonstrate to me how the MCTP's future teacher perceive the two disciplines as inextricably linked, not as separate entities to be taught within a vacuum.

> Susan:
> Well, I pretty much think that mathematics and science are interconnected. I mean, if you think about the formulas in science, you're learning all that in math, also.
>
> Katie:
> I think that one of the reasons Susan might think that and that I might think that, too, is just because we've been learning it that way, for the past 4 years (I know I have anyway). And so I say, "Oh yeah, math just fits in with science, and science just fits in with math naturally. How would they not?" And maybe some people don't see that and don't emphasize it. I don't know if it's something that we have to emphasize so much and try and make a point of doing it because we're just so used to doing it anyway, and it's just going to naturally kind of fit in.

As a science teacher educated in a large research university, I can reflect and characterize my first few years as teaching to that of the non-MCTP teacher candidates who were described as having not reflected on a rationale for making connections between the disciplines and who thought of math only as a tool for science. I have only recently come to recognize the common processes of the disciplines, a theme that permeates the words of the six students represented by this study.

The MCTP's continuum of education consisting of integrated, interactive content courses, methods courses taught by professors committed to an integrated approach, a unique capstone course supplemented by research internships have been well-represented by the participants comments. They understand the interrelationships between the various components and have integrated the MCTP's approach to present a seamless relationship between the two disciplines. I envy the future young members their classrooms.

Conclusion/Implications

In regard to McGinnis' goal of helping students understand the connections between mathematics and science, while he was quite successful in achieving this goal, we need to consider Steen's (1994) recommendations. While McGinnis' course did not promote the idea of mathematics only as a tool for doing science, the teacher candidates did not seem to view mathematics as more than this when discussing the *discipline* of mathematics. Referring back to Steen's notion that the two disciplines are "fundamentally different enterprises" (Steen, 1994, p.9), this finding serves as evidence that by viewing the disciplines from a connected perspective, a limited view of mathematics emerges. However, when discussing the *processes* as having not reflected on a rationale for making connections between the disciplines and who thought of math only as a tool for science. I have only recently come to recognize the common processes of the disciplines, a theme that permeates the words of the six students represented by this study.

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Conclusion/Implications

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When comparing the two groups of teacher candidates, at the beginning of the semester, we see fairly stark contrasts in their beliefs and perceptions about their preparedness to teach, their vision of an effective learning environment, and their understanding of connections between mathematics and science. Quite predictably, the MCTP teacher candidates had beliefs and perceptions that were consistent with their experiences in the MCTP program, while the non-MCTP candidate relied on more traditional, lecture-based preparation.

However, at the end of the semester, after sharing the common experience of being in a science methods course which was based on MCTP goals, both groups expressed similar ideas on the above issues. The difference at the end of the semester was not in the basic terminology used or the fundamental ideas expressed, but rather, in the depth and sophistication of understanding conveyed in the responses. Consistently, the MCTP teacher candidates offered responses that were more developed in the way they explained their ideas, and they provided more specific examples of their thinking as compared to the non-MCTP candidates. With a background of more experiences in this type of learning environment and with more opportunities to reflect on their thinking and learning (and the implications for their own teaching), the MCTP students articulated a well developed philosophy of teaching science. Whereas, the non-MCTP students just had begun this process.

This finding indicates that this one-semester course was enough to affect the beliefs and perceptions of both groups of teacher candidates. However, the impact was not enough to allow the non-MCTP teacher candidates to "catch up" to the MCTP teacher candidates in developing a carefully thought-out philosophy of teaching and learning. The question remains as to whether either group has been affected enough to bring about reform-based teaching in their future classroom practices.

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"R-BEST" RATIONALE FOR TEACHING ELEMENTARY SCIENCE: A STUDY OF FIRST YEAR TEACHERS' PERSPECTIVES ON THEIR PERSONAL RESEARCH-BASED ELEMENTARY SCIENCE TEACHING RATIONALE

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Every day elementary teachers must make thousands of decisions about their teaching practices. From whom should they first seek a response? Who should be asked the next question? Will the students be in groups for this activity or go it alone? The decisions are endless. These kinds of decisions become easier with experience. But, what are the beliefs and subsequent choices of novice teachers?

What does science teaching look like in first year elementary teachers' classrooms? More importantly, what do these teachers believe students should experience during science time? While few would argue that a main goal for an elementary pre-service teaching program includes attempting to prepare students to be effective elementary science teachers, many would argue about the most appropriate ways of getting them there (Tillotson and Yager, in press, Penick, 1988). The National Science Education Standards (NRC, 1996) also make it clear that teachers must have theoretical as well as practical knowledge and abilities about science, learning, and science teaching. How they gain this knowledge and skills is certainly debatable.

While many science educators have clear visions of strategies teachers should employ in science classrooms, the reality does not always match their vision. Teaching beliefs and actual practice have been shown to be dissimilar or not always congruent. Gee and Gabel (1996), for instance, discuss the mismatch between what teachers say they do and what is really observed in the first year classroom. These authors found that only one of four participants surveyed was actually doing the inquiry teaching and learning that was being professed by all. As a means to bring perceptions of reality and actual practice, Clough (1992) discusses the need to value the importance of science education research to inform actual practice. While Clough argues at the secondary level of science instruction, research-based methods could also impact and influence elementary teacher actions. It could be then be logically argued that students might ultimately experience a greater amount of appropriate science instruction in their elementary classrooms provided their teachers have a sound rationale for teaching science.

Given a well-known negative tendency toward science, what do elementary teachers know about, believe in, or feel comfortable with when it comes to what and how they teach science? Will they believe they should teach science as they were taught in a lecture course or adopt teaching strategies which are acceptable in the new school where they were just hired? Elementary teachers have long been included among teachers that classically have a disinterest in science and in teaching science. One source for this disinterest can be attributed to courses they experienced in high school (Watters and Ginns, 1995). And, traditional lecture-format science classes new teachers might have experienced in college may help strengthen negative perceptions.

Whereas high school teachers are typically responsible for teaching a single discipline, elementary teachers have a wide array of subjects to teach. How they teach these various subjects is certainly a complex endeavor. Despite the complexities, the reality is that the actions that teachers exhibit in their classrooms ultimately have profound impacts on the kind of learning that their students experience. Raizen (1994) for instance, discusses teaching processes, actions, or attributes of effective teachers of elementary science. She states the effective factors for teaching include being highly motivated and enthusiastic. How or where do new teachers acquire these attributes? Some researchers say that having a sound background in research-based methodology is the way to better science teaching (Penick, 1988, Clough, 1992, Clough and Berg, 1997, Tillotson and Yager, in press, Veronesi, 1998). Specifically, these authors conclude that developing a research-based rationale for teaching science provides a key influence in the professional development of pre-service teachers.

Literature indicates that Penick (1988) originated the discussion of the development of a science teaching rationale as a necessary prerequisite for a beginning science teacher. Clough (1992) furthered the concept of the rationale. Penick argued that beginning teachers who develop a research-based rationale for teaching science are better prepared to self-evaluate. And, having this ability seems to be very closely related to the art of being a reflective practitioner. In short, teachers have the opportunity to compare the model of teaching science they outlined in their rationale to the teacher they have become at any point in time. Penick also asserted that teachers who have a goal-centered research-based rationale for teaching science will more likely stay in tune with science education reform and examine how their teaching should be modified to reflect this new knowledge.

What is "Best" Teaching?

John Penick and Bob Yager (1993) discuss exemplary practices or teacher characteristics of the best in teaching that include:

- Providing a stimulating and accepting environment.
- Having high expectations of themselves and their students.
- Challenging students beyond ordinary school tasks.

- Being models of active inquiry.
- Not viewing classroom walls as a boundary.
- Using societal issues as a focus.
- Being extremely flexible in their time, schedule, curriculum expectation, and views of themselves
- Providing systematically for feelings, reflections, and assessments.
- Requiring considerable student self- assessment.
- Expecting students to question facts, teachers, authority, and knowledge.
- Stressing scientific literacy.
- Wanting students to apply knowledge
- Seeking science excellence.

Since these characteristics are said to be exemplary, they can be used in various ways as the core of a new teacher's rationale. And, while these seem to be what science educators would consider to be traits of high quality teaching and learning, it might be challenging for any single individual to possess all of these traits at all times. Surely, some individuals would be stronger at one trait over another and these strengths would vary over time.

Methods courses are a logical place for teacher candidates to acquire skills and attitudes that relate to the list of exemplary characteristics. Therefore, it was hoped that having teacher candidates write and defend their own elementary science teaching rationale during their methods course would provide support to them as they became new teachers who would be growing toward the exemplary traits outlined by Penick and Yager (1993). Since one of the roles of science methods instructors is to have an impact on their students, having teacher candidates in science methods courses can be a powerful way of creating a positive impact on new teachers.

Science educators have long suggested many different research-based methodologies or ideas for teaching science. Methods such as cooperative learning (Ellis and Whalen, 1992) or the use of questions (Penick et. al. 1996) are thought to be more efficient for increased learning in science than direct instruction. Whether implicitly or explicitly stated, these teaching approaches are grounded in research on teaching and learning.

Arguably, elementary teachers have the most difficult job incorporating research-based methods for teaching, especially science. They must address and teach the entire range of subject areas including math, science, social studies, and language arts. A need to feel knowledgeable in the subject content areas takes priority over learning about the most appropriate research-based pedagogy. Ultimately, the teaching strategies they use for the various subjects are influenced by a myriad of factors. These can include prior knowledge from methods courses, what is acceptable practice in the school where they are now teaching, what they believe to be right based on what has worked thus far, or their own experiences as students.

Beginning teachers' beliefs about their efficacy and their use of sound teaching methods are fragile (Soodak and Podell, 1997) and are formed prior to any methods instruction (Cronin-Jones and Shaw, 1992). Teacher candidates often ask themselves, What are the best ways for me to be teaching this material? Who should I believe? Or, What is right? The development of the research-based teaching rationale could aid in the answers to these questions about effective teaching strategies and attributes (Penick, 1988, Clough, 1992). However, while these suggestions seem logical, little evidence can be found in the literature regarding the impact of an elementary science teaching rationale on novice or beginning teachers (Veronesi, 1998).

Teachers who feel effective are able to pay more attention to academic instruction. While there are teacher attributes associated with teacher efficacy, little is known about the interactive processes that lead to and support teacher efficacy. Soodak and Podell (1997) suggest that many elementary teachers lose their confidence during their first year in the classroom. Yet, they suggest this confidence loss may be lessened if teachers are better prepared to enter the profession. Others have suggested that reducing the level of expectation for knowing the science content knowledge (Cox and Carpenter 1989) can also increase confidence. These authors suggest that a focus on the nature of science, process skills, and integrated teaching methods will increase the confidence of new teachers.

History

The developmental process of reflecting on and writing a science teaching rationale is one strategy that can address the concern of lower confidence. What impact does the process of writing and defending a rationale have on beginning teachers? The intent of the rationale paper used in an elementary science methods course was to help beginning elementary teachers strengthen their confidence toward science instruction. This pilot study begins discourse on a longitudinal research project in science teacher education to develop an effective strategy, which supports new elementary teachers' science instruction.

Teacher candidates enrolled in a science methods class during the fall of 1996 were assigned to write and orally defend a Research-Based Elementary Science Teaching Rationale for teaching science in their future classrooms (See Appendix). Students were given the first two months of the semester to draft an initial paper for mid-term, get instructor feedback, rewrite and resubmit, then finally orally defend their rationales. The rationale included their goals for their students' learning about science or how the world works and a personal vision of how learning should look in their classrooms. However, the primary focus of their papers included specifying the methods they would employ in their science teaching.

Each teaching action they envisioned as an alternative was to be based on relevant research. For example, if one of their goals for their students' science learning was to have students communicate their evidence to other group members, they might cite cooperative learning as a research-based means of realizing their goal. Whenever the teacher candidates referred to a teacher action, they were to show evidence of its learning effectiveness in the literature.

Various teaching and learning strategies for science teaching were modeled for students in their methods course. Each model (learning cycle, inquiry, open-ended questioning, wait-time, etc.) was research-based and the teacher candidates were free to choose those strategies that best fit their goals for their students. Some topics that received a great deal of perusal included constructivism, inquiry, questioning, Science, Technology, and Society (STS), cooperative learning, and alternative and performance assessment.

The final evaluation of their understanding of teaching elementary science came in a fifteen-minute oral defense of their rationale during finals week. Students were assessed on their completeness of thought and how well they had incorporated research-based methods into their explanations (Rubric in Appendix). As with any assessment, the quality of explanation ranged from very strong and articulate with substance to very weak, inarticulate with little knowledge of any research-based literature. The teacher candidates graduated the following May (1997) and began their job searches.

The Survey Procedure

Since this study sought to obtain the thoughts and attitudes of past methods students toward their *R-BEST* Rationale, it is mainly qualitative in nature (Interview Schedule in Appendix). Qualitative research can provide a very thick (Geertz, 1973), rich, and detailed description if it originates from the participants. Respondents were carefully chosen for this study rather than at random so that the greatest amount of data could be obtained. Selecting the respondents in this manner can be viewed as "purposive" as described by Chein (1981) or as "purposeful" by Patton (1980). Merriam (1988) further describes purposive sampling as being a way to discover and understand phenomena from a source known to provide the best possible information.

Eighteen months after writing and defending their *R-BEST* Rationale these new teachers were contacted by telephone. While telephone interviews have limitations some have found a fair amount of success with them (Conklin, 1997, Ouimet and Hanson, 1997). However, Conklin (1997) points out that telephone interviews are one of the most dominant and popular survey techniques today. As with any survey technique, obtaining quality data is of utmost importance. One way of increasing the integrity of the data obtained by using the telephone comes from creating a quality survey and training an interviewer (Suskie, 1992). The survey used for these interviews is located in the appendix and the graduate student who performed the interviews was trained in asking the initial questions and follow-up probing questions.

Respondents for this study were asked a series of open-ended questions to determine the impact of their elementary science teaching rationale that was written almost two years earlier. The interview schedule was designed to first provide the researchers a window into the classroom science experiences of the students being taught by these first-year teachers. As each interview proceeded, questions became more focused on the *R-BEST* Rationale and its impact on their current teaching of science. As the Table 1 demonstrates, out of 35 possible respondents, the eleven that were contacted and currently teaching were all willing to participate in the study.

Table 1
Number of Teacher Candidates and
Potential Participant Status: fall 1996 (n=35)

1. Individuals who had a teaching position for 1997-98 school year, had the opportunity/expectation to teach elementary science, and were amenable to a phone interview. In short *the study participants*. **n=11**

2. Wrong numbers, did not return calls after three attempts (answering machines), no forwarding number, no answers. There is currently no data available on these individuals. **n=10**

3. Was on a team and did not teach a science component. **n=1**

4. Were not employed as teachers as of fall 1997. However, five of these individuals obtained teaching positions for the 1998-1999 school year and will be involved in a similar study in 1999. **n=13**

Results

Each of the following participant quotes was chosen as representative for the majority of responses. While a few teachers expressed frustration in their perceptions of teaching science, the researchers felt that most of these comments resulted from pressures within a particular district. In one instance, frustrations in teaching science were caused as a result of the focus on the teaching of reading. Following are some comments intended to let the reader understand what these new teachers thought. While each respondent was known at the time of the interview solely by the graduate student interviewer, they were indeed anonymous as this paper was drafted. Each of the eleven respondents was tracked with a number that will be indicated prior to quotes. As was suggested by Suskie (1992), initial questions should invite the respondent into a conversation in a non-threatening manner.

When asked how much time their students experienced science, most respondents indicated that they taught science nearly every day of the year:

#9: "I teach science at least one hour a day every day of the week."

Respondents were then asked to report on what they recalled as their students' most memorable experiences in science that past year. Interestingly, each had a different example of student involvement in science and showed that multiple science content areas were indeed being covered at the various grade levels:

#3: "The unit on crayfish and natural surroundings was most memorable. As a culminating activity, we went to Ellison Park to catch our own crayfish. We observed them for a day and then let them go."

#7 "The dinosaurs unit was my students' most favorite unit. They made fossils and pretended they were paleontologists!"

#9: "We made volcanoes from scratch! Students were very involved because it was so much a hands-on experience for them. This was a topic that they were all interested in."

As questions continued on the interview schedule, there was an increasing emphasis on the *R-BEST* Rationale and things that informed their elementary science instruction. As with the initial paper, these teachers were asked about their current goals for their student's science learning:

#4: "For my students, to have a greater sense of their surroundings and to take greater notice when they are out in their environment."

#6: To enjoy and be interested in what they are doing. I learn along with my students. When my students see me interested in something they become more interested. My students learned a lot during science last year because they were interested in it. We had a good learning environment. There were a lot of conversations that would arise from our discussions. My students kept asking and learning more information all the time."

#10: I want my students to question everything. I would like them to ask why things happen the way they do and search and find out the answers. To be able to solve problems on their own."

Respondents were then asked to reflect back to their methods class and detail what they felt and thought about their instructor's goal for the *R-BEST* Rationale. In short, what did they think his goals were in assigning the *R-BEST* Rationale?

#1 "So we could look at ourselves. To set goals for ourselves for when we became teachers, and that the goals would already be in place."

#2: "To drive me crazy! But really, to make us more aware of science and how we feel about it so that we could put our goals into perspective. It was a soul searching experience and it made me think about teaching."

#5: "[The instructor] wanted us to be more comfortable with science. He wanted us to learn the important aspects of science [and teaching science] such as questioning and wait-time. He also wanted us to overcome our fears of science so we could teach it in our classrooms."

#6: "[The instructor] wanted us to dig deep within ourselves to see what direction we wanted to go as teachers. He wanted us to think about what kind of teacher that we wanted to be and to see if we were capable of being that kind of teacher. [The instructor] wanted us to be more student-oriented. I think now that kids learn through their experiences. Teachers should use everything in our environment to teach students. Teachers need to make things real for their students."

Conversely, one of the eleven respondents saw the exercise of writing and defending the *R-BEST* Rationale as a lesson in busy work- a waste of time.

Discussion

Results of this pilot study merit continued research on the impact of a science teaching rationale for elementary pre-service teacher candidates. The overwhelming views of the eleven respondents in this study, who obtained teaching positions immediately after graduation, clearly indicated that thinking about, writing, and then defending their *R-BEST* Rationale had a powerful impact on how they viewed and taught science in their first year of teaching. While one respondent felt that writing the *R-BEST* Rationale was mostly busy work, those who felt very positively about the experience were able to articulate the impact it had on their beliefs as a teacher in terms of science instruction.

It seems logical then, that some connection to teacher growth, reflection, and confidence in teaching elementary science may be attributed to the process of writing and defending the rationale paper. While an argument could be made that the lengthy telephone interview about science teaching, almost two years after the class, might be cause enough for individuals to provide more positive answers, the respondents were able to individually articulate clear and positive responses to questions about teaching elementary science. This could also be indication that long-term learning about teaching science did occur in ways suggested in the literature and was being acted upon in the first year of teaching.

Tillotson and Yager (in press) conducted research with new teachers in the area of secondary science education. These researchers found positive attributes for individuals writing a science teaching rationale. While focused on secondary science teaching, it does suggest that teacher candidates writing a research-based rationale might also strengthen effective science teaching at the elementary level. Interestingly, the preliminary results of this current study indicate that those students who successfully developed and defended their own *R-BEST* Rationale and obtained a teaching position were indeed teaching science to varying degrees. National trends of science avoidance in the elementary grades suggest that any science instruction at all would be an improvement. While these self-reports must be validated with observations, photo copies of lesson plans, student assessments, and videotapes, these newly hired teachers stated very lofty and inspiring goals for teaching their students science. Most did so with thoughtful enthusiasm.

A few respondents indicated that they would revisit their *R-BEST* Rationales to see how their current thinking compares to their initial statements. Two new teachers who were interested in changing their current teaching position indicated the intent to reflect on their *R-BEST* Rationale prior to interviewing for a new position. They now seemed to realize the importance of being clear, scholarly, and articulate about teaching elementary science, especially during a job interview.

This study does not imply cause/effect relationship between the process of crafting a *R-BEST* Rationale and teachers' actual practice. However, there is support for further research on this type of assessment for use in elementary science methods courses. When John Penick (1988) initially discussed the need for a similar document for secondary science teacher candidates he asserted that that a methods class without a science teaching rationale was missing a vital component. Reports from teacher educators in secondary science teacher education (Penick, 1988, Clough and Berg, 1997, Veronesi, 1998, Tillotson and Yager, in press,) provide a logical argument for new elementary teachers to have their own *R-BEST* Rationale.

Perhaps it is time to consider an *R-BEST* Rationale as a form of assessment for elementary science methods courses. Expecting students to write and orally defend their thinking on research-based elementary science teaching prior to employment offers a way for new teachers to begin the habit of reflection about research-based methods of teaching elementary science. A rationale acts as a vessel that takes teacher candidates into the scholarly pedagogical research that they can use in a practical way (Clough, 1992). Ultimately, this may encourage and support new teachers' efforts to have their students learn about science and to continue their own reflections on how teaching and learning of science should exist in their own newly acquired elementary classrooms.

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Appendix

Interview Schedule

1. I'd like you to please describe a typical day or week's general schedule in your classroom. That is, what subjects or classes did your students experience in general from hour to hour during a typical day last year?

2. Describe some of the most memorable kinds of **experiences** your students had with science this past year with you?

3. What would you say are **your goals for your students** when it comes to their learning of science?

4. What factors determine the goals you set for your students when it comes to them learning science?

5. How comfortable are you at this point in teaching elementary science?

6. What have you found to be **easiest** for you with regards to teaching elementary science?

7. What have you found to be the **most difficult** for you with regards to teaching elementary science?

8. Now I would like you to think back about some of your learning at Brockport. During that time you were assigned to write and defend your own *personal Research-Based Elementary Science Teaching (R-BEST) Rationale* for your future teaching of elementary science. What do you think the instructor's **goals** were for you in writing and defending *your own* elementary science teaching rationale?

9. Where or how did you obtain the ideas to write your rationale paper?

10. What were your feelings during the time your were writing your elementary science teaching rationale?

11. How might your elementary science teaching rationale have influenced your student teaching and your cooperative teacher?

12. What positive aspects came out of writing and defending your science rationale paper?

13. What purpose might your science teaching rationale have served when you were looking for a job?

14. How closely did what you wrote as your "*vision of teaching elementary science*" in your rationale paper match what you experienced in teaching science to your students this past year?

15. What relationships would you cite as examples **between what your students actually did** and what you wrote in your science teaching rationale?

16. Now that you have finished your first year (or wherever they are in their career), what role will/did your rationale play in your science teaching? That is, in what subtle or overt ways have you used or will use the ideas from your elementary science rationale?

17. How might your science teaching rationale serve to defend your techniques or methods of teaching elementary science if you had to explain any new science teaching ideas that you were trying employ in your classroom- Let's say to administrators or parents?

18. As a teacher with one-year experience, given the task to write and defend another elementary science teaching rationale, what would you now include in it to make it most relevant for your science teaching at this point?

19. After having experience with students, how do you now view the effort you invested in writing and defending your rationale paper?

20. What advice would you offer to a new pre-service teacher in the elementary science methods class who is getting ready to write their own elementary science teaching rationale?

21. Now that you are going to begin your second year of teaching, (or wherever they are) how might some of the ideas in your rationale paper be used in your next year?

22. If the instructor's main goal for writing and defending a personal R-BEST Rationale paper was to get pre-service teachers thinking about teaching science with research-based methods or ideas when they began teaching, what would you suggest to make the elementary science teaching rationale and its oral defense more meaningful for pre-service teachers?

Each respondent was asked each question in the same order. When respondents were vague, the interviewer attempted to ask further probing questions for clarification.

Research-Based Elementary Science Teaching Rationale: A Vision of Research-Based Elementary Science Teaching Methodologies in My Future Classroom

Good teaching is no accident. It is not done simply willy-nilly, nor on the basis of one's personal feelings of what is right and what is wrong.

Expectations

Research has shown that real learning or greater understanding about the universe occurs when the teaching of science occurs by acceptable methods. These methods require a teacher to know and truly understand a great deal in terms of research-based pedagogy as well as the nature of the scientific enterprise (namely questioning, curiosity, testability, repeatability, and communication with peers). Good elementary science teaching is not a product of someone simply "thinking" one way of teaching is better than another. On the contrary, there are sound teaching strategies that have been researched over the years and have been found to be better than others in creating real science learning situations for students. That said…

Your challenge is to determine which teaching strategies best fit your science goals for your future students and write a teaching rationale that is first person, double-spaced, 12 Times/Roman font, and <= 5 pages in length.

Your elementary science teaching rationale should be succinct and personalized, yet still reflect suggestions from various literature sources so that you can defend what you have written during finals week in a 10 to 15 minute individual exit interview with Dr. Veronesi. Your rationale will contain at least ten different citations from authors suggesting better ways of teaching science. (e.g. cooperative learning strategies = Johnson and Johnson, Mary Budd Rowe = wait-time I and II during questioning of students). ERIC and other periodicals such as the Journal of Science Teacher Education, The Journal of Research in Science Teaching, Science and Children, Science Scope are excellent sources for articles and easily found via computer terminal. The Internet can now be accessed as well. The document itself is only half the task. Your knowledge about what you write about is the other. Know the research you discuss well enough to talk about in your exit interview.

Ultimately, your rationale paper should read as a smoothly flowing document. The reader (me, a principal, a parent, etc.) must be able to understand it. That is, get a clear picture of what would be seen in your classroom when students are "doing" science. Your research support should indicate you have learned something of an academic or scholarly nature (your reading of articles) this semester and should link your goals and actions together with what you have found in the literature. You should address your knowledge of good teaching from various literature sources and how you plan to "get there" in a practical sense. A time will be scheduled for you to discuss and defend your paper at the close of the semester. Therefore, you should believe what you write.

Your elementary science teaching rationale will certainly evolve as your experiences increase. However, when you leave Brockport, you will have a research-based plan for what happens in your classroom. Keep in mind that YOUR ELEMENTARY SCIENCE TEACHING RATIONALE SHOULD REFLECT YOUR GOALS FOR YOUR STUDENTS.

Rationale papers from former students are in the reference department of the library on hold under: EDI 416/516 Science Rationale.

Rationale Rubric

Criteria in this rubric must be addressed in your personal science rationale:

After you have re-read your drafts several times, use this checklist to make sure you have addressed all these criteria:

1._____What your goals for your students are. Number each and place them at the top of your first page.
2._____What the National or NY State science standards discuss about teaching science and why science should be taught at the elementary level.
3._____What **specific actions** you would like your students to be doing while they are involved in a science lesson as a result of your teaching. (You must be specific and cite actions, behaviors, etc.)
4._____How these student actions might lead to fruition of your goals for them.
5._____What you as the teacher will be seen doing in your classroom to accomplish your goals (be specific!) Try phrases such as, "In my classroom, you will see…" or "What I would like to do in my classroom as a result of what I have read is…" etc. Whichever you choose, the reader must be able to envision ***your*** actions in ***your*** classroom and *reasonably* determine that they result in the interactions you desire and that which is desired from the literature you find.
6._____How your actions might enhance student attainment of your goals and the science learning they will experience (Cite the research here): For instance: *"When I question students I will expect a response and will wait an appropriate amount of time as suggested by Rowe (1981). Doing so gives the students time to think and respond with greater confidence."*
7._____How you will decide on what science content to involve students in.
8._____How you and other researchers see science as integrated with other curricular areas.
9._____The various ways you will assess student attainment of your goals or the science lessons you teach (Cite the research here also).
10._____How you plan to reflect upon your own teaching.
11._____A list of your references following a format similar to the one below:

Rowe, M. B. (1991). Assessment implications of the new science curricula. In: Kulm, G. Ed. and Malcom, S. (Eds.) *Science Assessment in the Service of Reform.* AAAS, Washington D.C.

1. **Due: First draft of rationale paper, October 26th.**
2. **Due: Final of rationale paper due December 4th.**
3. **Exit Interviews are during finals week.**

CARING TEACHERS: ADOLESCENTS' PERSPECTIVES

Maria M. Ferreira, Wayne State University

Introduction

Interviewer: So how do you know if the teachers care for you?

Susan: I don't know if they do or not!... When I was pregnant, they [my teachers] said they would care for me. One of them came to the delivery room... So I knew that *one* of them cared for me. But the other ones, they just sent me a big ol' card and some balloons and stuff.

Interviewer: That wasn't enough?

Susan: That wasn't enough for me.

Eighth grader Susan's story illustrates the complexity of the issues surrounding any study of the concept of caring. Clearly illustrated in her story is the issue of perspective. Many might say that teachers who send cards and balloons to a student in the hospital are showing caring. It is the conventional caring activity in the situation. Many might, indeed, be surprised that teachers who see as many as 140-160 students a day might take the time for such an effort for one student. Indeed, although sending things to a person in the hospital is not unusual, it might be considered special for busy teachers to be so involved with one student. Thus, as one observer of the situation, one might give the teachers a high score for caring. Then we ask Susan.

From her perspective the story takes a different twist. Caring to Susan was more than an action. Caring was defined by the relationship in which the action was embedded. The broader picture from Susan's perspective includes a promise by the teachers to "care" for her. Clearly, caring to Susan meant more than a card and balloons. It meant being there – physically. Either Susan's meaning of caring was not an interpretation shared by both parties or if it were shared at one time, the interpretation changed by the time Susan went into the hospital. The one teacher who cared, by Susan's definition, was the one who came to the delivery room. From this illustration, searches into the meaning of caring cannot be satisfied by looking solely at individual acts, but at the perspectives of the people involved in the caring relationships in which specific caring acts exist.

Noddings (1992) posits that caring is a receptivity to the needs of others. Likewise, James Beane (1990) contends that,

> To *care* about others means that we attempt to see beyond the "desirability" (in our terms) of particular feelings or aspirations and to understand how particular people came to want what they want, to be who they are, and to behave as they do. It also means that we are concerned about their sense of well-being and our part in maintaining or improving it. When we care about others, we do not simply act for people (or their behalf) as "objects" of our care, but also *with* them as mutual "subjects" in the human experience. (p. 62)

The missing voice in much of the conversation about caring in education is that of the students. What do young people see as caring in others? To be able to develop a caring community, students' perspectives must be considered.

Theoretical Framework

Teachers represent the main connection between the students and parents. They have an enormous impact on how the philosophy of the school is translated and communicated to these two groups of constituents. Teachers are also the intermediaries between the institution and the students. Yet, because of their sheer numbers in their institution, they are also part of the institution. Thus, how students perceive their teachers as caring or non-caring has a direct impact on how students perceive the culture of the school.

Thayer-Bacon and Bacon (1996) identify characteristics of a caring instructor in three categories. The first category focuses on content and curriculum. A second category focuses on teaching style, and a third category focuses on personal relationships. For example, Thayer-Bacon and Bacon describe a caring teacher as someone who "acknowledges, rather than ignores, what goes on outside of the classroom as being relevant for student learning" (p.260).

Hayes, Ryan, and Zseller (1993) studied sixth and eighth grade students' perceptions of a caring teacher and identified behaviors that were regularly perceived as caring: (a) provider of fun and humor, (b) helpful with academic work, (c) encourages trust and positive feelings, (d) interested in a student as a person, (e) provides a good subject content, (f) willing to counsel with students, and (g) responsive to the individual outside the classroom. Others found that caring teachers foster relationships at four levels: teacher-student, student-student, teacher-content, and teacher-student-content (Sickle & Spector, 1996).

Caring has also been found to be related to students' outcomes. Noblit and Rogers (1992) found from their observations of fourth-grade classrooms that caring created possibilities for "learning to read, feeling better about yourself through recognizing your capabilities, and learning how to work and play with others" (p. 11). In a longitudinal study of middle school students, Wentzel (1997) found that caring, as perceived by students, "was related significantly and positively to students' pursuit of prosocial and social responsibility goals and to students' academic effort" (p. 414). In their study of English secondary schools, Rutter and his colleagues (1979) found a number of factors, which one could label as *caring,* that influence student outcomes. These researches found that behavior was better in schools where teachers were available to students for consulting about problems. A more recent study found that students' sense of school as a community was negatively related to drug use, delinquency, and victimization (Battistich & Hom, 1997).

Students' perceptions of caring are also related to the way they evaluate their teachers, the content, and the extent to which they feel they have learned (Teven & McCroskey, 1996). In a study of exemplary junior high schools, Pink (1987) found that the reason students considered a school "exemplar" was that teachers really cared about students, gave everyone help, and were always there when students needed them.

To further understand students' perceptions of caring and particularly in the classroom context, we asked middle school students to describe a caring teacher. Our interest was in identifying teachers' attitudes and behaviors that students interpreted as caring.

Methods

Setting

The study took place in two middle schools in a Midwestern metropolitan area. One school was located in the heart of a major city and is identified as Urban Junior High School. The other school was located in a suburb of the same city and is identified as Suburban Middle School.

Urban drew its seventh- and eighth-grade students mainly from the neighborhood around it, though some students were bused from other sections of the city. The local neighborhood was one of poverty (90% or more of Urban's 800 students qualified for free or reduced-cost lunches), and it had one of the highest crime rates in the city. The racial mix was 51% African American and 48% European American. Other ethnic groups, such as Hispanics and Asians, were enrolled in very small numbers. At the time of the study, Urban had not passed state standards and was on state probation.

The neighborhoods that fed into Suburban can be described as in transition, with about 30% of the student population moving in and out every year. Although its families represented a wide range of socioeconomic backgrounds, they mainly consisted of blue-collar workers who were employed in business and commercial enterprises in the local area or in the city itself.

As the only middle school in the district, Suburban had 1,200 students in grades six, seven, and eight. Of those, 12% were African Americans bused in from a poor urban neighborhood as the result of a court-ordered desegregation plan. Another 8% of the students were Appalachian Caucasians from the poorest part of the county.

Participants

The participants consisted of 101 students in five academic teams -- three at the Suburban school, one at each grade level (sixth, seventh, and eighth) and two at the Urban school (seventh and eighth). Of these, 55 were female (36 European American, 18 African American, and 1 Hispanic) and 46 male (33 European American, 12 African American, and 1 Asian). The selection of the participants was based on teacher and peer nominations.

Procedure

All students in the five academic teams received a form that asked them to define caring and to nominate the five most caring peers in their team. The teacher nomination form asked teachers to define caring, nominate the five most caring students and the five most uncaring students in their team. The peer nominations were tallied into four groups: ten or more nominations, 5-9 nominations, 1-4 nominations, and no nominations. We used peer and teacher nominations to compile a list of students to interview in each team and school. Because we wanted a representative sample, we chose names from the four peer nomination groups, as well as some that had been nominated by teachers as least caring. We also tried to select a racially and gender balanced sample.

Data Collection and Analysis

Data were collected through taped interviews with each individual student. The interviews lasted between 30-40 minutes and involved questions regarding the following areas: definition of caring; how does one care for oneself, good friends and family, people in school, strangers; what are the barriers to caring for self, good friends and family, people in school, strangers; and description of a caring teacher.

Data analysis involved standard methodology in naturalistic inquiry (Guba & Lincoln, 1985). After the interview tapes were transcribed, individual descriptors to each question were transferred to 8 inch by 5inch cards which were color coded for schools and included a three letter code of the question, code number for the student followed by two letter codes, the first representing race, and the second gender.

Once all the descriptors to a question had been transferred, they were organized by theme into categories. Further analysis involved "member checking" and triangulation" before the final categories were agreed upon.

Results

Student responses were characterized into two broad themes: teacher behaviors related to content and pedagogy and teacher behaviors that implied a relationship between the student and the teacher. However, both themes dealt with teacher actions that were unidirectional, from the teacher to the student.

Teacher Behaviors Related to Content and Pedagogy

Six teacher behaviors related to content and pedagogy were identified in students' descriptions of a caring teacher: helping with work, explaining work, checking for understanding, encouraging, maintaining an orderly classroom atmosphere, and providing fun activities. Student responses in these areas portrayed teacher actions common in most schools. For example, the largest category, helping with work, included statements such as "[a caring teacher] helps you if you don't understand something;" "if you are stuck in a problem;" "when you ask a question;" "when you are having trouble."

Similarly, to some students a caring teacher explained the material and assignments well. The following exert from a seventh-grade African-American student is a good illustration of the student responses in this category: "[A caring teacher] explains your assignments before you do them, will explain an assignment thoroughly, show you how to do the work before you take it home."

The other categories of teacher behaviors related to content and pedagogy included student responses that portrayed teachers in more active roles. According to some students, a caring teacher actively ascertained student understanding of the material. The teacher did this by asking questions and by walking around the classroom. As an eighth-grade Caucasian male indicated, a caring teacher "doesn't just sit at her desk and let you do the work." At the same time, a caring teacher provides positive reinforcement for good work. In other words, "she says 'Good job!' when you get an A on a test or something," responded an eighth-grade Caucasian male. To a sixth-grade African-American male a caring teacher also gives encouragement during difficult times: "When you get bad grades, she says, 'you can do better than this.' According to these students, caring teachers provided this sort of encouragement because they wanted their students "to do good."

Student responses indicate that they viewed good classroom management as a very important aspect of a caring teacher's practice. As a seventh-grade Caucasian male indicated, a caring teacher "doesn't let students get by with everything." Thus, to some students providing guidance was a means by which a caring teacher maintained a positive classroom environment. This was particularly important to students who might have been experiencing discipline problems. According to a seventh-grade African-American male, a caring teacher "is on your back a lot. Tells you what to do. Tells you to straighten up." Another one added, "sometimes they can be a little rough or angry with us when trying to look out for our well-being, how we're going to act in the future." Even teacher actions such as calling parents and sending students to the principal's office were seen as caring from the point of view of many students. It was clear that to these students a caring teacher provided an orderly classroom atmosphere that was conducive to learning. An eighth-grade African-American male student described such classroom in the following manner:

> Everyone would be in their seats, doing work. The teacher would go around the room talking to everybody to see how they were doing, to answer questions. Sometimes she'd just say "good job."

Showing concern was closely tied to the theme of guidance. According to a seventh-grade Caucasian female "a caring teacher wants to make sure you don't get in trouble." An eighth-grade African-American male commented that "if you're failing a class, [a caring teacher] will take you over to the side and tell you what you're doing wrong and try to help you out."

A few students also mentioned planning fun activities such as field trips as characteristics of a caring teacher. However, the number of students who mentioned these types of activities was surprisingly small.

Teacher Behaviors that Foster Relationships

Many student responses illustrated teacher behaviors that implied a relationship between the teacher and the student. According to these students caring teachers accomplished this by treating their students as individuals. As one seventh-grade Caucasian female put it, "she doesn't see you as a unit; she sees each as an individual." In addition, caring teachers were interested in their students at the personal level. Or as a seventh-grade Caucasian male indicated, "she wants to know what type of person you are." Put simply," a caring teacher is not only a teacher but your friend, too" replied a seventh-grade Caucasian female.

Respect is a very important characteristic of a relationship. Thus, teachers who develop relationships with their students respect them. In other words, "they treat you the way they want to be treated" responded one seventh-grade Caucasian male.

A good friend is a good listener and caring teachers "will listen if you have a personal problem," pointed out a sixth-grade Caucasian female. To a seventh-grade Caucasian female, comforting was a very important aspect of such relationship: "If your feelings are hurt, she'll talk to you about your feelings." Another seventh-grade Caucasian female replied, "If you were like mad at one of your friends and you were really upset and were crying, they would probably help you guys work it out." These teacher behaviors were particularly prevalent in the responses of female students.

To some students, the dynamics of the relationship between the student and teacher extended outside the classroom. This might be expressed by attending extracurricular activities in which students participate. "She comes to every sport I play" reported an eighth-grade Caucasian male.

Discussion

The results of this study indicate that most students described caring teachers in rather traditional roles related to content or pedagogy. To many students, simply helping with and explaining schoolwork were the main characteristics of caring teachers. Furthermore, these actions were all initiated by the teacher and directed to the student. These results are rather different from the results of other studies such as those conducted by Schaps, Battistich, & Salomon (1997) who contend that effective schooling involves "important and engaging learning activities." Similarly, none of the students in this study identified any teacher attributes that reflected content or curricula, as was identified by Thayer-Bacon and Bacon. Except for a few students who saw caring related to fun activities, this group of students did not attribute caring to content or curricular issues. Most of the student responses were related to the process that teachers used in the classroom – helping with and explaining work, checking for understanding, encouraging, guiding.

Although many student responses in this study also indicated that caring teachers developed relationships with their students, these relationships did not appear to be characteristic of "classrooms as communities" described by Schaps and others. Indeed, all the teacher behaviors described by the students illustrated a "teacher-student relationship" composed of behaviors initiated by the teacher and directed toward the student. These results are also different from those of Sickle & Spector (1996) who found that caring teachers foster relationships at four levels: teacher-student, student-student, teacher-content, and student-content.

However, the results of the present study were rather similar to the results of a study conducted by Hayes, Ryan, and Zseller (1993). Although Hays and colleagues used somewhat different categories, most of the teacher behaviors described by the sixth and eighth grade students in their study were comparable to those described by the students in this study.

Why did the responses of the students in this study differ so much from the responses of the students in the aforementioned studies? The reason may be twofold. First, except for the study by Hayes and colleagues, the students in the previous studies were provided with scales that included ready-made responses. In the present study, as in Hayes' study, students were simply asked to describe a caring teacher. This discrepancy in the students' responses of the various studies highlights the potential difference between adult and adolescent views of how caring manifests itself in a teacher. The vignette in the introduction of this paper illustrates this discrepancy. Teachers act in a "caring way" according to their adult perspective (i.e. sending balloons and a card to a student in the hospital). Many teenagers, on the other hand, have another definition of what caring is and how they want to be cared for as students – seen as individuals and helped when having difficulty understanding the material. Teenagers, not interpreting teachers' actions as caring, feel that teachers are uncaring and give the teachers that feedback. Teachers see the teenagers' lack of appreciation and identify the teens as uncaring.

Another reason for the differences in student responses, might be a lack of language to describe caring relationships that are multidirectional. This absence of a complex language is probably the result of a lack of experiences that foster these types of relationships. The classroom of a caring teacher described by one of the students in this study portrays a very traditional classroom setting. The students are siting in rows, working diligently and quietly, while the teacher moves around checking for understanding. Our one-year long observations in these schools indicate that the teachers in both schools strove for this type of classroom environment. Although we observed some caring behaviors from the teachers towards individual students, none of the classrooms that we observed would be considered a caring community as described by Schaps and colleagues. Thus, when asked to describe a caring teacher, the students in this study drew on their experiences, which were different from those students whose teachers strive to develop caring communities in their classrooms.

Implications

According to Schaps, Watson, and Lewis (1996), the following approaches help foster a caring community within the classroom:

- Student involvement in shaping classroom norms and practices.
- Activities that help students and teachers to know each other as people.
- Activities that build a sense of unity within the class by joining students together in shared, enjoyable pursuits.
- Disciplinary approaches that deepen children's bonds with one another and with the teacher.
- Minimizing competitive activities.
- Collaborative pedagogies such as cooperative learning that allow children to work interdependently.

- Integrating discussions into the teaching of literature, history, science, and other subject areas about the lives and circumstances of diverse others, and about what it means to be compassionate, principled, and responsible.

The student responses in this study indicate that without these kinds of approaches students' understanding of caring and caring relationships will be limited. Students need to be involved in caring relationships in which they have opportunities to care for others – peers, teachers, others in and outside the school, and their surroundings. Only then will students be able to develop and ethic of caring and schools will become true caring communities.

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Reaching Out to Teachers in Appalachia via Distance Education

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Introduction to Distance Learning

> I find distance learning to be both fascinating and aggravating. I have enjoyed learning how to use the equipment and learning how to use PowerPoint. Distance learning is also a great way to share ideas with a larger group of educators than would be possible in a single classroom setting.
>
> I find it aggravating at times...due to technical difficulties.
>
> Jacqueline[1], a distance learning student.

As this student quote states, the distance learning experience can be mixture of both positive and negative experiences. Learning from a distance, using compressed video, Internet connections, and other communication technologies, has found a place within education. This study has endeavored to create a picture of the distance learning experience from both the perspective of a first time instructor and the students enrolled in a graduate level science education course.

A number of investigations evaluating televised instruction in terms of student performance are common (Wetzel, Radtke, & Stern, 1994; Delbeq & Scates, 1989; DeLoughry, 1988; Moore and & Thompson, 1990; Souder, 1993; Stone, 1987, 1988 Cohen, Ebeling, & Kulik, 1981). In general the findings of these research studies indicate that students taking televised courses at remote sites perform as well as their counterparts taught in traditional classrooms. Most of the research on distance education provides "snap-shot" profiles of student content learning and/or student attitudes. Studies which extend over the duration of a course are rare. Both cross-sectional and longitudinal assessments of student participants and distance education programs are necessary to evaluate the effectiveness of programs and to provide guidance for future development (Westbrook, 1997; Biner, 1993; Sachs, 1993; Eagen,. Welch , Page, & J. Sebastian , 1992). Also, in comparison with other distance learning topics, the degree of student satisfaction with education at remote sites has been neglected by researchers (Biner, 1993). On-going assessment of distant learner satisfaction can have far-reaching benefits--lower attrition rates, increased student motivation, increased student-generated referrals, and enhanced learning (Biner, Dean, & Melliger, 1994).

Background of the Study

Distance Education at Morehead State University, which operates via a fiber optic telecommunications system, has grown from one class delivered to seven sites, Fall semester 1995, to more than 29 classes delivered to eighteen sites, involving more than 23 faculty members and 622 students. The university utilizes a fully interactive telecommunications system that provides full motion video (compressed) and audio transmission. On-campus and off-campus students interact using either a voice activated microphone or a push-to-talk microphone. The instructor aided by a site facilitator at the origination site controls the delivery of course content and communication among sites by using a touch-controlled computer panel. All sites employ a site facilitator who operates the technology, acts as a liaison between the students at the remote site and university faculty, and performs class management duties, such as taking attendance, distributing materials, and proctoring quizzes and tests. The instructor makes

1 The names of all people in this paper are pseudonyms.

periodic visits to each remote site in order to establish personal contact with the students. Technologies present at each site include teacher and student cameras, a computer located at the podium for the use of the instructor, student computers, an overhead camera for display of class materials and a minimum of two monitors All classes transmitted are video-taped and made available to students.

Purpose of the Study

The primary goal of this investigation was to chronicle the experiences of an instructor and her students as they first experience a course delivered at a distance utilizing various technologies. Both the instructor and students had no or very limited experience with e-mail, Internet use, and supporting software. The challenge was to learn and utilize the technology without a reduction in course content.

According to Bullough, Knowles and Crow (1992) and Yin (1989) case studies are valuable when investigating situations where the researcher has little control in real-life situations. This method enables the researcher to preserve the integrity of the subjects' experiences and meanings, as well as encouraging sensitivity to changes within the context of the experience without being narrowly bound to preconceived courses of experimentation.

Methods

The instructor, Dr. Kern, is an assistant professor who has been with the university for 2 years. The students are 33 elementary teachers taking a graduate level science education course, Science 690: Advanced Science for the Elementary Teacher, which is a requirement for the Masters' Degree and the Fifth Year Program.

The Site

Morehead State University is a regional university that services the Appalachian region of Eastern Kentucky. The lack of major highways and weather conditions in the region cause the area to remain isolated. The students are distributed among five sites--main campus and four public schools in rural Eastern Kentucky.

Sources of Data

Data was gathered from the instructor and student journal entries, videotapes of televised classes, and student surveys given at three different times --after the first 3 weeks of class, at the midpoint of the semester, and at the end of the semester.

Results and Discussion

Launching the new semester.

The following entry from Dr. Kern's journal speak of her impressions after her first encounter with a *real* distance learning class.

> I felt good about the class, but I felt removed from my students. Unless I call on a specific site there is no feedback or response. I felt so alone and the equipment makes a physical barrier between myself and the students in the room.

At the beginning of the course the students expressed appreciation for the opportunity to take Science 690 at a location within driving distance of their home. Many stated that if the course had not been offered through distance learning, they would have been unable to take the course. Although some students were apprehensive about using computers approximately one-third of the class was excited about the opportunity to learn and use the new technologies. Most students were reluctant to speak on camera and remarked in their journals that they were uncomfortable "being on camera.".

> ...when I sat in on my first class, I was a nervous wreck. I didn't realize how camera shy I really was. The whole time during our first meeting I kept saying to myself, "I'm never sitting in the front row again." I felt really uncomfortable with the idea that I was on television.

Teaching a course via distance learning requires a high degree of organization, constant communication with the site facilitators, many hours of work preparing class presentations and activities, and a real effort to know the students. Typical planning for one distance learning class involves: first, planning the class at least one week in advance and making up packets for each site; second, making arrangements to have the materials sent to each site; third, contacting each site facilitator and discussing the next class; and fourth, planning a alternate activity in the event of technical failure and making back-up disks and "hard" copies of all presentations.

<u>Visits to the remote sites.</u>

In addition to the planning mentioned in the previous section, the instructor needs to determine the availability of equipment and the compatibility of computer programs when broadcasting from a remote site.

Most of the distance learning sites located in the public schools are new. The site facilitators (employees of the school district) are often inexperienced, but try to meet the needs of both faculty and students. The university works with the schools to train the site facilitators. But at the beginning of the semester these individuals are often struggling with the technology.

Traveling to the various sites is time consuming and expensive but Dr. Kern noted that after her visits the students were more willing to "come on camera" to ask questions or to participate in discussions. The students also increased e-mail conversations with her.

> Because of the smaller groups a professor's visit can be more of a personal getting acquainted time, as opposed to a large class on campus.

The return to campus.

Being on the road had its effects on the campus class, as evidenced by Dr. Kern's journal entry when she returned.

> March 12th I was back at Morehead. I felt that much of the good rapport I had established was beginning to erode. They now felt like a new class. The ones that I communicate with on e-mail still seem close, but those who won't do it seem removed. In the future e-mail will be required. If they can't do it, then they don't take the class. But I wanted so much for the class to succeed that I gave them several options. The ones that rely on faxes I have a harder time giving feedback.

Mid-semester.

After the first half of the semester Dr. Kern related that the hardest part of the class was her feeling of isolation. Although she had a group of students in the room, the equipment (document camera, control panel, monitors) was a barrier between her and the students. As she became more familiar and at ease with the technology she made a real effort to use the portable microphone and move around the room. This change was possible because the site facilitator could manipulate the cameras and the control panel. Another difficulty was perceiving how the class was proceeding at the remote sites.. If everyone was quiet the site was not seen because each site is voice activated. Some students voiced their own feelings of isolation from the instructor and other class members.

> I don't think you know me as well as you would have had we been in a traditional setting.
>
> I enjoy getting to know everyone in class and have not been able to do so through distance learning. I believe I have missed an opportunity to meet several new friends and share many other experiences.

Each class had to be well planned and organized, especially when the *hands-on* science activities were on the agenda. Discussions were hard to initiate and Dr. Kern felt that it took longer to "do things " via distance learning. She had to make a real effort to wait for responses because of additional wait time between her questions and student responses. This phenomena became apparent when she made a humorous remark. Laughter was heard from a remote site after she moved to another topic. Also, when the class time expired, transmission ended.

Student presentations

Student presentations gave students not only the opportunity to demonstrate their mastery of the subject but also provided the experience of being on camera and using the equipment, which helped them overcome their stage fright..

> The students gave presentations tonight. Each one did more than I asked for. They also said that they had a new respect for what I did after they had to manipulate the equipment.

Manipulation of the cameras and microphones was an added challenge for student presentations.

> I had to be on my toes at all times watching the monitor and making sure that what we were doing was being broadcast. Displaying handouts under the document camera; having a group of students work under the document camera; and making sure no water or other materials come close to any of the equipment is a real challenge...They (the presentations) don't quite have the impact as if you (the students at the remote sites) were actively participating.

Despite Dr. Kern's reservations several students indicated that the presentations were a valuable part of the class and worth the extra effort.

> I have picked up a number of ideas from my peers at Centerburg, and from the students at other sites through our presentations.

<u>Student involvement</u>

Dr. Kern did strive to have a distance learning class as close to her traditional Science 690 class as possible. She began and ended each class with a hands-on science activity and involved the students in class discussions and cooperative learning strategies such as jigsaw. Special arrangements had to be made to send materials to remote sites, students had to bring in materials, and extra planning and organization of activities and materials was needed (e.g., water, liquids and particles had to be kept away from the equipment.). Some early attempts were disappointing and the more vocal students expressed displeasure when their classmates were reluctant to participate.

...some people are a little backwards at the beginning of a class and do not talk much. For those people the thought of having so many other locations on line at the same time just makes matters worse for them and leaves us, who do not care to talk, doing all the talking.

For other sites student participation was less of a problem and the initiation and management of student activities and discussions improved with time.

We also did more cooperative learning. Having the students in groups with each having a role works well --director, recorder, and spokesperson.

Student satisfaction

Student satisfaction with the class was closely related to the number of students at each site. Students attending sites with three and four students stated that they had established a close working relationship with the other students at their site.

This class allows for a lot of cooperative learning. We depend on ourselves and each other. This is a student directed class ...and we are suppose to be doing that with our own classes...there are only four of us but I feel that we are closer than any of my other classes.

I personally like the small class size because it is not as intimidating as large classes. When I'm giving a presentation I only see 6 or 7, not 30 or so.

A student on campus (8 students at the site) reported that most of his classes contain 25 to 30 students. In these classes he normally sits at the back of the room and rarely, if ever, speaks to the instructor or other students. He said he felt comfortable participating with the smaller group in the distance learning class. With encouragement from the other students he often spoke on camera. Students at the site with the largest enrollment--13 students-- did not report the same feeling of closeness with other students.

Epilogue

At the end of the semester Dr. Kern voiced her excitement for the doors that distance learning can open, especially for the population she needs to reach--teachers in Appalachia.

> Teaching via compressed video is very demanding--both in time and in effort.
>
> It is worth the investment for the teachers that we need to reach.
>
> One of the problems in education is that once teachers are out in the schools, they shut their classroom doors and are isolated from their peers. This problem is compounded here in rural Kentucky. There are no major highways connecting many of the areas and weather conditions--snow in the mountains in the winter and heavy spring rains--further complicate the problem. Distance education via compressed video is one medium that can bring teachers together. I've always felt that the strength of this class is not what they gain from me, but what they gain from one another.

A student survey at the conclusion of the course indicated that students were generally pleased with their experiences in distance learning and Science 690. Everyone indicated that they would take another distance learning class and all. but one student, would recommend distance learning to others. Students gave the following reasons for enrolling in a future distance learning course (in rank order):

1. Close to home/work and require less travel.

Previously unavailable courses are now accessible.

2. Working with other students in smaller groups.

3. Opportunity to learn new technologies.

4. Opportunity to share/learn from other students (teachers) at different locations.

5. More involved in own learning and therefore, learned more.

When students were asked what they valued most about Science 690, they were evenly divided between the hands-on science activities and the use of technology. The distance learning feature most valued was sharing with the teachers at other sites. This answer ranked above the convenience of taking a course close to home/work or taking a course normally unavailable.

> I like the idea that I get to see the people from the other sites. I think that it is wonderful that so many of us can be reached through distance learning.

The least valued features were not associated with the distance learning aspect of the course. They were divided among assigned readings, the textbook, and lab reports. Although students stated early in the semester that the one distance learning feature they did not like was being on camera, at the end of the semester only four students listed this aspect as a problem. Thirteen students listed technology problems, especially sound quality as a major problem. Other concerns listed (in order) included: the amount of time wasted while setting up student presentations, not enough courses offered through distance learning and less teacher contact. The number of students expressing concern about the amount of teacher-student contact declined as the semester progressed. Students who actively used e-mail to send assignments and correspond with the instructor felt they had more interaction with the instructor and feedback on their assignments than in traditional classes.

Conclusion

Distance learning is a vehicle for reaching students isolated by distance, geographical barriers, or life circumstances. It is more than a convenience for students in our service region. It is a necessity. Courses that normally are inaccessible to the Appalachian population are now within reach.

Distance learning at Morehead State University is currently in its third year. Since Spring 1997, when data was collected for this study, facilities have been expanded and many improvements have been made in technology, communications, support and training of faculty and support staff.

This particular study followed a professor and a group of elementary teachers enrolled in a graduate level science education course. The subjects selected are a group of professionals who are charged daily with taking control and directing learning situations. At each site students--usually teachers with classroom experience--emerged as leaders. Therefore, the results of this study are not generalizable to other distance learning populations, especially undergraduates.

All students felt that the educational experience was enriched by their involvement with technology and collaborating with teachers from different locations.

> I feel I've learned just as much material and actually gained more teaching ideas than I would have in a traditional class setting by listening to and watching the presentations of other teachers from so many different places.

The class has made me become a more independent learner-a goal I strive to have my own students achieve, it has made me become a better listener and helped make me more responsible for my learning.

Distance learning is not without its problems. It is very easy to get "caught up" in the technology with the result being that it drives the class. Too much time can be taken away from course content teaching students how to use equipment and software packages. This problem can be alleviated through separate workshops and help sessions supported or sponsored by the college or university. When planning the instruction the professor needs to first set his/her content goals and then determine how the technology can help him/her achieve that result.

As with any job involving equipment there is always the possibility of a technology failure. The likelihood of such an occurrence diminishes with the quality of the equipment. The problems associated with the system have mainly occurred at sites which have economized by purchasing less expensive microphones, monitors and cameras. But even with quality the unthinkable can happen. Therefore, it is essential to have a back-up plan and an alternate lesson that the site facilitators can deliver to the students.

In a learning situation where the instructor is not physically present, it is easy for both the students and the instructor to feel isolated from the other. This problem can be alleviated by the use of the *Nicenet* network, *Course Information* system, and other Internet or software programs that have class conferencing, discussion groups and/or virtual chat room features along with the use of e-mail.

The delivery of materials to and from the remote sites must be considered before planning a distance learning class. The delivery system available- United States Postal Service, United

Parcel Service or Courier-will have a direct effect on the class activities, the work assigned (e.g., portfolios, resource notebooks) and due dates.

Distance learning is not easy. It involves much hard work and commitment on the part of the instructor, students who are willing to give it a chance, and a support system from the post-secondary institution. Teaching from a distance is challenging but it also has its rewards, as evidenced by the following journal entry of a student.

> The technology in our schools for teachers and staff is very limited. So using the distance learning facility was quite a challenge. Since beginning the distance learning class my team teachers and I have pushed our school to get us on line and up to par with the rest of the world. We now have e-mail available... E-mail and the Internet have opened a variety of services and facilities for us. I have acquired dozens of lesson plans and Internet addresses to use. I now use research from the Internet with my students.

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AN EXPLORATORY STUDY OF THE "EFFECTIVENESS" OF ELEMENTARY SCIENCE SPECIALISTS

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The national science education reforms, in their efforts to promote scientific literacy, envision active, hands-on, inquiry-oriented science lessons beginning in the earliest elementary grades (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). Elementary teachers are expected to develop and implement science activities that engage students in science processes and build on students' natural curiosity and common sense knowledge. Such an approach is vastly different from the more traditional, textbook-based approach that many elementary teachers tend to employ (Abell, 1990; Manning, Esler, & Baird, 1981; Stake & Easley, 1978; Weiss, 1978, 1987). In addition, the fact that science instruction is not given priority in elementary classrooms aggravates the difficulty of providing an engaging atmosphere in which science-literacy-related objectives are viewed as important and attainable. Reviews of the status of elementary science reveal that approximately 25% of elementary teachers do not teach science at all, and those who do spend less than two hours a week on the subject. Moreover, these latter teachers tend to emphasize vocabulary and heavily rely on textbooks in their teaching (Abell, 1990; Manning, Esler, & Baird, 1981; Stake & Easley, 1978; Tilgner, 1990; Weiss, 1978, 1987). Thus, the task of implementing an elementary science program consistent with national reforms' recommendations has been challenging, to say the least.

Elementary teachers have voiced several constraints to effective science teaching in elementary classrooms. Among these constraining factors are science content knowledge (Abell

& Roth, 1992; Dickinson, Burns, Hagen, & Locker, 1997; Ramey-Gassert, Shroyer, & Staver, 1996; Tilgner, 1990; Weiss, 1987), lack of time (Stake & Easley, 1978; Tilgner, 1990; Weiss, 1978), inadequate materials and facilities (Abell & Roth, 1992; Helgeson, Blosser, & Howe, 1977; Ramey-Gassert et al., 1996; Weiss, 1987), and other curricular priorities (Dickinson et al., 1997; Hounshell, 1984; Weiss, 1978). In addition to these constraining factors, elementary teachers have attributed their low self-efficacy toward science teaching to the lack of experiences with science, lack of science teaching experience, and perceived lack of achievement ability in science-related topics/areas (Dobey & Schafer, 1984; Perkes, 1975; Ramey-Gassert et al., 1996; Shrigley, 1977; Tilgner, 1990). These constraints, whether real or perceived, gain special significance in the context of national reform efforts (AAAS, 1993; NRC, 1996). Indeed, the ability of elementary teachers to implement the reforms' vision of science teaching has been brought into question.

A Role for Elementary Science Specialists

In light of elementary teachers' consistent voicing of constraints to teaching science and the growing importance of science literacy, many science educators have suggested that experienced elementary science specialists are more likely to promote science literacy among elementary students than are elementary classroom teachers (Abell, 1990; Hounshell & Swartz, 1987; Neuman, 1981; Williams, 1990). These arguments assert that employing elementary science specialists to teach science in equipped elementary science laboratories would abate the constraints of priority, time, equipment, knowledge, and experience. An elementary science specialist typically holds an undergraduate degree in a science area and additional training in elementary science education. As such, science specialists have substantially more science content and science pedagogy backgrounds than typical elementary teachers do. Because science specialists are only responsible for teaching science in elementary grades and since it is highly likely they are the most knowledgeable and enthusiastic about science in elementary school settings, their primary focus would be developing and implementing science lessons. Many believe that adequate science content knowledge and pedagogy, teaching in separate laboratory settings, and high priority for teaching elementary science enable specialists to deliver *more* innovative and "effective" science instruction relative to what the typical elementary classroom teacher can, or should be expected to, deliver (Abell, 1990; Hounshell & Swartz, 1987; Neuman, 1981; Williams, 1990).

Studies have supported the importance of science content knowledge in using an active, inquiry-oriented approach to science instruction (Dobey & Shafer, 1984). Furthermore, perceived ability to be effective in science teaching has been shown to be associated with factors such as more elaborate science content knowledge (Ramey-Gassert et al., 1996; Shrigley, 1977), successful science teaching experiences (Dickinson et al., 1997; Shrigley, 1977; Tilgner, 1990), and a commitment to more effective elementary science instruction (Ramey-Gassert et al., 1996). These factors have been used to support arguments for a role for elementary science specialists. However, *empirical* research about the effectiveness of elementary science specialists is lacking. Such was the focus of the present study.

Purpose of the Study

The present study attempted to assess the "effectiveness" of a science program implemented by two elementary science specialists in a school district in a western state. For the purpose of this study, "effectiveness" was measured in terms of achievement of the district's science-teaching objectives for students in grades 4-6. In addition, the study aimed to compare the potential of elementary classroom teachers and elementary science specialists to implement the reforms' vision for elementary science education in grades 4-6. In particular, the present study aimed to answer two questions, (a) What are the differences, if any, between elementary teachers' and elementary science specialists' views of science teaching and instructional planning for grades 4-6? (b) Are elementary science specialists more effective than elementary classroom teachers in helping students achieve "science literacy?" In the present study, "science literacy" was equated with achieving science-teaching objectives for grades 4-6 as outlined in the *National Science Education Standards* (NRC, 1996) and/or *Benchmarks for Science Literacy* (AAAS, 1993).

Method

The present study was exploratory and qualitative in nature. Much of the data for this study were collected as part of an evaluation project for a participant district's elementary science program. Given the nature of the evaluation process, the investigators did not have direct contact with the participant teachers or students. The investigators had to rely on district administrators for data collection. Nonetheless, frequent communications with the School District Board ensured full access to necessary data and cooperation of district personnel.

Participants

Two school districts, a "specialists" district and a "comparison" district, in a western state participated in the present study. The districts were comparable in locale and socioeconomic status. Class size for both districts averaged 24 students. The "specialists" district employed two elementary science specialists. All nine 4th grade, seven 5th grade, and seven 6th grade classrooms were taught by the elementary science specialists. All these classrooms, the two science specialists, and all 23 elementary classroom teachers for grades 4-6 from the "specialists" district participated in the study. In the "comparison" district, elementary classroom teachers assumed all science teaching responsibilities. From this district, 12 elementary teachers of grades 4-6, and 17 grade 5 classrooms participated in the study.

A profile of participant teachers from both districts and the science specialists is presented in Table 1. No significant differences were evident between participants in the two districts with respect to gender, age, and years of teaching experience. Both districts had substantially more female teachers than male teachers. The average age for classroom teachers in the "specialists" district was 42 years compared to 44 years for the "comparison" district participant teachers. Science content knowledge background for participant teachers for both districts' was mainly in the biological sciences (approximately 55% of total science course credits were in the biological sciences).

Some differences were evident in the amount and type of undergraduate and graduate science content courses completed by teachers in the two districts. Compared to the classroom teachers in the "specialists" district, excluding the science specialists, the "comparison" district teachers averaged 7 more credits of undergraduate science courses (14 versus 21 credits) and 4 more credits of graduate science courses (6.7 versus 11 credits). Moreover, 50% of the teachers in the "comparison" district had completed at least two graduate courses. In comparison, only 21% of the "specialists" district classroom teachers had completed any graduate course. "Comparison" teacher participants also had more courses in the physical sciences, averaging 9 total credits (undergraduate and graduate) in physical science versus 3 for teachers in the "specialists" district. The other content areas were similar for both districts. Differences were also evident in participation in professional development opportunities. Compared to 66% of teachers in the "comparison" district, only 44% of classroom teachers in the "specialists" district reported having participated in professional development programs or activities.

Table 1.
Profiles of Participant Teachers and Elementary Science Specialists

Variable	"Specialists" district						"Comparison" district		
	Classroom teachers			Science specialists			Classroom teachers		
	n	*P*	*M*	*n*	*P*	*M*	*n*	*P*	*M*
Gender	23	100		2	100		12	100	
Male	3	13		0	0		2	17	
Female	20	87		2	100		8	67	
Age			42			35			44
Teaching experience			15			11			15
Undergraduate science credits	20	88	14	2	100	70	11	92	21
Biological sciences	17	78	8.1	2	100	37	11	92	11
Physical sciences	10	44	3.4	2	100	18	9	75	7
Agricultural sciences	2	9	0.3	1	50	1.5	1	6	0
Geo- and space sciences	10	44	2.5	2	100	15	5	42	3
Graduate science credits	5	21	6.7	2	100	32	6	50	11
Biological sciences	4	18	5.4	2	100	32	4	33	5
Physical sciences	0	0	0	1	50	1.5	2	17	2
Agricultural sciences	0	0	0	1	50	1.5	1	8	2
Geo- and space sciences	1	6	4.5	1	50	1.5	3	25	2
Professional development activities	10	44		2	100		8	66	

Note: *n* is the number of participants who reported data for a particular variable; *P* is the percentage of total participants for the specified district; *M* is the mean of a particular variable for participants in the specified district

The two science specialists differed in terms of teaching experience (2 years versus 19 years) and graduate level science credits completed (17 versus 46). However, both had completed substantially more science credits than participant classroom teachers in either district. The science specialists averaged 102 total undergraduate and graduate science credits, whereas the classroom teachers in the "specialists" and "comparison" districts averaged 21 and 32 total undergraduate and graduate science credits respectively. Like classroom teachers in both districts, the two science specialists had approximately 55% of their total science credits in the biological sciences. In terms of professional development, both science specialists have been active participants in workshops and projects during their tenure.

Context: The Elementary Science Specialists Program

The "specialists" district had established and maintained the elementary science specialists program for 10 years prior to this study. In this district, students in grades 4-6 sit for two 45–55 minute science lessons each week. The lessons are taught by an elementary science specialist in a fully equipped science room. Lessons are intended to be student-centered with facilitation by science specialists and classroom teachers. The science specialist is responsible for lesson preparation, presentation, and grading. Classroom teachers escort students to the science room and are expected to participate as facilitators during lesson delivery. The district describes their elementary science program as comprising four phases. In the first phase, "preparation," the science specialist plans a science lesson that is aligned with the district curriculum goals, organizes the supplies in the science room, and prepares homework sheets and student activities/projects. During the second phase, "initiation," the science specialist introduces the lesson to students. She establishes rules and expectations, assigns students to groups, and gives directions for the activities. In the third phase, "maintenance," the science specialist and the classroom teacher circulate the room to address student questions, monitor progress, challenge students with thought provoking questions, and provide guidance when needed. In addition, they assess student achievement using scoring guides prepared by the science specialist for two sets of objectives per lesson. One set is related to performance or laboratory-skills objectives, and the other is related to content objectives. At the conclusion of the activity, the science specialist presents a closure to the lesson and assigns homework. The fourth phase, "follow-up," takes place in the regular elementary classroom where the classroom teacher makes arrangements for absent students or students with special needs, collects homework, and communicates with the parents about the activities of the science program.

Procedure

Several data sources were used to answer the questions of interest. To minimize potential bias in participant teachers' responses during data collection, every precaution was taken to insure that participants did not perceive the questionnaires they filled and other tasks they were asked to complete as evaluative.

First, all teacher participants in both districts were administered a survey to collect background data and assess their views of science teaching. Participants were asked to respond to four open-ended questions. These questions were:

1. Do you think that teaching science in your classroom is important? Why or why not?

2. What do you think are the most important things to emphasize when you teach science? Why?

3. What, in your view, is the "best" way to teach science to your students? Why?

4. What, in your view, is the best way to assess whether your students learned the science topics, concepts, etc., that you planned to teach them? Why would you use this (or these) assessment strategies?

Second, the science specialists and participant teachers in the "specialists" district were assigned instructional objectives and asked to provide lesson plans that addressed these objectives. Participants were asked to prepare elaborate lesson plans that *detailed* the content, instructional activities, teaching approach, and assessment strategies. The investigators chose the assigned objectives such that these were simultaneously emphasized in the district's elementary science teaching goals and the *Benchmarks* (AAAS, 1993) or the *Standards* (NRC, 1996). Different objectives were assigned to different grade level (4-6). Classroom teachers in each grade level were assigned the respective objective. The two science specialists were asked to write lesson plans for all three grade-levels. The objectives were:

1. Grade 4: Students will be able to analyze, interpret and summarize data from an investigation. In particular, students will be able to realize that just because B follows A does not necessarily mean that A caused B.

2. Grade 5: Students will be able to draw comparisons between three structures that are functionally equivalent in plants and animals.

3. Grade 6: Students will be able to distinguish among chemical, heat and mechanical energy.

Third, the elementary science teaching goals (grades 4-6) of the two participant districts were collected. These two sets of goals were systematically compared with each other and then with the goals specified, for corresponding grade levels, in the *Standards* (NRC, 1996) and *Benchmarks* (AAAS, 1993). This comparison was necessary for two reasons. First, the meaningfulness of any comparison between the two districts was determined by the extent to which the districts' science teaching goals for grades 4-6 overlapped. Second, since achieving "science literacy" in the present study was equated with achieving the science teaching goals specified in national reform documents, it was crucial to establish that the participant districts' elementary science program goals were consistent with those specified in national reform documents (AAAS, 1993; NRC, 1996).

Two types of data were used to determine the "effectiveness" of the science program implemented by the elementary science specialists. First, statewide science achievement test scores for grade 5 students in both districts (197 from the "specialists" district and 327 from the "comparison" district) were compared. Grade 5 students from both participant districts were the only students who took the same standard examination during the spring of 1998, and thus served as the only comparable group for achievement. Second, 40 student work samples from grades 4-6 in the "specialists" district were used to assess the achievement of objectives and/or goals that targeted higher order and critical thinking skills that are not typically measured by statewide standardized tests.

The work samples, or portfolios, were selected by the science specialists to reflect student achievement of cognitive goals with special attention to problem solving and critical thinking. The work samples comprised descriptions of lab activities and student investigations complete with student observations, hypotheses or questions, student-designed investigations, types of data gathered and analyses conducted, and conclusions, summaries, and essays. The two science specialists collected relevant work samples from at least three students in each of the 13 classes they taught during the third trimester of the 1997-1998 school year. They attempted to stratify the sampling based student abilities and achievement.

Data Analysis

Participants' responses to the open-ended science teaching survey were used to generate summaries for participant teachers' views of science teaching. These summaries focused on teachers' views regarding the relative importance of science in the elementary curriculum, science content or concept areas that should be emphasized, effective teaching approaches, and appropriate assessment practices. Participants' responses were examined individually for internal consistency, and then grouped into the appropriate participant category: "specialists" district classroom teachers, science specialists, and "comparison" district classroom teachers. Next, profiles were generated for each participant category. Views of the classroom teachers from both districts were compared and contrasted with those of the science specialists. Finally, views of the classroom teachers and the elementary science specialists were compared to recommendations for elementary science teaching practices and objectives as described in the *Standards* (NRC, 1996) and *Benchmarks* (AAAS, 1993).

The lesson plans prepared by participants were analyzed with a focus on the type of instructional activities used, plans for student involvement, accuracy of science content, and alignment between lesson objectives, instructional activities, and assessment plans. Comparisons were then made between the teachers' instructional plans and their views of science teaching as explicated in their responses to the aforementioned open-ended survey. Comparisons were also made between the instructional planning of classroom teachers and the science specialists.

Multiple linear regression analysis was used to compare the two districts' statewide science achievement scores for grade 5. Student scores served as the response variable while district membership, school membership, and classroom teacher served as explanatory variables. It should be noted that district membership indicated whether students were taught by science specialists ("specialists" district) or elementary teachers ("comparison" district).

Student work samples were examined for type of activities (observation, hands-on, manipulating equipment, inquiry), cognitive skills targeted (knowledge, comprehension, application, problem-solving, and higher order and critical thinking), and evidence for student achievement of target content or skills (adequate/weak). Student achievement was measured by appropriateness and completeness of responses, clarity of thought processes, and demonstrating understanding of the connections between the content and procedures performed. Particular emphasis was placed on student demonstration of problem solving and critical thinking abilities.

Results

Views of Science Teaching

The following sections present summaries of participant teachers' views regarding the relative importance of science in the elementary curriculum, science content or concept areas that should be emphasized, effective teaching approaches, and appropriate assessment practices.

Importance of Science in the Elementary Classroom.

Based on the responses to the science teaching survey, classroom teachers from both districts and the science specialists held similar views toward science teaching. All participants emphasized that science is important to teach. Several justifications were presented to support this view. As evident in the following quotes, these justifications consistently included viewing science as being relevant to students' lives, and science teaching as necessary for building critical thinking and problem-solving skills and encouraging students' natural curiosity:

> Science requires students to rely on higher level thinking skills as they discover and investigate concepts related to their world. (T 3427)

> Children have a strong interest to learn about the world around them. As an educator, I hope to be able to incorporate this inherent desire to learn into my classroom. I feel a strong background in science is necessary for success in an increasingly global society. (Specialist 2)

A few participants thought that teaching science in elementary grades is important because it helps students achieve other curricular goals such as language arts objectives:

> Concepts in science relate directly to math. Science also connects to reading and writing. (T 0974)

Important Emphases in Elementary Science Content.

The classroom teachers and science specialists were quite similar in emphasizing the "basics" of the different content areas (biological, physical, and earth sciences). Generally, all participants indicated that science instruction should involve problem solving and inquiry-type activities where students are encouraged to explore, experiment, analyze, and make conclusions based on their observations as is evident in the following representative quotes:

> I think the most important thing to emphasize when teaching science is to think. (T 9862)

> Some of the behaviors I emphasize in the science room include: developing a keen awareness, actively pursuing observations and pondering them, looking for correlations, considering evidence, wondering and asking questions, hypothesizing and testing theories, predicting, explaining, and using logic. (Specialist 1)

> [Students need] to become more aware of senses and how to understand what the data from the senses can mean . . . This is problem solving, an organizational tool to train the brain how to evaluate data. (T 6085)

Consistent with their responses to the first question on the survey, participants noted that lessons should emphasize the relevance of science to the students' lives. The majority of participants felt that science instruction should serve to enhance students' interest in science and respect for the natural world. These views explicated by classroom teachers from both districts and the science specialists were generally in agreement with the reform's vision for science education:

> To teach awareness to the students' environment and how they, as individuals, fit into their natural surroundings – and how they can help preserve this for the future years. (T 9436)

> Students need to be introduced to the science around them – nature, trees, plants, oceans and other things they see, feel, experience and take for granted on a daily basis. (T 1613)

The science specialists, however, explicated several *additional* and *important* aspects relevant to elementary science teaching. Both specialists stressed the importance of inquiry in developing problem solving and critical thinking skills. Their views of inquiry were clearly more consistent with current definitions of "scientific inquiry" as explorations comprising many processes and methods to produce reliable knowledge:

> Science is a process for producing knowledge. The process depends both on making careful observations of phenomena and on inventing theories for making sense out of those observations. (Specialist 2)
>
> [Inquiry] enables students to ask questions and then develop experiments or research to answer the question in their own terms. (Specialist 1)

Contrary to the view held by the science specialists, 25% of the classroom teachers from the "specialists" district and 50% of the classroom teachers from the "comparison" district explicitly stressed the use of "The Scientific Method" as a single algorithm for "doing science" and solving problems:

> The Scientific Method and describing the steps involved is most useful. This helps the student to inquire about nature; follow an orderly, controlled approach to solving a problem. (T 8365)
>
> I think it is important to emphasize the scientific method. Students need to learn how to form a hypothesis and design an experiment to discover whether their hypothesis is correct. (T 2865)

Furthermore, in contrast to classroom teachers and consistent with the reform documents' emphases (AAAS, 1993; NRC, 1996), the science specialists identified specific aspects of the nature of science they felt are important to emphasize when teaching science. For example, Specialist #1 emphasized the importance of teaching students about the tentative nature of science. She noted that "providing students with the opportunity to explore their own misconceptions and to construct their own understanding of concepts will allow students to realize that scientific ideas are subject to change." She also stressed the importance of teaching the empirical and creative nature of science. The second science specialist emphasized the importance of cooperation, sharing of ideas, and the tentativeness of scientific knowledge.

Approaches to Science Teaching.

Participants' views were similar regarding the most adequate approach to teach science. Eighty-five percent of all the teacher participants believed that an active, "hands-on" approach that emphasized relevance of science to students' lives was the "best" approach to teach science. Such an approach was intended to allow students to develop and answer their own questions. One classroom teacher stated, "Let the kids manipulate science materials and problem solve using open-ended questions."

However, the science specialists differed in detailing a teaching approach that was more aligned with a "constructivist" view. They also stressed the importance of integrating the different subject areas. Both science specialists also expressed the need to provide students with several opportunities to explore, synthesize and make connections between concepts in various contexts:

> I feel that science should be taught by way of an inquiry or constructivist approach . . . [that] . . . emphasizes the use of concrete, hands-on experiences; draws upon multiple learning contexts from a variety of disciplines and settings; and maximizes the students' use of the concept in language, both written and oral. In this student centered teaching model, independent activities are designed to support the concepts being taught while students are responsible for constructing their own understanding of the concepts. (Specialist 2)

By detailing specific lesson examples in their responses to the survey, they both indicated that such extended lessons may span several weeks or even a whole term, and allow integrating other disciplines and skills such as mathematics, history, writing, and oral communication.

Assessment Strategies.

In regard to assessment practices, classroom teachers from both districts were quite similar in their responses. In general, they viewed the use of various assessment techniques, both traditional and alternative, as necessary for gaining a sense of student achievement. The most recommended assessment method was student projects coupled with oral presentations. The majority of classroom teachers believed that formal and informal discussions are also important for "accurate" assessment. Of equal status with discussions, based on frequency of responses, was the use of recall tests. The precise nature of such tests was not elucidated by any of the respondent teachers, but the frequent use of the term "recall" indicated that such exams would target assessment of student knowledge of specific content and vocabulary. Next in importance, again based on frequency of responses, were laboratory reports and worksheets when used as summative assessment methods. Finally, a few (15% of the participant teachers) indicated they would also include guided reflections, creative writings, and standardized tests in their assessment practices. Overall, the classroom teachers focussed on summative assessment techniques.

The two science specialists also stressed the use of a variety of assessment methods, although more emphasis was placed on formative assessments. Specifically, they detailed means to assess psychomotor skills, cooperative learning skills, and "thinking skills" primarily by observations, and questions and discussions with students during the class periods. The specialists noted that they use laboratory journals with writings and reflections to assess the affective objectives of the science program. Summative assessments included laboratory activity worksheets requiring summaries of student work, conclusions, and answers to open-ended questions.

Additionally, the two specialists stressed the relevance of student term projects and outlined the assessment guidelines of such projects. For example, students are required to conduct an investigation of their choosing and give an oral presentation to their peers. The presentation is videotaped and reviewed by the presenter and the teacher for feedback and reflection. Written reports are scored according to content, organization, grammar, and use of resources.

Constraints to Teaching Elementary Science.

Even though the teacher participants were not asked to explicate their concerns about their individual abilities to teach science, many teachers from the "specialists" district stated several constraints to teaching science at their grade level in their individual classes. Among these constraints were lack of time, content knowledge, experience, and equipment and space:

> Hands on activities are by far the best way to teach science to students . . . Unfortunately, in a regular classroom, it is more difficult to offer as many of these kinds of activities due to restraints such as preparation time, lack of materials and space. (T 3982)

> There is not enough time to prepare hands-on activities for the regular classroom teacher. Also, I do not have the vast scientific knowledge to draw upon. (T 1375)

Additionally, 16 of the 23 participant teachers from the "specialists" district indicated the need for the science specialists to effectively teach science to their elementary students. Again, it should be noted that the teachers were responding to the aforementioned survey questions and were not prompted in any way to express their views about their *abilities* to teach science or their views of the science specialists:

> Having a science specialist is a great help because it takes time to prepare a lab and gather the materials for it. The specialist has more time to do this than a classroom teacher that is preparing for many other subjects. The science specialist also has time to research information so they have more specific knowledge about the topic areas. (T 2865)

> The best approach is to have a person who is trained and interested in science. Most teachers are not qualified to teach all areas of science (and 7 other subjects at least) in their classroom to the degree that the trained science teacher is. (T 1677)

> Hand on activities are best. Having a science specialist is most beneficial because that person has the time, the place and the materials to do a more thorough job than the classroom teacher. (T 6464)

These constraints to teaching science in elementary classrooms are not different from those documented in the literature. However, teachers' beliefs regarding the significance of these constraints might have been aggravated by having observed and helped science specialists teach well-planned and involved science lessons. This might explain why many classroom teachers from the "specialists" district, and none from the "comparison" district, felt they needed to articulate the aforementioned constraints (whether real or perceived) to teaching science even though they were not prompted to do so.

Instructional Planning

In general, the "specialists" district elementary classroom teachers' instructional plans were not congruent with their views of science teaching. Many plans were heavily textbook-based, and involved activities in which students copied and/or labeled various diagrams. This finding is consistent with previous research on textbook use (Stake & Easley, 1978; Weiss, 1978, 1987). This was especially apparent in the case of most grade-5 lesson plans that required students to look at diagrams of cell types and label their components. Furthermore, much of the "hands-on" activities were little more than students "handling" different materials during a single class period.

The activities planned by classroom teachers were loosely linked to the assigned objectives and lacked a "minds-on" or reflective components. Activities were primarily demonstrations of specific content requiring very little by way of problem solving or critical thinking. Assessments mainly comprised worksheets for vocabulary, observations, and lower level comprehension questions, and written summaries of the activity. These lessons were not consistent with the teachers' aforementioned views of what and how science should be taught in their classrooms, nor were they consistent with the reform recommendations for elementary science teaching. In addition, some of the elementary teachers' plans included inaccurate science content. Only 4 out of the 23 classroom teachers (17%) provided adequate details and appropriate lessons for the objective they were assigned.

By comparison, the specialists used a variety of hands-on activities, purposefully and accurately designed to achieve the specified objectives. Their lessons included inquiry-based activities where students were required to develop hypotheses, design and conduct investigations, and analyze their observations in relation to their predictions. Specialists' lessons spanned several class periods and encouraged students to establish connections between several ideas. Assessment plans included worksheets, open-ended discussions, and written and oral summaries of lessons where students draw conclusions from several activities and make generalizations. As such, the science specialists' instructional planning, when compared with the planning of the classroom teachers, was more consistent with their views of science teaching and with the national reforms' recommendations for elementary science education.

"Effectiveness" of the Elementary Science Specialists

The "effectiveness" of elementary science specialists was defined in terms of achieving the "specialists" district elementary science program goals relative to what could be achieved by regular classroom teachers. To shed light on this relative effectiveness, statewide science tests scores for students in the "specialists" and "comparison" district were compared. To insure the meaningfulness of this comparison, the elementary science program teaching goals in the two districts were analyzed for overlap. Moreover, the potential of elementary science specialists to help students achieve "science literacy" was defined in terms of achieving science teaching goals specified in national reform documents (AAAS, 1993; NRC, 1996). As such, the two districts' elementary science program goals were compared with goals specified in these latter national documents for corresponding grade levels.

Comparison of Goals of the Elementary Science Programs.

The contrast focussed on the content of the goals for the two districts, their scope, and their appropriateness for the specified grade levels. In general, there was substantial overlap between the two districts' goals.

Of the "specialists" district's listed goals, at least 90% were in agreement with the *Standards* (NRC, 1996) and/or *Benchmarks* (AAAS, 1993) for each grade level. For grade 4, the "comparison" district submitted only two science goals. Both goals were related to understanding aspects of scientific inquiry. Thus, the percent match between the two districts' science goals for grade 4 was only 9%. However, according to the *Standards,* these common goals that targeted scientific inquiry are appropriate and important for grade 4 students. For grade 5, there was 74% agreement between the two districts' goals, with 96% agreement between the "specialists" district's goals and the *Standards*. Finally, for grade 6, there was 50% overlap in goals for both districts, with the "specialists" district having a 90% match with the *Standards* and/or *Benchmarks*.

The above level of overlap between the two districts' goals substantiated the meaningfulness of the comparison of student achievement of science goals in the "specialists" and "comparison" districts. Goals common to both districts and at least one of the national documents were used for comparing student achievement in the two districts.

Analysis of Statewide Test Scores.

Scores for the state's 1998 statewide science test for 5th grade students in the two districts were compared by multiple linear regression. A summary of the analyses is presented in Table 2. Student scores (total scores as well as individual skill area scores) served as response variables while district membership, school membership, and classroom teacher served as explanatory variables.

It was determined that class size, although variable from 11 to 29 students, was not significantly associated with the student achievement scores ($p > 0.05$). Moreover, no significant differences ($p > 0.05$) were evident between total science scores on the science achievement assessment, inquiry, earth science, and unifying concepts for students in the two districts. However, there were two areas where student scores differed significantly according to district membership. These areas were life science ($p < 0.01$) and physical science ($p < 0.001$). Compared to the 5th grade student participants in the "specialists" district, 5th grade students in the "comparison" district tended to score on the average 3 points higher in the life science assessment and 8.5 points higher in the physical science assessment. However, the *practical* significance of this difference is minimal given that scores on these assessments averaged around 520 points. Thus, a difference of 3 or 8 points out of 520, although statistically significant, is of no practical importance. As such, 5th graders in the two districts did not differ in their achievement as measured by statewide science assessments. In this regard, the elementary science specialists were not more "effective" than the elementary teachers in achieving those science program assessed by statewide science tests.

It should be noted that for total, inquiry, earth science, and physical science scores, there were significant differences according to the particular school ($p < 0.05$) as well as the particular

Table 2.
Summary of Multiple Linear Regression Analysis:
5th Grade Scores on the 1998 State Science Assessment.

Response variable	Explanatory variables[1]	Coefficient	Two-sided p-value
Total	District	-2.8888	0.0536
	School	2.3058	0.0189*
	Teacher	-0.7961	0.0242*
Unifying	District	-0.5414	0.6116
Life science	District	-3.0190	0.0052*
Physical science	District	-8.4129	0.0001*
	School	4.8652	0.0007*
	Teacher	-1.4319	0.0053*
Inquiry	District	-1.0948	0.5800
	School	2.5721	0.0473*
	Teacher	-0.9734	0.0368*
Earth science	District	-2.9361	0.2059
	School	3.2820	0.0313*
	Teacher	-1.2187	0.0263*

[1]For the "District" variable, student scores from the "comparison" district were used as the reference. Thus, the coefficient value represents the estimated difference in scores obtained by the "specialists" students relative to the "comparison" students.
* $p < 0.05$

teacher ($p < 0.05$). Again the *practical* significance of these differences (1 to 5 points) was minimal.

It should also be noted that these results were based on a single performance of 5th grade students from the two districts on the statewide science assessment. As previously explicated, these were the only comparable data available at the time the study was conducted. Nonetheless, the results indicate that 5th graders in the "specialists" district did not achieve better than students taught by regular classroom teachers on standardized tests. However, standardized tests typically measure student achievement of knowledge and comprehension level objectives.

Analysis of Student Work Samples.

Student work samples contained various laboratory activity worksheets, summaries, and reflections from the third term of the school year. Each student folder contained work related to 10–18 different activities. Examination of student work samples indicated that the science-related experiences provided to students in grades 4-6 in the "specialists" district were consistent with the instructional plans written by the science specialists. Students were provided multiple opportunities to engage in inquiry-based activities. Many of these activities required students to design a method to address a given problem or question, conduct the investigation, and analyze the results relative to the initial question or problem.

When analyzing these work samples student demonstration of the use of some systematic approach to an investigation, rather than random trial and error, was considered evidence of problem solving ability. Demonstration of consideration of relevant evidence and variables to reach a conclusion was considered evidence of critical thinking ability. In addition, accurate responses to analysis, application, synthesis, and evaluation questions were weighed as evidence for higher order thinking skills.

Analysis of student work samples indicated that, in general, students taught by the science specialists demonstrated adequate understandings of science content and processes, and made relevant connections between content, concepts, and relevant applications. In addition, students demonstrated achievement of higher level cognitive objectives including problem solving and critical thinking. Additionally, students were fairly successful in demonstrating skills of science-based inquiry. Specific achievements of the three grade levels varied somewhat and are described below.

Grade-4 Work Sample Analysis.

Fourteen samples from grade 4 were provided. All 14 students demonstrated adequate knowledge and comprehension of most of the activities. They all demonstrated skills in use of a hand lens, measurement devices such as scales and rulers, and graphing techniques. Most of the included activities required students to make and keep record of observations. For example, students examined various types of feathers. From their observations, students were asked to make some inferences as to the functions of the different types of feathers. This activity related structure and function, a goal common to the *Standards* recommendations for 4th grade science.

The 4th grade students were provided opportunities to develop and demonstrate achievement of problem solving and critical thinking skills while participating in relevant and on-going investigations. More than half of the students in the sample demonstrated problem solving skills and critical thinking abilities. For example, in an activity involving the motion of a pendulum, students were asked, "How is the height of a swinging mass related to its energy?" The students were asked to provide an initial hypothesis and then investigate how changing the initial height of the pendulum relates to the distance a wooded block is moved when hit by the pendulum. After collecting data, the students were asked to explain what they learned. One student adequately noted, "I learned that the higher the swing mass is the more energy goes up. The higher the swing, the more work is done." (Tyanna).

Students performed a three-week project where they compared the growth rate of a bean and a corn seedling. This project required students to make observations over the three-week period, measure plant height, graph their results, and interpret the graph to determine the relative rate of growth of the two seedlings. They were then required to prepare a written summary of their project. In general, the students consistently made appropriate observations, demonstrated measurement and graphing skills, and drew appropriate conclusions from their results. Most students demonstrated accurate understandings of their results. They were able to describe their observations and compare the bean and corn seedling growth rates.

> My bean was smaller than my corn plant on the first week. On the second week my bean plant sped ahead at 13 centimeters and my corn only at 9 centimeters. The corn plant didn't grow half as fast as the bean plant. The corn plant sticks straight up and the bean seems to pop its head out. The bean plant has wavy veins while the corn sticks straight up. There's a purplish [color] at the bottom of the stem [and] the bean plant is mostly green. (David)

Students were also given opportunities to reflect on the activities in which they were engaged. When asked what the most interesting part of the corn/bean investigation was, most students responded favorably towards measuring the plants over time and then being able to determine that one grows faster than the other. To these students, the activity was fun, relevant, and an exercise in data collection and analysis.

Grade-5 Work Sample Analysis.

Eight samples from grade 5 were provided. All eight students demonstrated knowledge and comprehension of most of the activities in the folders. Their folders also indicated that these students had practice in using hand lenses, microscopes, measurement devices such as scales and rulers, and graphing techniques. All were able to make applications of concepts and analyze results, at least, in some of the activities. Most students consistently demonstrated adequate observation, description, and comparison abilities as they were provided many opportunities to engage these skills.

Of the eight students, only three demonstrated consistent problem solving and/or critical thinking abilities. The other five were inconsistent in applying problem solving and critical thinking. They were often unable to make connections between observations and inferences based on the questions of interest. In addition, they did not always carry out adequate analyses of data or reach relevant conclusions. For example, in an investigation of the effects of water temperature on respiration rate in fish, the students were asked to make a prediction as to how they think the water temperature affects the number of gill beats of the fish. Students conducted the experiment by counting gill beats of a fish in warm and cool water. The variety of student responses revealed that not all students were able to relate the data to their original hypothesis or even the topic of interest. One students noted that, "The average of the temp. when it was cold is 40. The average of the temp. when it was warm is 129. The highest cold temp. is 42. The highest warm temp is 150" (Russ).

The responses of a few students demonstrated an understanding of the experiment and some critical thinking skills. These students related the collected data to their original hypothesis in order to draw appropriate conclusions. For example, Julia noted that, "At 19 degrees my average beats per minute was 61. Then, at 28 degrees, the average beats per minute was 103. That raised 49. My hypothesis was right, when it got warmer the beats were faster."

Fifth grade students participated in several inquiry-based investigations. One such activity required students to design a container that "would hold as much heat energy as possible." Students were asked to describe their design, test it, and then describe how well it worked. They were to compare their designs and results with others in the class, and then suggest reasons for why their design worked well or not-so-well and suggest ways to improve it. Reports from this inquiry-based exercise indicated that most students (more than two thirds) were successful in demonstrating some inquiry-related skills such as design, testing, and making appropriate generalizations based on collected evidence. One student, Jennifer, reported her design and results to demonstrate problem solving, critical thinking, and inquiry-based skills involved in the investigation:

> This is the way we built our container. First we took one foam cup and tore the top part of the cup off. Then we took our other two whole cups and put one inside another. Next we took the bottom part of the cup and put it upside down in the two whole cups. Then we took our top part and stuffed it between the two whole cups and the one bottom . . .Our cup worked better because we had double insulation and it didn't have as much room to travel in. We could have improved it by pushing our top down more. (Jennifer)

In general, grade 5 students demonstrated some problem-solving and critical thinking abilities, although somewhat inconsistently. Similar to the 4th grade sample, students in the 5th grade sample were provided opportunities to develop problem-solving and critical thinking skills while participating in relevant and on-going investigations.

Grade-6 Work Sample Analysis.

Eighteen samples from grade 6 students were provided. All folders from the 6th graders contained a variety of inquiry-based activities that involved making observations, descriptions and predictions, collecting, analyzing, and synthesizing data, and applying the target concepts. One such activity required students to predict how temperature affects germination of radish seeds. They were to state a hypothesis, follow the general procedure given to them to collect relevant data, and then state their conclusions. They were not given any guiding questions to prompt them to relate their observations to their stated hypothesis. Thus, those students who drew appropriate conclusions from their data were considered to demonstrate critical thinking. Students were also asked to apply what they had learned to other plants in different climates. The analyzed work samples showed that a few students were able to infer meaning from relevant evidence, and then apply their knowledge to plant survival in different climate conditions:

> Hypothesis: I think that the seeds in the warmer temperature will grow and the others will die. This is because seeds need lots of sunlight and water and the right temperature to start growing.
>
> | | | | |
> |---|---|---|---|
> | Data: | Warm area: | # of seeds germinated: 10 | Total seeds: 10 |
> | | Cold area: | # of seeds germinated: 1 | Total seeds: 10 |
>
> Conclusions: The warm seeds grew better than the cold seeds, I found. Actually much better. About 97% of the warm seeds grew, but only about 22% of the cold seeds grew. So my hypothesis was right. The warm seeds grew better than the cold seeds.
>
> How would a change in climate select certain plants? If there was a loss of temperature it would probably kill the warm climate plants. If the temperature rose the cold climate plants would die. If tit began to rain, the desert plants would die. If it dried out, the rain forest plants would die. (Brian)

Controlling variables was common to many of the activities. For example, one activity involved the study of the concentration of borax on the texture of the final "GAK" product. The stated purpose of this activity was "to conduct a controlled experiment using one variable." One student, Andy, concluded that:

> The more borax solution you put in, the rougher the texture and the chunkier the gak is. I thought that the more borax you put into the mix the rougher the texture was. That was right. [Sample] M had 12 ml of borax solution, which was the most, and it had the roughest texture. Versus [sample] A which was "pourable" and looked like milk.

Some students suggested investigations to further explore their questions that arose from doing the investigations:

> As the concentration got higher the velocity [viscosity] also got higher. [Sample] A was liquid because it had less borax solution, and M was really hard because it had a lot of borax solution . . . One question I came with while working on it was, Would it affect the result of the gak by using salt water? (Delores)

Another activity required students to design an investigation to determine the relative densities of several liquids. The students then performed their proposed designs, analyzed their data, stated their conclusions, and reflected on the appropriateness of their procedure. The sample presented here demonstrates a logical thought process before and during the investigation to solve the target problem:

> Problem (given): Find which liquid is the most dense. Find the least dense liquid. Fill the small test tube with all four liquids stacked in colored layers, with the most dense liquid on the bottom.
>
> Strategy (Explain how you will solve the problem): We will mix 2 colors and find out which of the 2 is more dence [dense]. We will do it again with the other colors. Then we will test the dencer ones and find the more dence one and then we will do the same with the least dence. Last we'll stack 'em.
>
> Notes: We put red on the bottom first and then we put yellow on the top. They mixed so we put yellow on the bottom and they didn't mix. So red was more dence. Next we did green and blue with green on the bottom and blue on the top. They mixed, so we tried again and blue was more dence. Then we mixed yellow and blue, yellow was more dence. Then we knew that yellow was most dence. Blue was next. Red was second to least and green was the least dence.
>
> Conclusion: The most dence color was yellow and the least dence color was green. [She included a picture of the final test tube with the stacked liquids.] (Katie)

These types of activities indicated that the students were provided many opportunities to develop inquiry-related skills. In regard to these activities, the larger majority of these 6th graders demonstrated adequate knowledge and comprehension of the science content and concepts. More than two thirds of them demonstrated competent problem solving abilities, and critical thinking skills.

Several students demonstrated proficiency in synthesizing several ideas in order to answer another question. For example, students were given information about the tide levels at various times during several months. They were also studying the phases of the moon. Students were asked to relate the level of the tides with the positions of the moon. In addition, they were required to incorporate the effect of the gravitational pull from the moon and sun. Of the eight portfolios that contained this activity, six demonstrated understanding of the relationships. Four of these were able to suitably represent their ideas with both diagrams and written descriptions.

Summary of Analysis of Student Work Samples.

Analysis of student work samples indicated that the majority of students taught by the science specialists demonstrated understanding of science content and processes as evident in their problem-solving centered investigations and abilities to make inferences and connections from several activities. The instructional planning of the science specialists and apparent student achievement of higher order objectives revealed that the science specialists were successful in implementing their views of science teaching. They also demonstrated their ability to help students achieve science instruction goals congruent with those called for in national reform documents.

Conclusions

This study lends some empirical support to the suggestion that elementary science specialists may be more effective than regular classroom teachers in implementing the reforms' vision for elementary science education. The elementary classroom teachers in both districts expressed views of science teaching that were similar to those of the science specialists' views. The views of the science specialists, however, were more consistent with current views of "effective" elementary science instruction. Moreover, unlike the science specialists, the instructional plans of the classroom teachers were not congruent with their stated views of science teaching. In general, the elementary classroom teachers' planned lessons included few student-centered activities with minimal opportunities for student inquiry or enhancement of higher level cognitive objectives. In contrast, the lesson plans of the science specialists, as well as evidence for their planning included in the student portfolios, indicated that students taught by the science specialists were engaged in multiple activities, aimed to integrate several concepts and *engage* students in constructing meaning.

Analysis of science achievement for students taught by the classroom teachers versus students taught by science specialists indicated that students in grade 5 did not differ in achievement as measured by the statewide science assessment. However, analysis of other student data demonstrated that students in grades 4–6 taught by the science specialists did demonstrate higher order cognitive skills such as problem solving and critical thinking. In addition, as previously stated, the science specialists planned and implemented lessons appropriate for enhancing these skills. They used a variety of teaching approaches and encouraged students to make applications of the science content in the classroom to every day situations.

Even though more research is in order, the results of the present study seem to indicate that the *likelihood* was minimal for the classroom teachers in the "specialists" district to implement as effective an elementary science program as that implemented by the science specialists. The instructional planning of the classroom teachers suggested they were more likely to deliver teacher-centered, textbook-driven science lessons that targeted acquisition of knowledge and comprehension level instructional objectives. Classroom teacher plans did not articulate activities that would involve students in open-ended investigations that aim to help them develop higher order and critical thinking skills.

The quality and emphases of classroom teachers' planning (and possibly teaching practices) could be attributed, at least in part, to their limited content knowledge. This inference is supported by the fact that the elementary science specialists and classroom teachers in the specialists' district differed mainly in their science content knowledge. This inference is also consistent with previous research relating subject matter knowledge and teaching approach. (Dobey & Shafer, 1984; Hashweh, 1987; Hollon, Roth & Anderson, 1991). The science specialists' elaborate science content knowledge and science teaching experience may account for their success in implementing a science program that targets higher order objectives, and encourages inquiry, problem solving, and understanding of the nature of the subject (Hollon, Roth & Anderson, 1991; Lederman, 1992).

The apparent absence, in the case of the science specialists, of many of the constraints for teaching science in elementary classes often voiced by classroom teachers, coupled with evidence that supports the effectiveness of the specialists' program suggests that there may be a significant role for elementary science specialists in promoting "science literacy" among elementary students. However, the cost of supporting such a science program may be unrealistic for many school districts (Rhoton, Field, & Prather, 1992). Using science specialists solely as subject matter teachers may prove to be cost-ineffective. Several models for the use of elementary science specialists have been described that involve the specialists in a variety of roles (Abell, 1990). For instance, science specialists could play an active role in the professional development of elementary teachers. In the case of the present study, however, the science specialists assumed all responsibility for science teaching to the demise of their role in professional development. Furthermore, critics of the role of elementary science specialists suggest that such exclusive use of specialists in science teaching makes science more elite and impersonal (Hounshell & Swartz, 1987). Further investigation into these concerns is needed in order to develop a more complete understanding of the potential benefits that science specialists could bring into elementary science teaching. The present study provides evidence of the apparent benefits toward student achievement of "science literacy."

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PRESERVICE MIDDLE AND SECONDARY SCHOOL TEACHERS' MISCONCEPTIONS ABOUT MAKING MEASUREMENTS USING LABORATORY INSTRUMENTS

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Though measurement skills continue to be a curriculum focus in schools (American Association for the Advancement of Science, 1993; National Council of Teachers of Mathematics, 1989; National Research Council, 1996), U.S. students score poorly on measurement tests (U.S. Department of Education, 1996, 1997). According to the *Third International Mathematics and Science Study* (TIMSS), U.S. fourth and eighth grade students received their lowest scores in mathematics in areas that assess measurement skills (U.S. Department of Education, 1996, 1997). Measurement scores were not reported for grade twelve (U.S. Department of Education, 1998).

In the TIMSS report, U.S. fourth grade students scored above the international average in both mathematics and science. In science, fourth grade students were outperformed by only one of twenty-six nations and in mathematics by seven of twenty-six nations. Of the six mathematics subtests, only the measurement subtest was below the international average.

U.S. eighth grade students in the TIMSS study scored slightly above the international average of 41 countries in science and scored below the international average in mathematics. The U.S. received its lowest ranking, 36 out of the 41 countries, on the measurement portion of the mathematics assessment. Further results from the study indicate that U.S. eighth graders scored at or about the average in algebra; fractions; and data representation, analysis, and probability. However, they scored below the average in the areas of geometry, proportionality, and measurement. It was also stated in the TIMSS report that "the weaker performance in these latter three topics may pull the overall U.S. score down to below average" for eighth grade (U.S. Department of Education, 1996, p. 27).

Yet the U.S. literature has consistently reflected the importance of measurement to, both, the fields of mathematics and science. "Measurement has been identified as one of the twelve components of essential mathematics for the twenty-first century by the National Council of Supervisors of Mathematics (1989), which noted that 'students should learn the fundamental concepts of measurement through concrete experiences'" (Geddes, *et al*, 1994).

As a topic of emphasis in the National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics* (1989), measurement is mentioned as being of "central importance to the curriculum because of its power to help children see that mathematics is useful in everyday life and to help them develop many mathematical concepts and skills" (p. 51). Curriculum standard 10 for grades K-4, states that students should "develop the process of measuring and concepts related to units of measurement; make and use estimates of measurements; make and use measurements in problem and everyday situations" (NCTM, p. 51). Furthermore curriculum standard 13 for grades 5-8, relates that students should "extend their understanding of the process of measurement; estimate, make, and use measurements to describe and compare phenomena; and select appropriate units and tools to measure to the degree of accuracy required in a particular situation" (NCTM, p. 116).

The *National Science Education Standards* (1996) and *Benchmarks for Science Literacy* (1993) suggest that with the advances of modern technology heading into the twenty-first century, accuracy of measurement is becoming increasingly vital. Students must master these skills in order to make informed decisions and for the U.S. to remain competitive in our global society. Not only is measurement an integral part of the mathematics curriculum, it is also a necessary skill in science.

Hiebert (1984) found that first grade students are ready to learn measurement concepts and benefit from participating in a variety of concrete measuring experiences. He suggests that effective instruction should be designed to deal with children's underlying misconceptions.

Measurement continues to be one of the content strands in the National Assessment of Educational Progress (Reese, Miller, Mazzeo, and Dossey, 1997). According to the National Assessment of Educational Progress reports, the more experience students have using scientific equipment (Mullis and Jenkins, 1988; O'Sullivan, Reese, and Mazzeo, 1997) and the more types of equipment they use (Jones, Mullis, Raizen, Weiss, and Weston, 1992) the higher their achievement level is in science. It would seem to follow that knowing how to use the equipment accurately would also support if not enhance the meaningful learning of science.

Mullen (1985) analyzed how well elementary teachers from a state in the mid-Atlantic region of the country understood measurement by administering a written assessment. The results from the research project indicated that elementary teachers had difficulties with items involving the approximate nature of measurement and operations with approximate numbers (Mullen, 1985). Mullen (1985) also reported that teachers demonstrated many misconceptions about the use of significant digits.

This particular study was conceived when the lead author observed in the laboratory that with few exceptions college freshmen chemistry students did not know how to make accurate measurements. Once the students were made aware of this, they easily learned how. From this experience and in the interest of breaking the cycle, it was decided to assess the ability of preservice science teachers in a graduate education program to make accurate measurements using common laboratory equipment and to analyze the types of misconception they had.

If our children are to understand the concepts of measurement and be able to accurately perform measurement tasks, then it is imperative that their teachers understand the principles of measurement in order to teach the concepts in an appropriate and accurate manner. If teachers do not understand the fundamental and practical principles of measurement, then it would be highly unlikely that their students will learn these skills from them.

Methodology

As science educators, we were interested in developing a simple performance-based assessment format to evaluate preservice teachers' understanding of measurement. In addition, since the study was conducted as part of preservice science methods courses, we wanted the measurement assessment activities to be easily adaptable to high school and middle school students so that the preservice teachers could use the activities in the future to assess their students' understanding.

For this study, 195 middle and secondary school preservice science teachers (graduate students) completed three different measurement tasks. These tasks involved measuring the length of a plastic straw with a meter stick, the volume of a water sample with a graduated cylinder, and the mass of a test tube stopper with a triple-beam balance. Data were compiled over a three year period for all preservice science education classes offered during that time.

Subjects

The 195 subjects participating in this study had all completed a bachelor's degree and were enrolled in a 5th year teacher-certification program at a major university in the Mid-Atlantic region of the United States. Indicative of the highly mobile population in the area, over 75% of the preservice teachers had completed their bachelors degree from another institution.

A total of 146 students were enrolled in The Teaching and Learning of Science in Middle Education course. This three credit graduate course is part of the teacher licensure program for preservice teachers grades 4-8. The course emphasizes the collection, organization, and interpretation of data resulting from inquiry-based activities. This is a "hands-on" activities course in the biological, physical, and earth sciences which requires students to plan curriculum materials that meet state and national standards. Field experience in the public schools is also required.

In addition to these students, 49 students were enrolled in Teaching Science in Secondary Schools, which is also a three credit graduate course for preservice science teachers grades 9-12 who seek licensure in earth science, biology, chemistry, or physics. The course involves the methods, materials, content, and organization of science programs. Emphasis is placed on curriculum planning, current methodologies, and trends in education that are applicable to secondary schools. Field experience is required for those seeking initial teacher licensure.

For both classes, 48% of the teachers were between the ages of 20-29. However, the educational level (beyond a bachelor's degree) of students in the two classes varied. For the students in the secondary school class, 26% had earned a master's degree or higher, as opposed to 9% of the middle school teachers. Another difference between the two classes was in the area of gender. The male-female ratio in the middle school class was 24:76, as compared to 52:48 for the secondary school class.

All preservice teachers from both courses completed the measurement tasks during one of the first class meetings in either the Fall 1993, Fall 1994, Spring 1995, Fall 1995, or Spring 1996 academic semesters.

Performance Tasks

Each participant measured (as accurately as the apparatus allowed) the length of a plastic straw using a meter stick, the volume of water in a graduated cylinder, and the mass of a test-tube stopper using a triple-beam balance (Sterling, 1998, 1999). The objects to be measured were all selected or set between the lines of measurement on the measuring devices, thus necessitating estimation of the final digit. The actual measurements for each item were pre- and post-determined by the course instructor and graduate assistant.

Written and oral instructions were presented to the participants in order to ensure that the directions were understood. The two written instructions were, "Make all measurements as accurately as the instrument allows," and "Label all units." In addition, a brief oral explanation of each measurement station was given. Each participant had an unlimited number of attempts to perform the measurement task and could take as many measurements as they deemed necessary in order to ensure that their measurements were accurate. After completing each task, the participants wrote their responses on a data sheet. All measurement data were collected anonymously.

The length measurement station was set up with a meter stick and one plastic straw. The participants were allowed to use any method or procedure that would allow them to measure the length of the straw as accurately as possible using the meter stick. For the volume measurement task, water was placed in a 50 ml, glass, graduated cylinder. A drop of blue food coloring was added in order to allow the meniscus to be read more easily. After all, this was a test of measurement skills, not vision. In addition, a piece of Parafilm was secured on top of the graduated cylinder to prevent the water sample from evaporating over time. The participants were allowed to move around however they desired in order obtain an accurate reading of the water sample.

In arranging the station for the mass measurement task, two different test tube stoppers and triple-beam balances were set up. Two different mass stations were set up because the preservice teachers generally take much more time to measure mass than either length or volume. To facilitate class discussion of mass data after all measurements were made, the two stations were set up so that the test-tube stoppers had the same mass. This was done by using a more accurate balance and placing a small amount of clay in the hole in the stopper until both stoppers had the same mass on the more accurate balance as the two balances used by the preservice teachers. Each station was labeled separately, and the participants were instructed to record the label on their response sheets. After recording the mass of the stopper, the participants were also instructed to reset the balances back to zero.

Criteria for Accurate Responses

The National Bureau of Standards and National Science Teachers Association (Youden, 1984, 1985) recommend procedures for accurate measurement which are used by scientists and science textbook publishers (Gabel, 1993; Haber-Schaim, *et. al.*, 1987; Nelson and Kemp, 1977). Criteria for determining whether a response was completely accurate, or not, was based on two major factors: 1) accuracy of actual digits measured and 2) designation of the appropriate standard measuring unit.

For recording the actual digits, if a meter stick initially indicates that the length of a plastic straw is somewhere between 19.5 cm and 19.6 cm, then the participant would be expected to make a more precise reading and determine the most accurate measurement such as 19.57 cm, by estimating the final digit. In addition, a standard error of $\pm$ .02 cm, .2 ml, and .03 g was taken into account when determining the accuracy of the measurements. So in the case of 19.57 cm, the measurements 19.55, 19.56, 19.57, 19.58, and 19.59 cm would be considered accurate.

For the standard units of measurement, the participants were expected to include the appropriate measuring unit in their responses. In the case of length, both millimeters and centimeters were considered correct as long as the appropriate digits and decimal place were recorded. Nonstandard abbreviations of the measurement units were not considered correct.

Analysis of Measurement Misconceptions

The measurement data collected were analyzed for types of misconceptions. For the actual digits measured, the misconception categories identified were (1) number of "significant digits", (2) answers in the form of "fractions", (3) missing "initial digit", (4) "multi-unit" combinations of two or more units in an answer, and (5) one labeled as "other" for measurements that appeared well off the mark. The final number of "significant digits" was divided into three subcategories (all significant figures correct, one significant figure missing, and two significant figures missing). These subcategories were used to record the number of digits that were measured accurately. If the final answer should include four digits and the student gave a correct answer containing only three digits, then the response was recorded in the "one missing figure" category. In another category, participants wrote their responses in the form of fractions, when all of the measuring devices were metric instruments. Missing "initial digit" describes the category that was created for responses where the initial digit was missing such as 9.75 cm, when the correct answer was 19.75 cm. Responses that included two units of measurement in the answer, such as 19 cm 6 mm, would also be marked as incorrect and recorded in the "multi-unit" category. Finally, a response of 20.8 g to an answer of 27.75 g would be marked as incorrect in the "other" category..

Misconceptions relating to the standard units of measurement existed in two forms: (1) the unit was incorrect, such as a response of 19.77 mm when the correct answer was 19.77 cm and (2) the correct unit was recorded with a non-standard abbreviation, such as "gm" for grams instead of "g".

Results and Discussion

The data were compiled in the form of three different data sets that corresponded to the type of measurement conducted (length, volume, and mass). Each data set was further divided into 2 groups, middle and secondary school preservice teachers. Incorrect answers were analyzed to determine misconceptions.

Accurate Measurements

Though neither group did very well, the secondary school teachers performed better than the middle school teachers on all the measurement tasks (see Figure 1 & Table 1). The chi-square test was used to determine that there is a significant difference between the values recorded for the middle and secondary teachers at the .001 level. Therefore, the null hypothesis stating that there was no significant difference between the ability of preservice middle school and secondary science teachers to make accurate measurements was rejected.

Figure 1. Percentage of completely accurate measurements for preservice teachers on each measurement task.

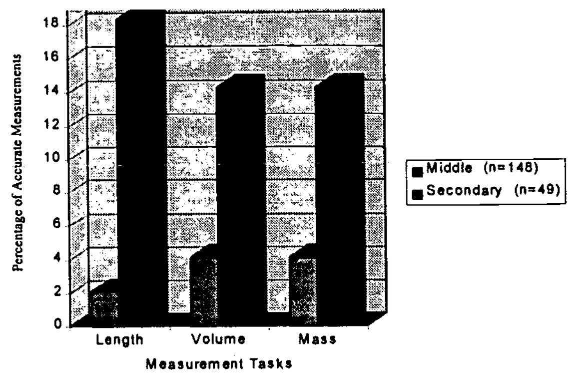

Table 1
Percentage of Completely Accurate Measurements

		Measurement task		
Group	n	Length	Volume	Mass
Middle	146	2.1	4.1	4.1
Secondary	49	18.4	14.3	14.3
Mid. + Sec.	195	6.2	6.7	6.7

Note. $X^2 = 17.1$, df=1, p<.001

For the length measurement task, only 6.2% (or 12 out of the total 195 participants) responded with completely accurate measurements for the length of a plastic straw. Out of this group, 9 of the 12 participants who responded correctly were secondary school teachers. When the two groups were analyzed separately, it was found that 18.4% of the secondary school teachers provided correct responses as opposed to only 2.1% of the middle school teachers.

For volume, the data indicated that 6.7% of the teachers provided completely accurate responses for the measurement of a water sample in a graduated cylinder. Again, the secondary school teachers provided more correct responses than the middle school teachers. Of the secondary school teachers, 14.3% responded with completely accurate measurements compared to 4.1% of the middle school teachers.

Results of the mass measurement task indicated that the teachers responded similarly to the way they did on the two other measurement tasks. It was found that 6.7% of the teachers responded with completely accurate measurements for the rubber test tube stoppers. As the two groups were compared to each other, it was discovered that 14.3% of the secondary school teachers provided completely accurate measurements as opposed to 4.1% of the middle school teachers.

Misconceptions in Measurement

For length, the most common misconception for both groups occurred in the estimation of the final significant digit with 74.4% of the preservice teachers making this type of measurement error (see Figure 2 & Table 2). The second most common misconception involved using the wrong standard unit of measurement. The data revealed that 32.8% of the teachers had misconceptions in reporting units of measurement with 40.4% of middle school teachers making more errors in this area as compared to 10.2% of the secondary school teachers. Also for the length measurement task, 7.7% of the teachers had misconceptions that were classified in the fraction category. For missing initial digits, 8.7% of the misconceptions were in this category, 1.0% in the multi-unit category, and 2.1% of the misconceptions were classified in the "other" category.

Figure 2. Percentage of misconceptions on the length measurement task for middle and secondary teachers.

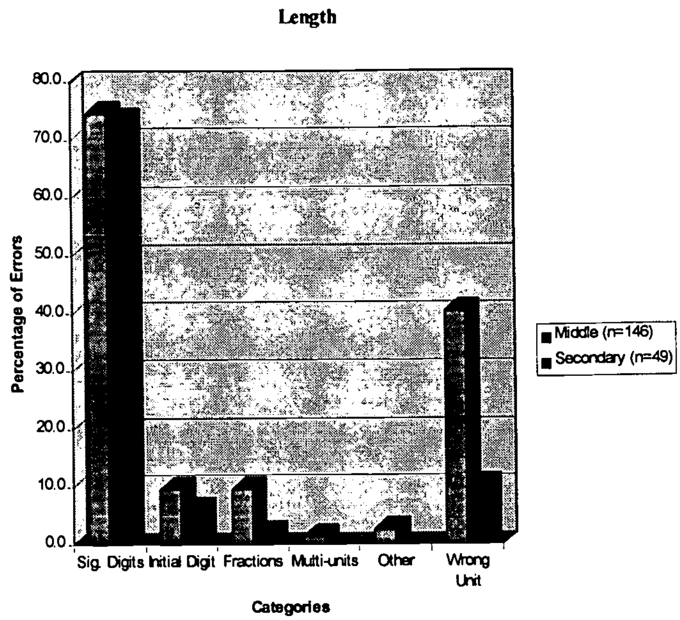

Table 2
Percentage of Misconceptions for Length Measurement Task

		Misconception Categories					
Group	n	Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	74.6	9.6	9.6	1.4	2.7	40.4
Secondary	49	73.5	6.1	2.0	0.0	0.0	10.2
Mid. + Sec.	195	74.4	8.7	7.7	1.0	2.1	32.8

Note. The values represent percentages of responses due to a particular type of misconception.

For volume the most common misconception was also accurately measuring the significant digits with 83.6% of preservice teachers making this type of error (see Figure 3 and Table 3). Both groups faired well in listing the appropriate unit of measurement for the volume task, as only 7.2% of them responded incorrectly in this category. This trend was noticed across both teacher groups as only 8.2% of the middle school teachers and 4.1% of the secondary school teachers had misconceptions in using the correct standard measuring unit for volume measurements. The volume measurement task provided fewer misconceptions in the other respective categories. Only 2.1% of the misconceptions were classified in the fraction category, while only 1.5% of the misconceptions fit into the missed initial digit category. There were no misconceptions in the multi-unit category, but 5.6% of the misconceptions were classified in the "other" category.

Figure 3. Percentage of misconceptions for the volume measurement task for middle and secondary teachers.

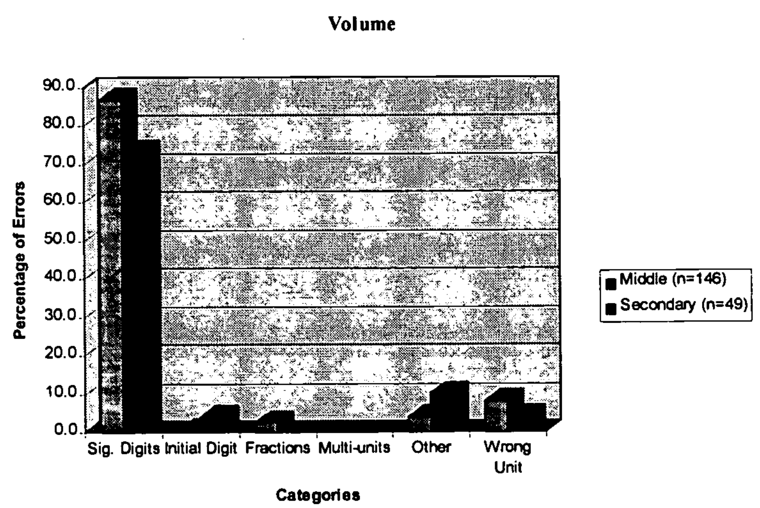

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Table 3
Percentage of Misconceptions for Volume Measurement Task

		Misconception Categories					
Group	n	Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	86.9	0.7	2.7	0.0	4.1	8.2
Secondary	49	73.5	4.1	0.0	0.0	10.2	4.1
Mid. + Sec.	195	83.6	1.5	2.1	0.0	5.6	7.2

Note. The values represent percentages of responses due to a particular type of misconception.

For mass, 65.1% of the teachers recorded the number of significant digits incorrectly. The percentage of teachers who used the incorrect standard measuring unit in their responses was 16.9% (see Figure 4 & Table 4). The two groups also displayed similar results in using the incorrect measuring unit in their responses as 16.3% of the secondary school teachers and 17.1% of the middle school teachers recorded the inappropriate unit. Data from the mass measurement task indicated that 3.6% of the teachers recorded measurements in fractions. Only 0.5% of them had misconceptions classified as missed initial digits, and 1.0% were in the multi-unit category. On the other hand, 21.5% of the teachers recorded measurements that were recorded in the "other" category.

Figure 4. Percentage of misconceptions for the mass measurement task for middle and secondary teachers.

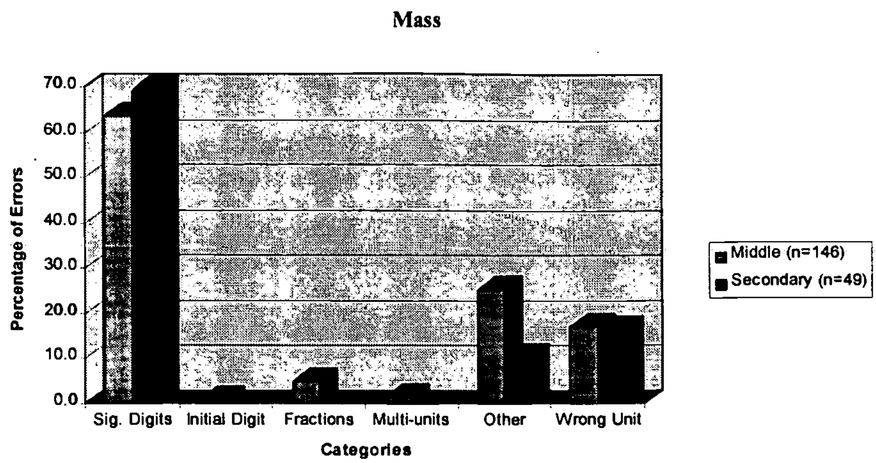

Table 4
Percentage of Misconceptions for Mass Measurement Task

Group	n	Misconception Categories					
		Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	63.7	0.7	4.8	1.4	25.3	17.1
Secondary	49	69.4	0.0	0.0	0.0	10.2	16.3
Mid. + Sec.	195	65.1	0.5	3.6	1.0	21.5	16.9

Note. The values represent percentages of responses due to a particular type of misconception.

Significant Figures

The significant figure data for length, volume, and mass is further broken down in Figure 5 and Table 5. This figure illustrates that not only do most preservice teachers eliminate the final significant figure but many did not correctly measure the final two digits, especially for volume and mass. For middle school preservice teachers, 61.6% eliminated the final digit and 13.0%

missed the final two digits for length, 36.9% eliminated the final digit and 50.0% missed the final two digits for volume, while 29.5% eliminated the final digit and 34.2% missed the final two digits for mass. For secondary school preservice teachers, 67.4% eliminated the final digit for length while 6.1% missed the last two digits. For volume, 40.8% eliminated the final digit and 32.7% missed the last two. For the mass measurement task, 44.9% of the preservice teachers in the secondary school group eliminated the final digit, while 24.5% did not record correct responses for the final two digits. Accurately reading all of the significant digits was the most common misconception for both middle and secondary preservice teachers.

Figure 5. Percentages of significant figure responses for measurement tasks, for significant figures recorded correctly, with one figure missing, or two significant figures missing.

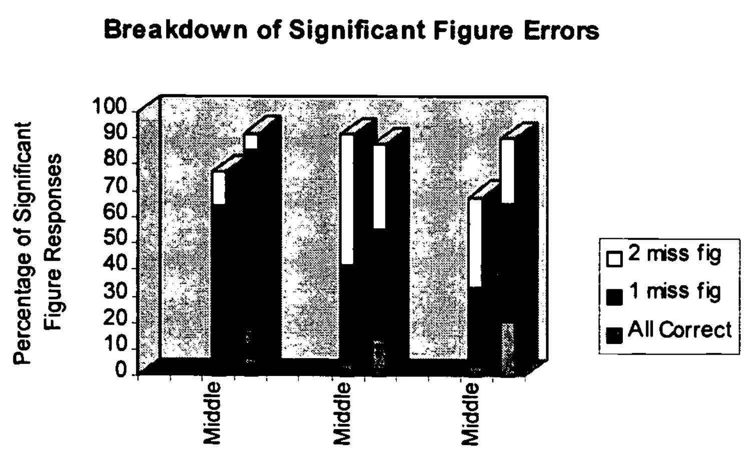

Table 5
Breakdown of Significant Figure Errors

Tasks	Group	Significant figures (%)		
		All correct	1 missing figure	2 missing figures
Length				
	Middle	2.7	61.6	13.0
	Secondary	18.4	67.4	6.1
Volume				
	Middle	4.8	36.9	50.0
	Secondary	14.3	40.8	32.7
Mass				
	Middle	4.1	29.5	34.2
	Secondary	20.4	44.9	24.5

Standard Units of Measurement

When analyzing the data regarding units of measurement, we found that the misconceptions included responses in which an incorrect unit was recorded (e.g., a response of 19.75 mm when the correct answer should have been recorded in centimeters [cm]), responses in which the standard unit of measurement was not correctly abbreviated (e.g., a response of 89.37 gms. when the correct abbreviation should have been recorded as "g"), and responses in which the unit of measurement was completely omitted.

For the length measurement task, 28.8% of the middle school teachers recorded an incorrect unit of measurement (see Table 6). This was, by far, the greatest percentage of misconception for units of measurement for both groups. Only 6.1% of the secondary school teachers had misconceptions in this category. Also for the length measurement task, 1.4% of the middle school teachers incorrectly in abbreviated the unit, and 2.7% did not record units for their measurements. As for the secondary teachers, none of them (0%) had any misconceptions in abbreviating the unit for length. However, 2.0% omitted the unit from their measurement responses.

Table 6
Percentage of Errors for the Standard Units of Measurement

		Measurement task		
Error type	Group	Length	Volume	Mass
Incorrect unit				
	Middle	28.8	2.7	5.5
	Secondary	6.1	0	0
Abbreviation				
	Middle	1.4	0	2.1
	Secondary	0	0	6.1
Missing unit				
	Middle	2.7	2.7	3.4
	Secondary	2.0	4.1	10.2

For the volume measurement task, 2.7% of the middle school teachers responded with incorrect units of measurements. None (0%) of the secondary teachers had incorrect responses in this category. Neither group appeared to have any problems with abbreviating the unit for volume as none of them (0%) recorded incorrect abbreviations for this measurement task. As the data was analyzed for missing or omitted units for volume, we found that 2.7% of the middle school teachers omitted the units from their responses while 4.1% of the secondary school teachers failed to record any units for the measurement task.

For mass, the data revealed that 5.5% of the middle school teachers recorded incorrect units in their responses, 2.1% abbreviated their units incorrectly, and 3.4% omitted units from their responses. Data for the secondary school teachers revealed that none of them (0%) responded with an incorrect unit. However, 6.1% of them did not abbreviate their units correctly, and 10.2% of them did not record a unit with their responses. The latter percentage was the most common unit of measurement error for the secondary school teachers among all three measurement tasks.

Missing Initial Digit

The misconception that we had not anticipated was the missing initial digit. It became apparent when analyzing the measuring devices that devices such as meter sticks often label in increments of one through nine between larger increments of 10, 20, 30, and so on. For people who have not yet internalized how big a quantity is, the large unit is overlooked leading to measurements such as 8 instead of 28. For preservice teachers the data revealed initial digit misconceptions for length of 8.7%, for volume of 1.5%, and for mass of 0.5%.

Preservice Teachers' Reaction

After the preservice teachers performed the measurement tasks and turned in their responses, they got to see the class results. They were surprised to find that most of them did not know how to measure accurately. The instructor led a discussion about the performance assessment activity and pointed out common misconceptions that occur. Many of the preservice teachers, particularly the middle school teachers, expressed that they could not remember being taught how to make accurate measurements. They had always just assumed that they know how to make measurements accurately.

In the secondary class, the discussion also suggested that the special education science teachers had greater difficulty in making measurements. Since the data was collected anonymously within each class, this can not be proved. However, since these teachers tend to have less science background, it would seem likely that they would have greater difficulty.

Youden (1984) stated that "when making scientific measurements, it is standard practice to estimate positions in steps of one tenth of the interval." He went on to state that "in scientific work the knack of estimating tenths of a division on scales and instrument dials becomes almost automatic. The way to acquire this ability is to get some practice" (Youden, 1984).

After the common misconceptions were brought to the preservice teachers' attention, they displayed no problems in making the necessary adjustments to minimize errors. The only innovation used in teaching how to measure was a transparency of a meter stick which when projected on a screen allowed the teachers to physically see how the measurements were determined. The size of most instruments makes it difficult to directly observe what is being discussed in a measurement discussion. Turning the meter stick transparency 90° and drawing a few lines to make it a graduated cylinder, brings home the point that all analog measuring devices are read using the same procedure. In general, the teachers seemed pleased to know that there is a procedure to determine how many numbers can be read from a particular measuring instrument.

Conclusions and Recommendations

The preservice teachers in this study have great difficulty in accurately performing measurement tasks. Since over 75% of the preservice teachers in this study had received their bachelor's degree from institutions of higher education from across the U.S., this study suggests that this is not a local problem but a national problem. Perhaps one of the reasons why U.S. students fair so poorly in measurement skills may be that many U.S. teachers do not fully understand the complete process of making accurate measurements.

According to the Third International Mathematics and Science Study (1996, 1997, 1998), U.S. fourth graders faired much better than eighth graders who in turn scored better than twelfth graders in the mathematics and science comparison. In mathematics content areas, our fourth graders exceeded the international average in five of the six areas assessed. They only scored below the international average in the one content area that assessed measurement skills (U.S. Department of Education, 1997). In eighth grade, scores dropped in both mathematics and science with U.S. students scoring below average in mathematics and slightly above average in science. For the six mathematics subject areas assessed, measurement was again the area of poorest performance for U.S. students. At twelfth grade measurement scores were not reported (U.S. Department of Education, 1998).

The most common measurement misconceptions made by the preservice teachers in this study was reading all of the digits accurately, especially the final estimated digit. The teachers tended to read fewer digits than what could actually be read by the instrument. The second most common error was recording the correct unit of measurement using standard abbreviations. Other misconceptions were recording metric measurements using fractions, omitting initial digits, and combining multiple units. When the teachers became aware of the common measurement misconceptions and that there was an actual process to make accurate measurements, they quickly learned how. Therefore, awareness seems to be the greatest issue.

The need to teach accurate measurement skills in the elementary, middle, and secondary school classrooms has been identified in the *NCTM Standards* (1989) and the *National Science Education Standards* (1996). In order for this to occur, it is vital that teachers understand the measurement process in order to teach these skills to children. If teachers know how to use standard measuring devices to make accurate measurements and understand the common misconceptions, then they will be better able to teach children how to measure accurately. With practice, accurate measurement will become an automatic skill. This may not eliminate the deficit shown in our performance in assessments such as the TIMSS, but it will get us started in the right direction and maybe back up to standard.

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CLASSROOM LEARNING ACTIVITIES THAT GENERATE THE MOST PARTICIPATION IN MIDDLE SCHOOL SCIENCE

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The Problem

A common and frustrating problem for most teachers is that despite sincere attempts to meet the needs of all our students, many students elect not to participate in classroom learning activities. The factors contributing to this problem are widespread, but for this project we focused on the links between participation and motivation, setting objectives, and cooperative learning.

Background/Theory

Brophy indicated that "teachers can capitalize on intrinsic motivation by planning academic activities that students will engage in willingly because they are interested in the content or enjoy the task" (Brophy, 1987, p. 44). Teachers should use assignments that are relevant and correlate to students' interests, offer alternative ways to meet instructional objectives to encourage autonomous decisions, provide immediate feedback such as verbal response or answer keys, and incorporate something new or different into each activity.

Agreeing with Brophy's assertions, Dev (1997) stated that "an assigned task with zero interest value is less likely to motivate the student than is a task that arouses interest and curiosity" (p. 13). It is not always possible to use activities that meet the interests of every student; however, the teacher can incorporate elements that most students will find rewarding.

Providing tasks at the correct level of difficulty is also important in encouraging students to participate. "If the assigned task is within the child's ability level as well as...interesting, the child is very likely to be intrinsically motivated to tackle the task" (Dev, 1997, p. 13). Danner and Lonky (1981) indicate that success at moderately difficult or challenging tasks is explained in terms of personal effort and abilities, and these explanations cause feelings of pride, competence, determination, satisfaction, persistence, and personal control, all ingredients of intrinsic motivation.

Karsenti and Thibert (1995) discuss a concept called amotivation, and describe students who possess this characteristic as not understanding why they are going to school. Alderman (1990) said these students consider themselves "helpless" and believe "they can do nothing to prevent failure or assure success" (p. 27). This research is included because we expected to find, and indeed did find, students in our classes that felt or acted as though they could do nothing to prevent failure.

Assignments should be clear and precise, and Wong (1991) stated "if students know what they are to learn, you increase the chances that the student will learn" (p. 210). He calls these objectives "action verbs" and emphasizes they specify what students are to accomplish. The students must know before the lesson begins what they are responsible for learning.

The ability to work with others is almost a prerequisite to success in this world, and cooperative learning groups provide important time to develop this skill. Students work together in small groups to complete assignments, study for tests, and solve problems. According to Johnson and Johnson (1989), cooperative learning provides a structure for intensifying academic achievement while promoting participation. Further, students are much more willing to attempt problem-solving tasks when they work together in groups, rather than by themselves.

Hendrix (1996) supported using cooperative learning strategies in the classroom citing such benefits as increased student participation and achievement, positive attitudes toward learning, higher student self-esteem, and even improved race relations. He says, "cooperative learning activities allow…an interactive, investigatory, and intimate learning environment. The unilateral classroom pattern-from instructor to student-is eliminated, and bilateral, cooperative interaction comes into existence" (p. 335). Students functioning in this environment are empowered to take responsibility for their own learning which fosters increased participation in school.

Kagan (1994) advocated using cooperative learning strategies in the classroom because "the lowest achieving students and minority students in general benefit most, but…not at the expense of the higher achievers; the high achieving students generally perform as well or better in cooperative classrooms than they do in traditional classrooms" (p. 3:1).

This study was modeled after a 1994 Action Research Project conducted by Phyllis Green, an eighth-grade science teacher from the C.W. Ruckel Middle School in Niceville, Florida. There are, however, several important differences.

Ms. Green's target group only included two male subjects, while this study included all students from four science classes (115 students), with a target group of four students from each class (16 students).

The Green study analyzed 43 individual learning activities set within the work environment of whole class, cooperative, or individual activities. This project focused on three different types of learning activities: those done individually, those done within small cooperative groups (3 to 4 students), and those completed as whole-class activities. Additionally, one longer, more comprehensive project, the Higginbottom Salt Project, was selected that blended both cooperative group and individual work.

The purpose of this study was to ascertain whether one type of learning activity generates more participation among students, especially among those students who are non-participatory. The first author, a beginning teacher, is concerned that classroom activities, approaches, and teaching strategies reflect the most current research in education. Consequently, answering our research questions and reflecting upon the first author's role in the classroom helped make adjustments so there may be immediate improvement in teaching abilities.

Research Questions

The questions that guided the research were:

1. Which types of learning activities promote the highest percentage of student participation, especially among those students who typically resist participation?
2. As the first author progresses through her teaching day, do teaching strategies improve in such a way that student comfort and confidence is promoted within the classroom, thereby increasing participation (particularly for the target students)?

Procedures

Data Collection

This study took place during the months of January, February and March of 1998, in a middle school in southeastern Washington, where the first author was assigned to complete student teaching in eighth-grade science. The city has a population of 36,500 and the middle school serves about 700 students primarily from white, upper-class families with a large percentage of parents associated with either the Hanford Nuclear Project or Washington Public Power Supply System. There are some minority families in the area; the middle school has a 13% minority student population.

The participants for this study included all students from four eighth-grade general science classes. This group of 115 students (54 girls and 61 boys) remains together as a team throughout middle school, and they tend to be grouped according to their abilities in mathematics. Because of this, Period 1 and Period 3 would be ranked as average, Period 2 above average, and Period 4 below average. Two groups proved to be challenging: students in Period 2 because of many strong personalities, and they finished activities in shorter time periods compared to the other classes; Period 4 because of management problems, and they consistently took 10 to 15 minutes longer for most activities. This information is relevant because the first author expected her teaching practices and strategies to improve as she progressed through the day, and we believe they did. However, participation rates for Period 4 and the target group in that class, do not necessarily reflect any improvement.

Four students from each class who typically resisted participation were selected as target groups. The first author and her Field Specialist (master teacher for student teaching) used the Student Observation Checklist (Figure 1) and the first author's observations during the first three weeks of student teaching, to help identify those students who were usually non-participatory. Target groups in Periods 1, 2, and 4 consisted of two girls and two boys, while one girl and three boys made up the Period 3 target group.

Adopted from a research study in 1996 by Adams, Cooper, Johnson, and Wojtysiak, the Student Observation Checklist (Figure 1) documents responsible behavior in the classroom by assessing class preparation, and completion of in-class assignments and homework. Signs of students being engaged in learning may be noted through student alertness, participation, and demonstration of understanding.

Immediately following the activities that were included in this study, I asked the students how they felt about those activities by requesting that each student complete a Student Opinion Survey form (Figure 2). Student Opinion Survey forms were color-coded to help simplify data analysis.

The survey form used was modified from the Green study (1995) by changing the opinion rating scale to more closely resemble a standardized Likert scale. Likert scales may start with a particular point of view and all statements favoring a position are scored using a scale value as follows:

	Scale Value
Strongly agree	5
Agree	4
Undecided	3
Disagree	2
Strongly disagree	1

Thus, the rating instrument yields both individual scores for each question as well as a total score for each respondent.

The Likert-type survey instrument does have some limitations; "it is somewhat inexact and fails to measure opinion with precision...and even though the opinionnaire provides for anonymous response, there is a possibility that students may answer according to what they think they should feel rather than how they do feel" (Best & Kahn, 1993, p. 250). However, the Likert scale is widely accepted and we felt that used in conjunction with the actual learning activity, it served as a useful way to find out how the majority of students felt about a specific activity or assignment.

This modified survey form was field tested and validated by a similar grade-level population in a sixth-grade language arts classroom at the same middle school in November, 1997. These students immediately completed a second form, which asked for clarification of ease in filling out the survey form. These form and field test results are included as Figure 3.

After deciding to include the Higgenbottom Salt Project that encompasses both cooperative group and individual work, we further modified this survey form to ask specific questions about aspects of the project (Figure 4).

Student Survey forms were marked according to classroom seating charts; in this way, confidentiality was assured while still allowing access to target group opinions on different learning activities.

The validity of this study was established through triangulation of the following data sources:

1. Student Opinion Surveys
2. Students' work and evaluation of that work
3. Anecdotal journal which includes notation of behaviors and events regarding different classroom activities as well as a record of the first author's reflections about those events
4. Classroom Observation Checklists completed by the first author and her Field Specialist

Data Analysis

Student work included in this study was categorized as individual, small cooperative group, or whole class. Color-coded Student Opinion Survey forms accompanied these activities, and they were separated into class periods. We compared target group percentages to class percentages by activity, including the information that appeared on the accompanying survey forms. This information was categorized using a nominal scale showing different activities within specific class periods for target groups and for entire classes. Although nominal scales are generally considered the least precise method of quantification (Best & Kahn, 1993, p. 208), we used qualitative data to interpret and verify emerging patterns or correlation.

Organizing the anecdotal journal writings into similar observed behaviors and events was the first step in analyzing the qualitative data. We color-coded different categories corresponding to previously described activities. These records provided an opportunity to revisit initial perceptions and to compare changes in those perceptions to determine if patterns existed which could be correlated to the quantitative data.

Second, we described the purpose of the activities, the viewpoints of the participants, and the effects of the activities on the participants. Next, we interpreted the data in an attempt to find out why specific events occurred during different learning activities, hopefully attaching significance to particular patterns and results which will help provide meaning to all the words and numbers accumulated throughout the project.

Finally, we noted and provided explanations when it was observed that insufficient time was given for students to complete activities, or when we determined that students' weak skills contributed to difficulty with assignments. By describing events we felt were significant, and providing a discussion within the Data Analysis section of this research report, our study is meaningful and results are as accurate and informative as possible.

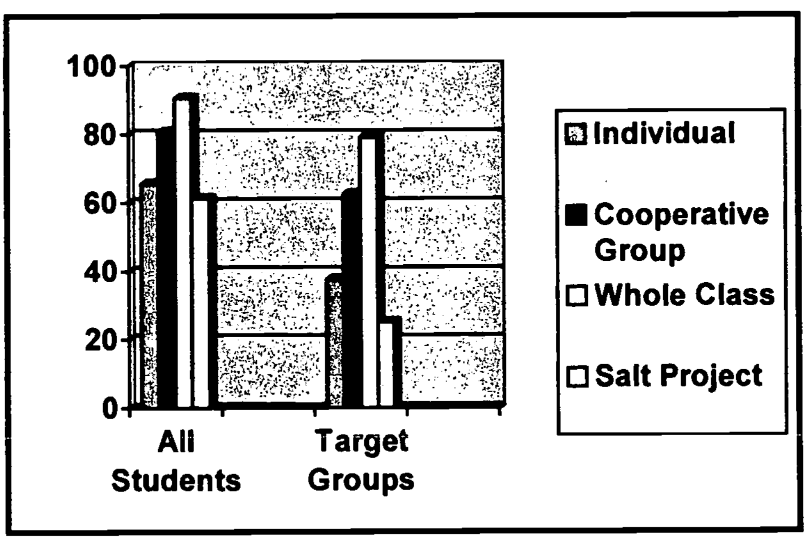
Our data indicated that on assignments done individually, the participation rate for the whole class was 66% while the target group only performed at 38%. For assignments done within the cooperative group environment, the entire class participation rate was 81% and the target at 63%. The assignment done as a whole-class activity showed whole class rates at 91% and the target group at 79%. The whole-class participation rate for the Higginbottom Salt Project was 61% and the target group's rate was 25% (Table 1).

Table 1.
Participation by Assignment

	Individual	Cooperative Group	Whole Class	Salt Project
Period 1 Class	65%	92%	84%	64%
Period 1 Target	50%	75%	100%	25%
Period 2 Class	85%	88%	94%	55%
Period 2 Target	50%	100%	100%	0%
Period 3 Class	67%	78%	96%	70%
Period 3 Target	50%	50%	50%	75%
Period 4 Class	45%	64%	88%	56%
Period 4 Target	0%	25%	66%	0%

According to data in the following chart, students in the target group showed the highest participation when the work occurred within a cooperative group or whole class setting.

Figure 5.
Class and Target Group Percentage Participation



The individual assignment used was an activity called a Dichotomous Key (Figure 6). In this activity students practiced the same methods used by scientists to categorize or "key out" unknown organisms, by grouping them according to similarities and differences. Students were asked to look at a collection of common household items and follow the descriptions on their worksheets until a particular item was categorized or "keyed." That item was then assigned a nonsense name. This activity was done in class and no one was allowed to complete it at home because the items remained at school. It should be noted that there was less structure to this activity than to some other individual activities and this may have contributed to the target group's lower participation score.

The cooperative group project selected for this research was frog dissection. Students spent two class periods actually dissecting frogs working in teams of four students and one frog. There were worksheets to complete (Figure 7) about organs and features including size, texture, color, etc. Students seemed quite enthusiastic about this activity and journal entries were made about how engaged everyone, including the target group in each class, appeared to be. It should also be noted that more students participated in the actual dissection of the frog than completed the worksheets; the percentages were computed on the number of students who completed the worksheets. Students in each team were allowed to share information on this worksheet and they were even encouraged to appoint a recorder at their table so all the information could be written down. After frogs were cleaned up and disposed of, students were given time in class to discuss their findings and fill out the remaining worksheets.

We selected a jigsaw activity to use as the whole class assignment (Figure 8); it was also a new activity for the students. Here, seven or eight teams of students (3 or 4 in each team) were each given a different article to read; these articles were short, about one page in length, on science mysteries. Students read these articles a few days before and on the day of the activity, were given ten minutes to review the article and confer with their teammates making sure that everyone was familiar with the article's main points. Next, each team sent out a "teacher" to a different table and taught that article in four minutes while other students took notes. At the end of the teaching time, "teachers" returned to their home tables and another "teacher" rotated to a different table to share the article with a different set of students. This activity continued until all tables received information about all articles, and everyone had an opportunity to teach at least once, sometimes twice.

This activity showed the greatest participation in both whole class and for the target groups. We believe that the relatively short duration of teaching time with all students participating as "teachers," in addition to the general excitement caused by moving around the room and the noise of seven or eight people talking at once, contributed to getting the students involved. Even shy students did not appear too uncomfortable because they were speaking to only two or three of their classmates at any one time.

The Higginbottom Salt Project which was included as a separate category was a problem-solving activity in which students worked cooperatively to set up a problem, tested one hypothesis, and shared their results; the required worksheet packet was completed individually (Figure 9). We feel that two factors contributed to low percentage participation; these students had no prior experience with a problem-solving activity involving numerous steps, and no stated procedure on how to solve the problem.

Before students began working on this activity, we reviewed several pages of the packet along with related concepts. For example, we extracted pertinent information from the introductory memorandum and inserted that information onto the appropriate work pages. We also reviewed the required math functions on three different occasions, and sample computations and explanations were presented. We did not, however, read every word to them nor were students told exactly how to present their results and conclusions in the final memorandum (the information for the requested memorandum is that which would normally be presented in a lab write-up; the only difference was the format). The projects that were turned in were extremely creative and complete, and only one team from all four classes elected to pool their efforts and create one memo. The number and type of student questions combined with classroom observations, indicate that many students neglected to read the packet for instructions.

The survey results for the numerically ranked questions that accompanied each activity are shown in the following tables:

Table 2.
Individual (Dichotomous Key)

Ranking:

Strongly Agree	5		
Agree	4		
Undecided	3	Class	Target
Disagree	2	Average	Average
Strongly Disagree	1	Score	Score
1. I enjoyed today's class.		4.0	3.1
2. I feel that I learned a lot today.		2.9	2.3
3. The activity was too hard.		1.9	1.6
4. I am interested in this topic.		3.0	2.4
5. I can really use what I learned today.		2.9	2.5

Note. The target group in this survey expressed negative reaction to the individual activity, and corresponds to their low participation as illustrated in Figure 5. Although students seemed to enjoy looking at the various objects and talking about how they should be categorized, more students might have participated if the activity had been more realistic by actually looking at plant and animal samples rather than common household items.

Table 3.
Cooperative Group (Frog Dissection)

Ranking:

Ranking		Class Average Score	Target Average Score
Strongly Agree	5		
Agree	4		
Undecided	3		
Disagree	2		
Strongly Disagree	1		
1. I enjoyed today's class.		4.4	4.2
2. I feel that I learned a lot today.		4.4	4.2
3. The activity was too hard.		1.6	1.8
4. I am interested in this topic.		3.4	3.1
5. I can really use what I learned today.		3.5	3.5

Note. Students seemed to enjoy the entire frog unit, which ended with the two-day frog dissection. This was apparent by the responses for both whole class and target group average scores, as well as the higher percentage participation, which is seen in Figure 5. Generally, students in both groups rated this activity as interesting and useful although more students participated in the frog dissection than actually completed the lab worksheet. With two students opting to complete an alternate assignment in the library and not be present during dissection, the percentage of whole class dissection participation was 98.2% , compared to 81% completing the worksheet. 100% of the target group students participated in the dissection while only 63% completed the worksheet.

Table 4.
Whole Class (Mystery Jigsaw)

Ranking:

Strongly Agree	5		
Agree	4		
Undecided	3	Class	Target
Disagree	2	Average	Average
Strongly Disagree	1	Score	Score
1. I enjoyed today's class.		3.6	2.9
2. I feel that I learned a lot today.		3.6	3.4
3. The activity was too hard.		1.9	2.0
4. I am interested in this topic.		3.0	2.9
5. I can really use what I learned today.		3.0	2.8

Note. This activity had the highest participation rates for all students as well as the target groups. Although the target groups did not particularly like this activity or find it difficult, they did feel they learned something but were not sure how they would use what they learned. We felt one important factor affecting the participation in this activity was that every student was responsible for teaching a short article to a small group of students. The activity was fast-paced and very focused; each student had a job to do with others depending on him/her for their information.

Table 5.
Higginbottom Salt Project

Ranking:

Strongly Agree	5		
Agree	4		
Undecided	3	Class	Target
Disagree	2	Average	Average
Strongly Disagree	1	Score	Score
1. I enjoyed the Higginbottom Project.		3.2	2.6
2. I can really use what I learned from this project.		3.0	2.9
3. I enjoyed working with my teammates on this project.		3.4	3.6
4. I liked working alone on this project.		2.5	2.2
5. This activity was too hard.		2.3	2.7

Note. The Higginbottom Salt Project survey asked slightly different questions. Here, two questions asked in different ways established whether students enjoyed working alone or with other members of their team. The target group had a higher indication that they enjoyed working with their teammates than the class average even though they did not enjoy the project.

In general, the target groups rated the difficulty of the activities higher than the class average with the exception of the individual Dichotomous Key activity. The target scoring was also more negative in the other four questions on the survey forms.

Findings

Initial research suggested that underachieving or non-participating students lack intrinsic motivation, and are less willing to participate in an assigned activity that is either not relevant to students' lives or is not interesting in and of itself. We definitely found this to be true during this student teaching experience for the target group as well as for the entire class.

The highest percentage of participation for the target group occurred in those activities within a cooperative learning or whole class environment. Further, the target group revealed they preferred working with their teammates versus working alone in the Higginbottom Salt Project survey. As stated in the Green (1995) study, "the activity required less risk taking than it would have if they had had to work alone" (p. 29).

The lowest percentage participation occurred in the individual assignment and the Higginbottom Salt Project. One of the journal entries noted that several members of the target group sat idly at their desks, while several others wandered around the room not working on the task at hand. Although these students were redirected on several occasions, they never became engaged with the material.

These findings also fit with the concept of amotivation discussed earlier, where students do not understand why they are going to school and actually consider themselves "helpless," not able to do anything that would prevent failure. We believe there were several students in the target group who may have this characteristic and participated less than 25% of the time.

One of our original goals was to evaluate teaching strategies and methods for improvement as the first author moved through the day. We were unable to empirically test this hypothesis for two reasons. First, the classes were somewhat ability-ranked, which altered the perception of performance because the lowest-average class was the last class of the day. Second, watching videotapes of the first author teaching should have provided some insight; however, there was no videotaping done in any classroom during this time.

Implications

As we reflect on the six-week, science education experiences with these eighth-grade students, we understand that at least part of the time students need to have some input during lesson or unit planning so they share "ownership" of their learning. Student teaching offers an excellent training time in the classroom; however, stepping into another teacher's routine, curriculum, and discipline system is not always conducive to working through a research project such as this one.

It was also found that well-defined objective(s) tend to generate more participation than objectives that are either not clear or that are not stated at the beginning of a lesson or activity. Additionally, the research on cooperative learning shows that communication, thinking, and the social skills necessary for successful functioning within a group increase student involvement; however, these strategies had not been incorporated into the science classes, so there was some resistance to using them. Because of the relatively short period of time devoted to student teaching, it was not possible to teach, model, and practice many of these strategies.

Following this action research, it is understood more fully how important it is to choose activities that are meaningful in themselves in addition to providing opportunities for discovery and skill mastery for students. The more we, as teachers, focus on topics that are relevant to students' lives and that they have chosen, the more students will be intrinsically motivated to participate. There should be activities available for a range of student abilities and although teachers cannot always provide activities that will be interesting to every single student, every attempt can be made to design tasks that are engaging and pique students' curiosity.

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Figure 1

OBSERVATION CHECKLIST

Teacher: ____________ Class: ____________ Date: ____________

Target Skills: ____________

Ratings:
+ = Frequently
✓ = Sometimes
O = Not Yet

NAMES OF STUDENTS	participates	completes assignment	follows directions	cooperates	displays effort	displays initiative	uses time wisely	displays realistic self assessment	COMMENTS
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
21.									
22.									
23.									
24.									
25.									
26.									
27.									
28.									
29.									
30.									

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Figure 2

STUDENT OPINION SURVEY

The following statements represent opinions, and your agreement or disagreement will be determined on the basis of your particular beliefs.

Kindly circle your position on the scale as the statement first impresses you. Indicate what you believe, rather than what you think you should believe.

Ranking:	**Strongly Agree**	**5**
	Agree	**4**
	Undecided	**3**
	Disagree	**2**
	Strongly Disagree	**1**

		Your Ranking Score				
1.	I enjoyed today's class.	5	4	3	2	1
2.	I feel that I learned a lot today.	5	4	3	2	1
3.	The activity was too hard.	5	4	3	2	1
4.	I am interested in this topic.	5	4	3	2	1
5.	I can really use what I learned today.	5	4	3	2	1

Figure 3

SURVEY FOLLOW-UP

Circle **YES** or **NO** to the following questions.

1)	**The Student Opinion Survey was easy to understand.**	**YES**	**NO**
2)	**I needed additional help to fill out the survey.**	**YES**	**NO**

Survey Field Results

1. The Student Opinion Survey was easy to understand.

   Yes - 25

   No - 2

2. I needed additional help to fill out the survey.

   Yes - 1

   No - 26

Questions asked by students:

* What was the activity?

* If I thought it (the activity) was easy how do I score it?

Figure 4

STUDENT OPINION SURVEY

The following statements represent opinions, and your agreement or disagreement will be determined on the basis of your particular beliefs.

Please circle your position on the scale as the statement first impresses you. Indicate what you believe, rather than what you think you should believe.

Ranking:	**Strongly Agree**	**5**
	Agree	**4**
	Undecided	**3**
	Disagree	**2**
	Strongly Disagree	**1**

		Your Ranking Score				
1.	I enjoyed the Higgenbottom project.	5	4	3	2	1
2.	I can really use what I learned from this project.	5	4	3	2	1
3.	I enjoyed working with my teammates on this project.	5	4	3	2	1
4.	I liked working alone on this project.	5	4	3	2	1
5.	This activity was too hard.	5	4	3	2	1

Date: ________________ Names: ____

DICHOTOMOUS KEY

INTRODUCTION: Once plants and animals have been assigned by scientists to certain families, how do you figure out their names or species? This is done by using a device called an identification key.

OBJECTIVE: In science, organisms are identified and classified according to characteristics that they possess. These characteristics may be either similar to or different from those of other organisms. When differences are observed so that the presence or absence of a characteristic determines which category the organism (or object) falls into, the identification tool is called a DICHOTOMOUS KEY. In this activity, we will use a dichotomous key to give household items nonsense names.

PROCEDURE: 1. For each item provided, start with description number 1 and follow the instructions at the end of the line of the description that fits your item until the end of the line provides a name for that item.
2. In the space beside each nonsense name provided, write in the actual name of the household item.

1 a. Object is partly or completely made of metal .... go to 2
1 b. Object has no metal on it .... go to 16

2 a. Object has nonmetal parts .... go to 3
2 b. Object is completely made of metal .... go to 5

3 a. Object is less than 10 cm in length .... whippersnapper ____________
3 b. Object is 10 cm or greater in length .... go to 4

4 a. Object is pointed at one end .... tapered doodad ____________
4 b. Object is not pointed at one end .... common doodad ____________

5 a. Object is greater than 10 cm .... go to 6
5 b. Object is 10 cm or less .... go to 9

6 a. Object has a twisted area .... thingamajig ____________
6 b. Object has no twisted area .... go to 7

7 a. Object has three or more prongs .... left-handed monkey wrench ____________
7 b. Object has no prongs goto8

Date: ________________ Names: ____

8a.Object has a cutting edge .... geegaw ____________

8b.Object has no cutting edge .... scooperdoo ____________

9a.Object has spiral grooves .... go to 10

9b.Object has no spiral grooves .... go to 11

10a. Object has a hole .... cashew ____________

10b. Object has no hole .... whatsit ____________

11a. Outside edge is a circle .... go to 12

11b. Outside edge is not a circle .... go to 13

12a. Object is silver-colored .... Quinto ____________

12b. Object is not silver-colored .... uno ____________

13a. Object is silver-colored .... go to 14

13b. Object is not silver-colored .... go to 15

14a. Object is less than 4 cm in length .... micro whatnot ____________

14b. Object is 4 cm or more in length .... macro whatnot ____________

15a. Object is brass-colored .... skyhook ____________

15b. Object is not brass-colored .... dingus ____________

16a. Object is white .... go to 17

16b. Object is not white .... go to 24

17a. Object has holes .... wadget ____________

17b. Object has no holes .... go to 18

18a. Object is a circle in at least one dimension .... go to 9

18b. Object is not a circle in any dimension .... go to 20

Date: ________________ Names: ________________________________

19a. The circumference of the circular dimension is 6 cm or less.............bric-a-brac ____________

19b. The circumference of the circular dimension is greater than 6cm......Roundabout____________

20a. Object is made of plastic ....go to 21

20b. Object is not made of plastic ....go to 23

21a. Object has 3 or more prongs .... doohickey____________

21b. Object has no prongs goto22

22a. Object has a cuffing edge .... gismo ____________

22b. Object does not have a cuffing edge ....flim flam____________

23a. Object appears to have a string running through its center ....Wickey____________

23b. Object does not appear to have a string running through its center ....scrubadub____________

24a. Object is made of plastic ....go to 25

24b. Object is not made of plastic ....go to 28

25a. Outer edge of the object is round ....go to 26

25b. Outer edge of the object is not round ....whatchamacallit____________

26a. Object has holes goto27

26b. Object has no holes ....spinaroo ____________

27a. Object has 2 holes ....bihole ____________

27b. Object has 4 holes ....Tetrahole ____________

28a. Object is made of glass ....seethru ____________

28b. Object is not made of glass ....go to 29

29a. Object is yellow in color ....screecher ____________

29b. Object is not yellow in color ....Soaky ____________

Figure 7

Name: ______________
Period: ______________

Digestive	Respiratory	Muscular
Circulatory	Skeletal	Nervous
Endocrine	Excretory	Reproductive

Figure 8

MYSTERY ARTICLE

Name ______________________________ Period _________ Date _____________________

Teacher:

Article Title:

Main Ideas:

*

*

*

*

*

*

Other Information to Stress:

Teacher:

Article Title:

Main Ideas:

*

*

*

*

*

*

Other Information to Stress:

Teacher:

Article Title:

Main Ideas:

*

*

*

*

*

*

Other Information to Stress:

Teacher:

Article Title:

Main Ideas:

*

* *

*

*

*

*

Other Information to Stress:

Figure 9

HIGGENBOTTOM EGG CO.

WHERE THE ONLY FRESHER EGGS ARE STILL UNDER THE HEN

To:	Mrs. Pringle's Science Lab at Chief Joseph Middle School
From:	Elaine Higgenbottom, Owner
Date:	Monday, March 2, 1998
Re:	Accident at Warehouse #5

We have a terrible mess here at my company! Last Tuesday we received our weekly shipments of supplies. As you know, we must have huge quantities of supplies so our company can produce our products. Everything was going fine until the "BIG MIX-UP" happened. I am very concerned that this is going to cost us a lot of money if we don't get an answer soon. I sure hope all of you can help me!

Problem: Last Tuesday, we received our usual shipment of sand. We use a lot of sand because, well you know, we have 15,000 chickens laying eggs and, well...they eat a lot of food. We use the sand to clean up after the se chickens and then we spread it out in our farm to help fertilize the crops we are growing. Warehouse #5 holds our sand supply. Banker Gravel delivered 100,000 kg of sand on Tuesday.

One of our other products is called HiggenGrow, which is a high-energy chicken feed that helps our hens lay more eggs. We use about 50,000 kg of NaCl per week to make that product. This product is always delivered to Warehouse #4. Last Tuesday, one of our new employees, Chick Hiller, was guiding the delivery trucks to the warehouses (since we have 15 warehouses, it's a big job!). He told Banker Gravel and D&G Salt to deliver to the same warehouse. And that's the problem! The two trucks mixed the NaCI and sand together in one huge pile.

If the hens eat feed with sand in it, it will kill them. I guess we could just write-off the NaCl as a complete loss and just use it with the sand to clean up after the chickens. The problem with that though, is that the NaCl may hurt the plants we are growing out in the farm. Information for your consideration:

The NaCl cost us $0.15 per kg. The sand cost $0.001 per kg.

We would be willing to write-off the sand as a complete loss, but what about the salt? Can you help me? I need to announce our plan to the Board of Directors in two weeks. They want to know the following:

- The problem. State the problem very clearly.
- What we're going to do about the problem.
- Design for what we're going to do. Some drawings here might help.
- Data from any experiments that we've done to solve the problem.
- The costs involved. If we can save the NaCl, how many percent we save. Final outcomes from your experiments.

HIGGENBOTTOM EGG CO.

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THE BIG MIX-UP WRITE-UP FOR SCIENCE

This packet is designed to help you with the final write-up. **IT IS NOT YOUR FINAL WRITE-UP!!** The final write-up is due Thursday, March 12 before I leave the building at 4:00.

The penalty for late work is 10%, and you will NOT have the opportunity to rewrite for a higher grade. No late work will be accepted after Monday, March 16.

Having said that, if you're one of those students who turn in your work early, you'll have an opportunity to earn a 10% bonus! And the people who turn their assignments in on time have the opportunity to rewrite this lab for a higher grade. Pretty good deal? I think so.

Part 1: The Data

Beginning weight of sand and salt mixture ______grams

Ending weight of sand ______grams

Ending weight of salt ______grams

Total ending weight of mixture ______grams

Part 2: The Math

Percentage recovered from your experiment ________%

What formula did you use to get that percentage?

Show me the math:

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**WHERE THE ONLY FRESHER EGGS
ARE STILL UNDER THE HEN**

THE BIG MIX-UP WRITE-UP FOR SCIENCE

Part 3: How Much $$$ Can You Save Higgenbottom?

What was the price per kg of salt? __________

How much salt did Higgenbottom buy from D&G Salt? __________

What was the bill for the salt from D&G? __________

What was the price per kg of sand? __________

How much sand did Higgenbottom buy from Banker Gravel? __________

What was the bill for the sand from Banker Gravel? __________

What is the EXACT quote from Mrs. Higgenbottom that tells you which most interested in recovering?

Based on the percentage of recovery from Part 2, how much money can you save Higgenbottom? Please make the following assumptions when you calculate the savings in money:

1. She is now prepared to throw all of the sand and salt away at this point. Any savings would be appreciated.
2. The process to recover the sand/salt costs nothing. I know that's not real, but go with it anyway.

Savings for Higgenbottom:

Please show me the math:

HIGGENBOTTOM EGG CO.

WhERE THE ONLY FRESbER EGGS
ARE STILL UNDER THE HEN

THE BIG MIX-UP WRITE-UP FOR SCIENCE

Part 4: The Scientific Method

Use the scientific method to **pre-write your memo to Mrs. Higgenbottom.**

What's the problem?

What background information have you learned about this problem?

What was your hypothesis?

Describe - **IN DETAIL** -your plan to test your hypothesis. Include drawings.

HIGGENBOTTOM EGG CO.

**WHERE THE ONLY FRESHER EGGS
ARE STILL UNDER THE HEN**

THE BIG MIX-UP WRITE-UP FOR SCIENCE

Part 5: Error Analysis

Why didn't you get 100% of the sand or salt back? Where could the sand/salt have gone?

Why would I be suspicious of results that are greater than 100%?

Part 6: The Memo

Write a memo to Mrs. Higgenbottom that communicates EVERYTHING you've done to solve her problem. Use the scientific method as your guide.

Memos must be clearly written, proofread for mistakes, and in black ink or word processed. Please skip lines or double space.

Part7: What Do I Turn In?

Make sure you have the following in your report IN THIS ORDER:

1. **Neatly designed cover entitled "Higgenbottom Egg Company Big Mix-Up". Other designs are yours to choose. Include your name on the cover.**
2. **Final draft of your memo to Mrs. Higgenbottom.**
3. **This completed lab packet.**
4. **All rough drafts, notes, and/or other data collected from your experiments.**
5. **Bear in mind: NEATNESS COUNTS. See the grading sheet for the lab.**

HIGGENBOTTOM EGG CO.

WHERE THE ONLY FRESHER EGGS
ARE STILL UNDER THE HEN

The page following these notes contains a grading sheet of how I will determine your grade for the Higgenbottom Egg Company Big Mix-Up Problem.

Look at On-Time Performance! 10% of your grade is whether or not you turned in the write-up on time. But if you look more closely you not only DON'T receive 10% for on-time, you LOSE an additional 10% for late work. Advice: Get your work in on time!!

This write-up also asks you to make a cover for your report. Keeping your rough drafts and notes is important as well.

Working with others can be a real chore. Don't you hate it when one of the group members does nothing? You are responsible only to work as a group during the investigation - the write-up can be your own thing. If you would like to turn in one (1) write-up for a group, you'll need my permission first.

Good luck to all of you as you begin writing up the BIG MIX-UP AT HIGGENBOTTOM EGG COMPANY.

Mrs. Pringle

Higgenbottom Egg Company's Sand and Salt Problem: The Big Mix-Up

Grade Sheet

Due Date		
Early? (of your earned grade)	**+10%**	________
On-Time?	**30**	________
Late? (of your earned grade)	**- 10%**	________
Cover		
Cover Essentials	**15**	________
Cover Creativity	**15**	________
Memo		
Format	**15**	________
Problem Stated?	**15**	________
Background Info	**15**	________
Hypothesis	**15**	________
Experiment Discussed in Detail?	**15**	________
$$ Saved H. Egg?	**15**	________
Pre-Write Packet		
Part 1: % Saved	**15**	________
Part 2: Math	**30**	________
Part 3: Money	**30**	________
Part 4: Scientific Method	**30**	________
Part 5: Error	**15**	________
Drafts		
Roughs, Notes	**15**	________
Overall Look		
Neat & Quality	**15**	________
Points	**300**	________
Grade		________

A SYNTHESIS OF EMPIRICALLY SUPPORTED BEST PRACTICES FOR SCIENCE STUDENTS WITH LEARNING DISABILITIES

Juanita Jo Matkins, University of Virginia
Frederick Brigham, University of Virginia

Best Practices for Science Education

National Standards Documents

Science literacy for all Americans! This noble sentiment echoes in the documents which form the philosophical and practical foundation for science education reform in the United States: *Science for All Americans (SAA)* (American Association for the Advancement of Science, 1990), *Benchmarks for Science Literacy (BSL)* (American Association for the Advancement of Science, 1993) , and the *National Science Education Standards (NSES)* (National Research Council, 1996). These documents synthesized current ideas among scientists and science educators about the best practices for developing a population that will become scientifically literate adults. *SAA* emphasized "teaching for understanding", and described several aspects for doing that in science education. The *BSL* recommended a foundation of content knowledge, and a coherent sequence of topics and concepts shaping science instruction so the knowledge and skills gained would last through adulthood. The *NSES* emphasized an inquiry-based approach and prescribed that approach as the most desirable for teaching science. The *NSES* also recommended a "less is more" approach to curricular choices. These three documents emphasized inclusion of science for all populations in K-12 schools in the United States as a foundation for meeting the goals set in the documents.

Science Education Research

There are other factors which influence decisions about the best ways to structure K-12 science instruction. Driver's (1982) research into the characteristics of young learners led to a revised Piagetian approach to science instruction, constructivism. Subsequently, the study that led to the video "A Private Universe" (Schneps, 1989) brought into sharp focus the fallacy of assuming that traditional instruction led to a common core of learning and understanding, and reinforced the beliefs of many in constructivism.

International Science Tests

The results of the Third International Mathematics and Science Study (TIMSS) (Harmon et al., 1997) have provided a sobering reminder that students in middle and high schools in the United States are performing poorly in science compared to students in many other countries. The TIMSS data show that middle and high school teaching in the United States differs from higher scoring countries in the time spent on fundamental concepts. This echoes and supports the NSES recommendation of the need for a "less is more" approach.

State Science Standards

State science standards are another factor in choices for science instruction. Most states have in place a set of science standards which stipulate what is to be taught, and, in many cases, how things are to be taught. Indiana (Indiana Department of Education, 1997), a state which earned a grade of "A" for its science standards (Lerner, 1998) incorporated "Action shots" -- sample science lessons -- into their standards document. Virginia's "D" science standards emphasized a grade by grade list of science content which a student should "know and understand", yet Virginia's standards (Virginia Board of Education, 1995) provided no recommendations on how to teach to these standards. Both these states and many other states are developing student tests to assess the meeting of their standards, and schools, teachers, and students are being held accountable for student achievement on the tests. National tests for science achievement loom in our future as the pressure to improve education increases.

Classroom Practices

What is a teacher to do, to meet the challenge of the science reform documents and enable all their students to be science literate? What are the recommended classroom best practices for meeting these goals? What practices have teachers used in the recent past to teach science?

Reform and Best Practices

Words and phrases found in the national science reform documents and recent research in science teaching (i.e., American Association for the Advancement of Science, 1990; American Association for the Advancement of Science, 1993; Lawson, Abraham & Renner, 1989; Tobin, Tippins & Gallard, 1994) on best practices in K-12 science education include the following: Inquiry, constructivism, learning cycle, hands-on (also hands-on/minds-on), process-based, laboratory, and Socratic method. In their study of the curriculum projects of the 60s, Shymansky, Kyle and Alport (1983) found that inquiry-based approaches to science instruction had a positive effect on student achievement. The curricula studied by Shymansky, et al., incorporated aspects of the learning cycle, which became a model for structuring science instruction.

Inquiry

The word "inquiry" is often used synonymously with constructivism, the learning cycle, hands-on, process-based, and problem-based instruction. "Inquiry" generally refers to question-generated instruction. In some inquiry settings, questions are asked by students. In others, teachers ask guiding questions or manipulate student responses until the desired questions are raised by the students.

The Learning Cycle

The learning cycle has been defined as a method of instruction characterized by the use of an investigation prior to formal introduction of a science concept (Tobin et al., 1994). There were three stages to the original learning cycle of the SCIS program: exploration, concept development, and concept application. Though the stages have been revised through the succeeding years (Bybee et al., 1989), the essential structure continues to be (a) an exploration activity occurs early in the instruction, (b) teacher direction is emphasized after the exploration, and (c) a concluding activity may or may not be followed by assessment.

Recent research on the learning cycle instructional approach indicated student achievement and attitudinal benefits (Abraham, 1989; Glasson & Lalik, 1990; Lavoie, 1992; Scharmann, 1992), yet cautioned that the role of peer and teacher interaction in such instruction has yet to be fully investigated. Nonetheless, the learning cycle appears to fit into the category of "best practice" for science instruction.

Laboratories

The use of laboratories in science teaching and learning seems to fit into both inquiry-based and traditional instruction, though laboratories developed with an inquiry approach should differ in process and outcomes from laboratories developed with a traditional approach. Inquiry-based laboratories can be student-generated, and involve outcomes which are often unknown by the students until the lab is completed. Traditional laboratory instruction involves confirmation-type labs, which reproduce experiments and have a finite set of correct answers.

Traditional Approaches

Traditional approaches to science instruction such as direct instruction have not received as much attention in the science reform documents as have inquiry-based approaches. Nonetheless, K-12 teachers have not abandoned such traditional practices in their classrooms. Thus it is appropriate that science education researchers continue to factor these ideas into their projects. Traditional instruction is characterized by descriptors such as: Textbook-based, content-based, and laboratory.

Textbook and Content-based Instruction

Textbook-based and content-based instruction are similar, in that both usually rely upon written information for the conveyance of knowledge. Coverage of the content was a motivation for dependence upon the textbook for information, and teachers partitioned their class time according to the goal of coverage, with little consideration for student understanding (Abraham, 1989).

Laboratories

Science laboratory activities in traditional classrooms tended to be "cookbook" - emphasizing following the directions of the laboratory packet and performing the activities accurately and skillfully. There was little opportunity for student planning or interpreting of results (Tobin, 1990).

Use of Traditional Instructional Approaches

Tobin and Gallagher (1987) and Tobin (1990) found that teachers continued to employ instructional strategies which emphasized the traditional laboratory approach and textbook/content emphasis despite the lack of consistency with the best practices delineated by the science education research community and the reformers. The influence of tradition and the pressures of the culture to cover the content and teach so students will be successful on tests may explain this phenomena. It is also possible that traditional approaches do benefit students in some ways not examined sufficiently or not understood within the popular culture of science education. Calls for reform in science education consistently support higher achievement for all Americans in science. Many classroom teachers responded to calls for increased achievement by increasing the amount of content covered in textbooks and lectures. However, evidence regarding outcome measures tended to support less use of textbook and lecture approaches and greater reliance on activities-based approaches.

Students with Learning Disabilities

At the time the reform initiatives were developed, dramatic changes in service delivery options were being called for on behalf of students with disabilities. Science education is one area that is consistently considered to be an appropriate area for inclusion of students with disabilities (Cawley, 1994; Patton, 1995). Most of the initiatives in science education, although supportive of the concept of science for all Americans, have been developed primarily with typical students in mind. Also, many practicing science teachers have little training or experience in identifying and meeting the needs of students with disabilities (Norman, Caseau & Stefanich, 1998). Because students with learning disabilities (LD) comprise the largest category of students in special education, science educators are very likely to work with students who have LD in their classrooms. In the next section, we provide a brief overview of the major characteristics exhibited by students with LD. We also discuss factors which may add to the variability of individual students within the category of

The Rate of Occurrence of Learning Disabilities

Although the term learning disabilities is a relative newcomer in the field of human services, its roots can be traced back to medical practitioners before the turn of the century. Reports as early as the 1890s described children who although typical in almost every other area of development were unable to acquire the skill of reading (Hallahan, et al. 1996). In the early twentieth century estimates of this condition's prevalence were thought to be, at most, one in 1,000 (Hinshelwood, 1917; Thomas, 1908). At the close of the twentieth century, prevalence rates for the condition of learning disability range approximately from five to ten percent of the U.S. population of school-aged children (Kavale & Forness, 1995).

Variability within the Population of Students with LD

The rise in prevalence rates suggests that students identified with this problem may be very different than those identified in the past. Probably, this reflects a broadening of the definition of LD so that the variety of students represented by this terms is wider than ever before. The variation in prevalence currently existing in American schools also suggests that many factors besides individual student characteristics affect the identification process. Therefore, students with LD may not only be quite different from each other within school districts or buildings and but between districts as well. That is, extra-student factors may lead a student with learning or behavior problems to be identified as having a disability in one district but not considered to have a disability in another district. All of this is to point out the difficulty in prescribing treatments from students with LD. Because of the difficulty in describing students with LD, it is a very daunting task to prescribe treatments which can work across a large number of students with LD. Nevertheless, several important characteristics common to most students with LD can be identified in the special education and psychology literature.

Characteristics of Students with LD

General characteristics of population

Kavale and Nye (1985-1986) examined the variables for which the performance of students with and without LD has been shown to be different. In all, 38 variables were grouped together into four categories or Domains: linguistic, achievement, neuropsychological, and social/behavior. Kavale and Nye then applied meta-analytic techniques to calculate effect size statistics for the variables. Effect size statistics express the magnitude and direction of difference between groups on a given variable on a z score scale. An effect size of zero would indicate no difference between the groups at all. An effect size of ± 1.00 indicates a very large difference between the groups. Generally, effect sizes beyond the –0.25 to +0.25 range are considered notable and beyond chance variation. Effect sizes are also given signs to denote which group demonstrates the superior performance. In the case of the Kavale and Nye meta-analysis, a positive effect size favors the group of students without LD and a negative effect size favored the group of students with LD.

The overall mean effect size for LD and non-LD group differences in the Kavale and Nye study was +0.660 (SD = .585). According to this effect size, approximately 75% of the students with LD could be clearly differentiated from students without LD across all four domains (Kavale & Forness, 1995). When the four domains were examined within the groups of students with LD, the greatest differences were found in the language domain, followed by achievement, neuropsychological measures, and social/behavioral indices respectively. Although these differences could be ranked in the preceding order, no statistically significant difference was found among the domains. Thus, this study and analyses of other characteristics research (e.g., Kavale, Fuchs & Scruggs, 1994) found that students with LD were clearly distinguishable from their peers without disabilities but no single domain emerged as the hallmark of the condition. Practitioners developing interventions for students with LD must therefore, remain sensitive to variability within the group. An intervention that is helpful to one student may be irrelevant to another student.

Sources of individual variation within the population

The complexity of intervention with students who have LD is further complicated by the interaction of individual strengths and weaknesses and the specific task demands faced by the student. Levine, et. al, (1993) described the ability of an individual to use a specific strength to compensate for a limitation as functional overriding. "An example of such functional overriding is seen when a student with excellent language skills and deficient nonverbal reasoning conceptualizes conventionally nonverbal mathematics tactics through a linguistic route. Such alternative or unorthodox may or may not engender success" (Levine et al., 1993, p. 237). Conversely, functional undermining occurs when a "...function is so inadequately developed or insufficiently automatized that it drains excessive mental effort (i.e., cognitive/mnemonic/attentional resources from one or more other (ordinarily intact) elemental functions needed to generate a production component. For example, a child with a motor dyspraxia may have to exert so much effort to form letters that little if any resource remains for adequate spelling" (Levine et al., 1993, p. 237). Further, the effects of functional overriding and functional undermining may be content specific such that a student with a strong interest or affinity for animals may perform noticeably better in a biology course than she might in a physics course. Therefore, the effects of learning disabilities may appear to come and go depending on the draw of competing mental processes and the course material itself. This phenomenon is often mistaken for a motivational or self-discipline problem and in some students (even students with LD) it is. However, in other cases, the implication of this theory is that interventions and accommodations necessary for a given student in one class or task may not be helpful or could possibly interfere with learning in another class or task given the interaction of the individual's specific characteristics, the class, task, and the constellation of other cognitive demands placed upon the learner.

Summary

The concept of learning disabilities remains difficult to precisely define, nevertheless, students with LD perform differently from students without LD on a wide variety of performance measures. Although the category of LD is characterized by problems in the linguistic, achievement, neuropsychological, and social/behavioral domains, no single domain stands out as a primary problem of most individuals with LD. Rather, LD is better conceptualized as a complex and individual-specific mix of all four of these domains. Even within a specific individual, the manifestation of LD may change from task to task and subject to subject because of the interaction of functional overriding and functional undermining of cognitive processes. Clearly, accommodation of students with LD in general education classes is a complicated endeavor. It is unlikely that a blanket approach can meet the needs of all students with LD. Nevertheless, some techniques appear to be strong candidates for supporting students with LD. The likelihood that any technique will work for all students with LD is, however, small. Educators are advised to monitor individual students to ensure that the support they provide yields the outcomes they desire.

Supporting Students with LD in Educational Programs

Mastropieri and Scruggs (1993) identified five areas of functioning that inhibit classroom performance of students with disabilities in classroom learning tasks. These areas are consistent with the domains described by Kavale and Nye (1985-1986) but are more specific to the types of observations that teachers in classrooms are likely to make. The areas are: (a) language and literacy, (b) intellectual and cognitive development, (c) attention and memory, (d) affect and social behavior, and (e) physical and sensory functioning. The last item, physical and sensory functioning is not a primary characteristic of LD but may exist as a co-occurring condition along with LD. All five of these areas contribute to the general achievement deficits which are noted across students with LD. Some general recommendations can be made for all teachers working with students who have LD, after that, teachers should consider the specific students in relationship to the curriculum that he or she is expected to learn.

General Considerations for Working with Students Who Have LD

The place to start when the goal is supporting students with disabilities is by ensuring that the instruction they receive is excellent and as free from unnecessary obstacles as possible. Most students benefit from higher quality instruction so it makes sense to first examine the teacher and classroom variables. The "hands-on, minds-off" approach to instruction that mentioned earlier is an example of the kind of barrier to achievement that should be examined before the student characteristics.

Mastropieri and Scruggs (1993) provided the following suggestions for working with students who have disabilities, including those with LD. First, remember that each students is an individual and any techniques must be considered in relation to each students and his or her needs.

Second, with appropriate support, most students can succeed in some mainstream settings. The appropriateness of the mainstream setting is based on the goals of the class and the needs of the student, not on the presence or absence of a disability.

Third, working with a competent special education teacher can make things better for both the student and the science teacher. Most special education teachers openly welcome the chance to help other teachers "work with their students."

Fourth, consider the student's IEP objectives. Students in special education are evaluated at the end of the school year on the extent to which they have attained the goals set forth in their Individual Education Plans. Teachers should monitor the extent to which the classes in which students with LD enroll serve the needs identified in the IEP.

Fifth, keep expectations high. Too often, teachers and classmates do tasks for students with disabilities rather than showing them how to do things for themselves. If students with LD are to develop optimally, they must receive the supports to experience legitimate success. Too easy success and false praise actually tend to undermine students' self-efficacy.

Sixth, employ a matter of fact approach to the student's disability. A matter of fact approach downplays the disability and avoids singling the student out more than necessary because of his or her disability.

Seventh, if the student's disability is unfamiliar to his or her classmates, prepare the class for the student with a disability. Special educators and often the parents of the students can be a good resource for disability awareness.

Finally, use effective instruction techniques. In general, these variables appear to improve the achievement of all students. They are crucial for students with disabilities. Mastropieri and Scruggs (1993) provided the following guidelines for effective instruction:

- Use daily and weekly review to be sure that students have retained previously presented information.
- State your objective clearly so that students understand the purpose of the lesson. People learn better when they understand the purpose of the lesson.
- Deliver information clearly and succinctly. Speak with clarity and precision. Avoid unnecessary digressions, and provide clear examples.
- Use the "SCREAM" variables:

  Structure

  Clarity

  Redundancy

  Enthusiasm

  Appropriate rate

  Maintain active participation
- Provide guided practice. Give students a chance to demonstrate their understanding of your lesson with your supervision.
- Provide independent practice. Give students practice at applying the principles of the lesson independently.
- Use formative evaluation. Obtain a measure of their understanding of the lesson material as often as reasonably possible. (p. 5)

Characteristics of Effective Inclusion Programs in Science

Mastropieri et al. (1998) and Scruggs and Mastropieri (1994) identified seven characteristics that were present in successful inclusive science education programs. In sum, successful inclusion programs in science were associated with (a) administrative support, (b) ample support from special education teachers and staff, (c) teachers who maintain a positive and supportive environment where special needs were considered and diversity was valued, (d) activities-oriented science approach, (e) teachers who demonstrated the effective instruction variables, (f) peer assistance for the physical as well as the cognitive demands of the curriculum, (g) teachers who were skilled at disability-specific adaptations. It should be noted, however, that success in these programs was determined by successful participation and completion of the activities. Little data exists to validate the achievement of students of students with LD in inclusive and non-inclusive settings. Mastropieri et al. (1998) reported that students with LD in an inclusive activities-oriented science program ranked at the median of their class and outperformed many general education students in a textbook-oriented comparison class.

Techniques Related to Students with LD in Science

Reading decoding

Despite the endorsement of activities-based approaches to science education, textbooks remain quite popular. Examinations of science texts suggest that they can often be difficult for students with typical reading. Students with reading disabilities (one of the primary academic features of LD, particularly students identified in the earlier grades) have even more difficulty reading and understanding their textbooks. Reading components of activities-based science programs are also difficult for students with disabilities, but because these programs place less emphasis on reading as the primary means of acquiring information, they are less problematic than textbook approaches.

Tape-recorded textbooks are one obvious source of support for students who have reading decoding disabilities. Students whose reading decoding is so slow and laborious that it undermines their comprehension are most likely to benefit from taped texts. Peer readers can also be used to support students with reading difficulties. Teachers should be aware of the difficulty of the vocabulary and the concepts in the text even when selecting taped texts of readers. Many science books present a great deal of unfamiliar vocabulary, are difficult to understand, and place a considerable "cognitive load" on the reader. Simply providing tapes of difficult-to-understand material may be an insufficient strategy to support a students with a reading problem in a science class. A number of strategies have been developed to also support comprehension of reading material.

Reading Comprehension

Many students with LD experience comprehension difficulties. Sometimes these are the result of deficits in prior knowledge, failure to link current reading with prior knowledge, lack of comprehension strategies, ineffective use of strategies, or failure to systematically monitor understanding. Often, students with LD present combinations of these problems. No matter what the source of the problem, explicit instruction in comprehension is usually required. Several techniques for comprehension are described below.

Several techniques for activating prior knowledge are already familiar to most teachers. Small group discussions of a topic prior to reading have been effective with many students (Baldwin, Peleg-Bruckner & McClintock, 1985). Some students with LD may need considerations such as "priming the discussion" with pre-teaching of some relevant concepts, or allowing students with recall problems to make contributions early in the discussion before their ideas have been taken by other students.

Another technique which can support students comprehension of reading is semantic feature analysis (Bos & Anders, 1990). A semantic feature analysis (see figure one) takes the form of a matrix with important ideas across the top and related vocabulary along the side. Students then systematically encode the relationship between the items in each cell using a four items code. A "+" is placed in cells with a positive relationship. A "-" is placed to show a negative relationship. A "0" is used to show no relationship. A "?" is used when students are uncertain about the relationship. The technique can be used along with other comprehension activities such as small group discussion as well as in laboratory activities.

Vocabulary development

For a variety of reasons, students with LD often lack the vocabulary development of their classmates without LD. Clearly, there is more to learning than reciting vocabulary lists. However, if one is going to use language to demonstrate competence in science, it is worth the time to ensure that the students know the necessary language.

Keyword mnemonics are the strongest technique available for teaching vocabulary. In mnemonic instruction, links are explicitly (and pictorially) developed between units of to-be-learned information and information already possessed by the student. Figure two provides an example of a mnemonic illustration linking the metals attracted by a magnet to the word magnet. It uses the acronym "INC" in Magnets, INC to prompt recall of the three metals (iron, nickel, and cobalt). Because cobalt is likely to be unfamiliar to many students, it is represented by the keyword "cobra." At recall, students are instructed to think of the picture of Magnet, INC and think about the things in the picture, one for each letter in the acronym.

Keywords require preparation and devotion of class time to explicit teaching of vocabulary. However, they are probably worth the effort. A substantial body of research exists demonstrating that students can remember keyword-instructed vocabulary for long periods of time and use their vocabulary flexibly and appropriately. Further, work in secondary education suggests that content-specific vocabulary development is the most accurate predictor of grades in core content area classes such as science (Espin & Denos, 1994-1995).

Some science teachers may find it easier to provide such specific vocabulary than others. Additionally, some general education students may already have acquired the necessary vocabulary for instruction and, therefore, find time spent on this technique counterproductive. In such cases, it may be appropriate for special education teachers to "preteach" the necessary vocabulary outside of the given lesson. In some cases, this could be done in a separate area of the classroom or in other cases, this might be better done in a different classroom at a different time. Rather than following the "same place for everything and everyone" ideology, we suggest that teachers and students examine the competing demands of the science classroom and the vocabulary instruction. If a separate environment promotes greater success and less disruption, it is foolish to insist on the same environment. Under certain circumstances, peer-tutoring and computer-based instruction could also be considered to support the acquisition of vocabulary.

Written expression

Many activities-based science classes require students to complete lab notebooks or write descriptions of activities. Writing is probably the most difficult aspect of language and many students with LD have particular difficulty with it. Several excellent programs are available to teach writing skills (e.g., Case, Mamlin, Harris & Graham, 1995; Englert, Raphael, Anderson, Anthony & Stevens, 1991; Harris & Graham, 1992). These programs can be used within science classes, but they are focused on general writing. Science teachers and special education teachers could collaborate to support student writing using these programs if writing is a major focus of the student's IEP and time allows. For other students, supports include alternative forms of expression. Students could dictate their responses to an aide, another student, or to a tape recorder. Speech recognition programs for computers are another option, but these must be "trained" to recognize individual students' voices. Little information is available regarding their effectiveness. For some students, written tasks can be reduced to checklists or multiple choice formats. Teachers should be alert to the extent to which changing the response format changes the learning task. In some cases, the format is easily altered, in others, the response format is important.

Attention

Often students fail to pay attention because they cannot perform the targeted tasks or understand the instruction. Other students are distracted because of personal problems or a history of failure which prevents them from taking instructional risks. Another source of poor attention is unenthusiastic and dull teacher behavior. Activities-based instruction is one way of reducing attention problems. Most students enjoy working with materials and respond positively. For those who need more help, direct appeals to pay attention, explanations of the relevance of the activities, and reinforcing attention may be helpful. Brigham, Scruggs, and Mastropieri (Brigham, Scruggs & Mastropieri, 1992b) reported that enthusiastic teaching resulted in twice the achievement and only one-third the behavior problems compared to unenthusiastic teaching of the same material to similar students.

Classroom behavior

Classroom behavior is often mediated by the instructional and environmental demands of the classroom. Also, teachers and peers may be inadvertently or intentionally reinforcing misbehavior. Classroom demands and reinforcement patterns are sometimes difficult to identify in one's own class. Asking other science teachers or special education teachers for assistance is one way of identifying classroom aspects which could be easily changed and may modify student behavior. Fuchs and Fuchs (Fuchs, Fernstrom, Scott, Fuchs & Vandermeer, 1994) provided a classroom ecological inventory which can be used by general and special education teachers to examine the "goodness of fit" between a given classroom and student characteristics and needs.

Simple behavior management techniques include direct appeal to the misbehaving student, teacher proximity, reinforcement of appropriate behavior, and group reward systems such as the "Good Behavior Game (e.g., Brigham, Bakken, Scruggs & Mastropieri, 1992a). A number of more complex techniques are available for classroom use. Because students with disabilities are often participating in structured behavior management programs science teachers should consult with special education teachers or check their students' IEPs. In some cases, misbehavior is involuntary (for example, verbal tics associated with Turret's Syndrome) and should be minimized or overlooked. In other cases, the student's misbehavior is a direct manifestation of a disability and requires more sophisticated intervention. In many cases, however, students with disabilities misbehave for the same reason as students without disabilities. Excusing misbehavior which is not related to a disability probably does more harm than good for students with LD.

Summary

The preceding sections have described a small number of support techniques related to several of the problems that students with LD are likely to display in science classes. In general, supports for students with LD focus on making the tasks clear and within the ability of the students to accomplish by altering the task (e.g., listening instead of reading) or structuring the task to promote better application of student abilities (e.g., systematic comprehending with a semantic-feature analysis. Activities-based approaches tend to minimize attention problems and some forms of behavior problems. Finally, students may need support to demonstrate what they know (e.g., transcriptions and taped responses). When special education teachers and general education teacher work together to provide appropriate support, student achievement is likely to increase substantially. It is important that specific supports be applied appropriately. Misuse of these supports (e.g., allowing a student who is capable of written response to use taped responses only) can actually be detrimental to students achievement (Mastropieri et al. 1998). Because LD is a complex and variable condition, science teachers should work closely with special education teachers and even the students themselves to tailor supports to promote optimal learning.

The Proper Emphasis for Inclusion in Science Classes for Students with LD

The Dilemma of Inclusion

Given the amount of attention that inclusion has received in recent years, one would suppose that a great deal of empirical support for the construct and its associated techniques has been generated. Unfortunately, inclusion remains as difficult to define as LD and empirical support for full inclusion of all students with disabilities is unavailable (MacMillan, Gresham & Forness, 1996). In fact, for some students, inclusion has been found to be harmful (Brigham & Kauffman, 1998) or associated with unsatisfactory results (Zigmond et al., 1995). Also, the current educational zeitgeist for increasing academic achievement outcomes in the areas of math, science, social studies, and reading and writing skills often works against the goals of socialization in general education settings promoted by advocates of full inclusion (MacMillan et al. 1996).

Application of Science Best Practices

Activity-based science practices have been shown to be beneficial for including students with mild learning disabilities. The learning cycle model of instruction should be adaptable for most students in this category, if modifications are considered. For example, the exploration stage of the learning cycle should be structured so that LD students can determine what aspects of the activity to focus upon. The BSCS model of the learning cycle, with the addition of an engagement stage prior to exploration, provides additional support for LD students. The engagement stage can involve discussion and introduction of important vocabulary, and can introduce important questions for students to think about during the exploration of the phenomenon or concept. When using the engagement stage as an additional part of the learning cycle, it is important for teachers to avoid a much-used and abused traditional approach - that of assigning a list of vocabulary words for students to look up in a dictionary and define. This approach emphasizes the reading and writing weaknesses in LD learners, and establishes little in the way of concept development. Direct instruction can be beneficial to LD students if delivered with consideration of the reading and writing deficits of these students and if the relevance of the instruction is established by appropriate engagement and exploration activities.

Learning disabled students need some structure in instruction; but they benefit from freedom to explore physical phenomena. They can become frustrated and display disruptive and counter-productive behaviors if the instruction is too open-ended. Therefore, science teachers must carefully apply the more open-ended interpretations of inquiry-based instruction. Whether a teacher calls the instruction constructivist, Socratic method, or open-ended laboratory exploration, the teacher must provide some level of guidance in order for learning disabled students to gain from the instruction.

Though structure is comforting to learning disabled students, there is a possibility of too much structure in science lessons that are based upon reading and writing tasks. Traditional approaches such as copying notes, completing worksheets, and answering questions after reading sections of text can be as frustrating and counter-productive as approaches that are too open-ended. The problem with LD students and science instruction can be characterized by the dilemma faced by Goldilocks with the temperatures of the porridge. Teachers must ask themselves if the instruction is too open-ended, too structured, or just right.

Summary

We have not yet discovered the one model of science instruction that works for all students, and such a perfect approach may not exist. Of the existing models and the best practices that are coupled with those models, no approach can meet the needs of all learning disabled students. Science educators must work with special education specialists to determine the best practices for particular students. There is no magic model. While we are able to support the goals of greater inclusion of individuals into society and educational systems, the evidence regarding elimination of separate programs for all students with disabilities suggests that such a step is at least premature if not unjustifiable. Inclusion of students with disabilities in general education settings should not be viewed as an either-or proposition. To be against full inclusion does not mean that one is for exclusion (Lieberman, 1992). Supporting students with disabilities in general education creates another highly desirable option for education of students with disabilities and is, therefore, an appropriate area of endeavor with the potential to improve the education of many but not all students with disabilities. It is only through a thoughtful and empirically based analysis of particular situations that science educators and special education specialists can move our learning disabled students toward the understandings they need for science literacy.

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SCIENCE INCLUSION IN A CLIMATE OF REFORM (SICOR)

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We are each provided with different strengths and weaknesses, but when the instructional environment supports each students use of their strengths to work towards their maximum potential, we set the ground work for equitable conditions beyond school. Close collaboration between professional educators in the interests of students must be supported and maintained if an equitable environment is to be created in schools. Not only does the area of the inclusion of students with special needs offer a great potential for supporting equity, equity is mandated by the laws and regulations supporting special education.

Inclusion is a fact of life that many teachers in secondary schools are forced to deal with, often without in-depth knowledge or proper support. Yet teachers are held accountable in meeting the needs of all students, whether those needs are special or not. How teachers construct and interpret curriculum at the classroom level is informed by years of experience as students and teachers. Basic assumptions about how students learn and how curriculum is constructed and enacted must be examined in order to create opportunities for meaningful learning in all students.

The purpose of this paper is to describe a novel approach to preparation of science and special education teachers in the construction of curriculum for science classrooms including students with disabilities. The basic is inclusion is constructively accomplished by design and collaboration, rather than by attempting to modify existing curriculum or lessons. Specific objectives include: (a) describing the activities of the SICOR, (b) describing potential research trajectories with respect to the effectiveness of the SICOR, and (c) discussing implications of SICOR for science and special educators as they relate the dual processes of science education curriculum reform and inclusive special education service delivery.

Background

The inclusion of students with special needs in the regular classroom has clearly become part of the overall educational landscape. Despite the sincere interest of many teachers to address the educational needs of all of their students (Scruggs & Mastropieri, 1994), the current emphasis on inclusion remains a source of frustration, misunderstanding, and distrust by teachers, parents, and students. Many regular educators are ill-prepared or supported to accept the challenges of teaching students with special needs.

Most people associate the term "special needs" or "disabilities" with students with orthopedic disabilities such as paraplegia, movement restriction, or visual and/or auditory impairments. Yet these students make up less than 4% of the total disabled population in schools (U.S. Department of Education, 1996). The majority of the disabled population has some form of learning disability, developmental disability, or combination of conditions that are neither as evident nor as well understood as physical disabilities. Teachers are responsible and held accountable for seeing that students' special needs are being met in the classroom, whether they are fully aware of how to deal with such disabilities or not.

Inclusion, or its predecessor mainstreaming, came about as a direct result of the passage of Public Law 94-142 in 1975, which specified that all students were to receive a "free and appropriate public education" in the "least restrictive environment." This has been interpreted as putting students with special needs, to the extent possible, in classrooms with non-disabled peers. The law further specified that each student have an Individualized Education Program (IEP). The IEP is to specify goals and objectives as well as spelling out specific modifications and accommodations that the school must make. This law was strengthened and reinterpreted in Public Law 101-476 or the Individuals with Disabilities Education Act (IDEA) of 1990 and 1997 (Epps, Neville, & Ormsby, 1997).

Science Education and Inclusion

Science education is in a unique position to serve the needs of students with special needs in that accommodations can easily be made part of the normal variation in instructional modes. Hands-on learning, cooperative groups, dialogue and discussion, and authentic assessment, which figure prominently in current thinking on effective science teaching (Champagne, Newell, &

Goodnough, 1996; Gabel, 1995), are also opportunities for accommodating students with special needs (Mastropieri & Scruggs, 1996).

The proposed collaboration between the science teacher and the special education teacher, however, places an increased demand on the already limited time of teachers in general. In fact, many of the workshops and guidebooks offered to teachers on classroom modifications become "just one more thing", and without a cogent plan and a sense of shared need, science teachers and special education teachers will not provide appropriate services to their special needs students.

In order for science teachers to facilitate the learning of their students with special needs, Scruggs and Mastropieri (1994) suggest seven items that support an inclusion plan:

1) Administrative Support - school administrators should demonstrate strong support for inclusion.
2) Special Education Support - direct assistance by special education teachers and staff should be evident.
3) Accepting Classroom Atmosphere - student diversity is clearly appreciated and recognized.
4) Peer Assistance - using nondisabled students as aides to students with disabilities.
5) Appropriate Curriculum - curriculum that does not exclude students by their special needs, i.e. text-dependent curriculum mismatched with dyslexic students.
6) Effective Teaching Skills - teachers possess a broad repetiore of instructional approaches.
7) Disability-Specific Teaching Skills - teachers adapt their instructional approaches to the needs of their students.

Furthermore, effective collaboration requires intrinsic motivation, commitment, and valued knowledge base between both participants in the partnership (Finson, 1998).

The SICOR Project

Science Inclusion in a Climate of Reform (SICOR) is a project that was developed at West

Virginia University in response to the need to facilitate the collaboration of science and special educators in North-Central West Virginia. The objectives of SICOR are for teachers to:

1) acquire knowledge, skills, attitudes and practices related to co-teaching in science and special education;
2) develop methods for planning and implementing instruction in science with regard to specific science content areas, Coordinated and Thematic Science (CATS) and the unique and diverse individual needs of students;
3) develop methods for utilizing West Virginia Science Instructional Goals and Objectives (IGOs) and Individual Education Plans (IEPs) of students with disabilities to design and implement science lesson plans;

SICOR was piloted in 1997 with a group of 12 elementary and middle school science and special education teachers. Their task as part of the workshop phase was to generate CATS instructional module components that included specific accommodations for students with disabilities, as described in several case studies of special needs students. The original project met its initial goals, but faced difficulty in that many of the discussions and lesson frameworks developed by the participants were in the abstract and often divergent with respect to their actual instructional needs.

During the summer of 1998, another group of 14 science and special education teachers were recruited to participate in a two week workshop that built upon the previous year's work. Consistent with the CATS program, teachers received instruction around a central theme, in this case "Earth and Space." Science content and activities were built around the four major science content areas (Earth Science, Physics, Chemistry, and Life Science). After participating in specific science learning activities, teams of science and special educators scanned the state science framework for grade-level specific objectives. Once the objectives were identified, they were grouped by investigative questions. The teams then began the development of Learning Cycle Lesson plans that included the content of the workshop modules suitably modified to the teams' grade levels.

Simultaneously, each team referred a specific "case" student with special needs in considering the accommodations needed in instruction. The cases, which were generated by the teams, consisted of a rich description of the student, identifying disabilities and history. The case also specified general accommodations that were needed as well as a prototypical IEP. In each phase of the Learning Cycle lesson plan, the teams inserted specific accommodations that met the needs of the case student. At the completion of the workshop, the teams defined their action plans for the Fall of 1998 in their classrooms and for their participation in the West Virginia Council of Exceptional Children (WVCEC) and West Virginia Science Teachers Association (WVSTA).

Much of the previous work that has been developed with respect to science inclusion has been divergent, in that experts have provided science teachers with specific and useful strategies to use with students that have particular special needs or disabilities. The science teacher and the special education teacher work largely separately and independently, with the science teacher translating science curriculum into instruction and the special education teacher interpreting the IEP. SICOR differs from previous work in that it is convergent, such that the student's IEP and the state curriculum are considered concurrently in the development of the lesson. As a result, the science and special educators become teammates in a common cause. They have a shared context for co-planning and co-teaching as the circumstances allow. Furthermore, it is anticipated that teams of teachers will be able to leverage more administrative support for co-planning and co-teaching than individual teachers alone (Koballa & Pyle, 1995). The work that has been generated by the 1998 SICOR teams thus far indicates that inclusion can become anticipated and often times seamless in terms of implementation in the class. This presentation will share examples of their work.

Assuming one knew that a particular student had special needs and an IEP, a means of serving that student's needs would be in designing lessons and assessments for inclusion from the start rather than attempting to devise modifications later (Pugach & Warger, 1996; Pyle & Butera, 1997). In designing instruction for inclusion, a teacher should start by concentrating on the strengths identified in a student's IEP. A well prepared IEP should contain both the strengths and deficits of a student. By working with the strengths, teachers can attempt to generalize learning into other areas. The IEP document is the tool that serves to focus the selection of instructional approaches as much as the curriculum determines the content to be addressed. Bear in mind, IDEA specifies that both parents and regular educators participate in the development of the IEP, so teachers should ask parents for information to best help their child get the most from what the school has to offer. Principals can support inclusion by facilitating teachers attending IEP meetings and providing the resources necessary to carry out both the science curriculum and the IEP.

During the Fall of 1998, several SICOR participants were able to participate in team presentations at the WVCEC and WVSTA meetings. A novel format was adopted such that each member of the SICOR team adopted a role as one of the case students, acting out to the best of their abilities the various behaviors and limitations of their student. They performed their role without the prior knowledge of the remainder of the audience, who assumed that the SICOR participants were at the session for the same reasons as they were.The representations in the cases were authentic in that they represented students that the participants had had direct personal experience with. Furthermore, the guidelines suggested by Epps (1997?) that simulations involve debriefing, descriptions of limitations, and adequate time devoted to the simulation were used as a regular part of the simulation. Session attendees were provided with the overall framework of the activity, descriptions of the representation of the case students modeled, and a direct application of the collaborative model applied in the SICOR program. Both sessions were well received by the audience, with session evaluations averaging approximately 4.8 on a 5 point scale. Evaluation of the impact of SICOR on the students of past participants will continue throughout 1999.

Potential for Research

Because of the controversial nature of inclusion in any classroom setting, careful evaluation of any project's effectiveness is required. Furthermore, dissemination of effective program elements is of critical importance. A primary audience for such research is science teacher educators who wish to best prepare prospective teachers. Other audiences are parents, school board officials, and clinical diagnosticians, all of whom generally have limited information about inclusion but have primary decision-making responsibilities.

One line of research that would be particularly important to define would be the effects of interventions such as SICOR on special needs students' progress towards both IEP and academic goals. Data such as these are readily quantifiable, but their equivalence is an issue of concern. In particular, IEP goals are by their very nature idiosyncratic and cannot generally be norm-referenced. On the other hand, many special needs students are exempted from the normal standardized testing procedures, as the nature of some of the tests are in direct contradiction with IEP-stated modifications and accommodations, such as additional test time, tests read aloud, etc. The highest legal authority in such cases is the IEP. In addition, sensitivity by many special needs students' parents might preclude the direct use of data gathered from these students. Thus, both methodologic and ethical obstacles exist for quantitative research. These obstacles do, of course, exist for qualitative approaches as well. Interviewing or observing a special needs student, without a deep familiarity with the exact nature of the student's disability produces a threat to the validity of studies employing such an approach.

That is not to say, however, the picture is bleak for research on science inclusion. The unique nature of the science classroom and the activities that can occur within make it fertile ground for understanding how <u>all</u> students can learn, as certain science related tasks fit very well into individual students' strengths, whether they are disabled or not. Anecdotal evidence suggests that inclusion increases a classes' or small group's cohesiveness, as students without special needs "look out for" the student with special needs. They can, in fact, become quite defensive. The capacity for a teacher to take advantage of such cohesiveness in instruction would seem to increase the chances of meeting academic and IEP goals. The framework for doing this, however, is only in its infancy.

The future of inclusion is not at all certain. It will depend upon the willingness of all parties to adopt a student-centered approach. This approach, however, cannot always be guaranteed. Some possible futures include:

- Polarization: Between teachers and administration;

  Between parents and school systems;

  Between parents of "regular" students and parents of students with special needs;
- Stagnation: Teachers burdened with additional demands on limited time;

  Parents confused about disabilities, regulations, and documentation;

  Administrations overwhelmed by and increasing caseload;
- Maturation: Science and special educators comfortable with learner-centered collaboration;

  Science planning, instruction, and assessment that meets the needs of <u>all</u> students;

  Teachers receiving support for co-planing and co-teaching.

Given sincere work by all parties, maturation is possible, but it will not be easy or quick in coming. Projects such as SICOR offer a mechanism for teachers to make the appropriate choices from professional expertise and not external coercion.

Conclusions

Inclusion of students in the regular classroom is a fact of life now for many teachers, but it need not be feared, both in terms of one's own teaching as well as the impact of inclusion on students without special needs. Rather than being cast to one's own devices, structures such as the IEP and curriculum are the primary tools at a teacher's disposal. On the next level, the support of the special education staff and the student's parents are also available, but only to the extent that there is open communication and a common language and mind set. Special educators are generally not well versed in science, just as many teachers (and most parents!) are not well versed in the complexities of their child's special needs as well or the services associated with the education of students with special needs. Clear communication, purposeful intention towards student learning, and focused advanced planning will serve well not just the students with identified needs, but all students.

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UNIVERSITY-HIGH SCHOOL PARTNERSHIPS FOR SCIENCE EDUCATION: MULTIPLE PERSPECTIVES

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Science education has enjoyed a renewed national emphasis in recent years. The *National Science Education Standards* (National Research Council, 1996), the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), and *Science for All Americans* (American Association for the Advancement of Science, 1989) have become known not only within the science education community, but also among the general population. The impact those documents have actually had on the classroom practice of science teachers and on the teacher education programs responsible for educating and developing prospective science teachers has been less wide-spread. That lag in the implementation of reformed practice is consistent with Goodlad's (1994) appraisal of the change in teacher education programs across all disciplines.

Structured alliances among universities and K-12 schools have been suggested as one route to renew both the education of young people in America's schools and to re-create and re-conceptualize what it means to educate prospective teachers (Goodlad, 1994; Osguthorpe, Harris, Black, Cutler, & Harris, 1995). These joint endeavors to prepare prospective teachers have been identified by various names and philosophical concepts. Many educators are familiar with the Professional Development Schools which emanated from the work of the Holmes Group (1986). Professional Development Schools were conceptualized as schools where school faculty and administrators and university students and faculty would be involved in the processes of:
(1) mutual deliberation on problems with student learning, and their possible solutions; (2) shared teaching in the university and schools; (3) collaborative research on the problems of educational practice; and (4) cooperative supervision of prospective teachers and administrators. (p.56)

More recently, Goodlad (1993) coined the term "partner schools" to describe the type of egalitarian relationships that would lead to the reform of teaching and learning in K-12 schools and university-based teacher education programs. Ideally, partner schools would represent "Centers of Pedagogy" (Goodlad, 1994) and would exemplify best practice, create knowledge through collaborative research, assist in the redesign of teacher education, and provide renewal for teachers.

When we think about partnerships in science education, we might initially conjure a picture of school-industry (Carter, Park, & Copolo, 1998) or school-university science (Herwitz & Guerra, 1996) alliances. In the context of science teacher education, however, the concept of a partnership centers on the collaborative relationships that are built among school faculty, students, and administration and university science education faculty and students. The notion of school-university partnerships for the development of prospective and inservice science teachers is supported by the *National Science Education Standards* (National Research Council, 1996). The professional development standards advocated in that document stipulate that teachers of science engage in discourse with their peers and work collaboratively with university science and science education faculty. The products of such interactions would, theoretically, be enhanced field experiences for prospective science teachers and richer professional development opportunities for inservice teachers. To specifically guide the process of teacher education in the profession, the National Science Teacher's association has begun the development of a set of published "Standards for the Education of Science Teachers." Included among the set of ten standards is that of "professional practice." A "professional" science teacher, according to the NCSTA standards, "participates with others in science education to develop opportunities for continuous learning as members of a professional education community" and "takes responsibility for new science teachers, teacher interns and practicum students and works with them collegially to facilitate their growth and entry into the profession." Those goals can be effectively met through teachers' participation in partnerships with university faculty and teacher education programs.

Workable school-university partnerships depend on a number of factors. The most important aspect in initiating such partnerships is developing a means of effective communication based on a shared sense of equity and trust between and among all the partners. Since K-12 schools and universities often consider themselves to be attacking different goals, partnerships must identify and address "overlapping self-interests" (Goodlad, 1994). Frequently, frustration over an inability to realize desired outcomes sets the stage for the development of closer ties between university teacher education programs and area schools. Harris and Harris (1995) described the launch of their partnership with an elementary school to be the result of three issues:

(a) dissatisfaction with their teacher preparation program and public school function, (b) a need for leadership at all levels, and (c) a need for school and university faculty who were willing to embrace new models concerning knowledge, teaching, learning, and leadership.

As these cross-community partnerships develop, what do the emerging relationships look like and how successful are they? Few of the descriptions of partnerships in the current literature involve high school-university relationships. The lack of reports derived from high school settings may reflect the difficulty universities have establishing collaborative relationships with high school faculties. Discipline-specific curricular demands within university programs and scheduling issues at the high schools could hinder the potential to develop programs requiring prospective high school teachers to consistently be on a public school campus for any significant length of time. Those difficulties may be further enhanced when the partnerships involve science teachers. The dearth of qualified science education graduates has forced many high school administrators to hire science-trained professionals from business and industry who desire to become teachers, but do not have a background in education. The lack of understanding these teachers have concerning the scope, sequence, and purpose of teacher education could pose a significant, but not insurmountable, barrier to their full participation in the development and implementation of programs designed to prepare prospective teachers to enter the teaching profession. The goal of this panel presentation was to provide descriptions of and dialoguing about the development of various school/University partnerships in the context of high school-based science teacher education programs.

The Perspectives

The panel consisted of three members of the science education community who contributed a range of viewpoints about the details of school/university partnerships within the context of secondary school science teacher education programs. Each of those perspectives will be summarized in the text that follows.

A Whole-School Partnership

A partnership between Cary High School (CHS) and NC State University was formalized in May 1996. This partnership grew out of existing connections between a cadre of mentor teachers who were participants in the Model Clinical Teacher Program and a CHS teacher who was employed at NC State as clinical faculty. The partnership was initiated by the CHS faculty and was quickly embraced by the NC State faculty. During May and June 1996, several day-long retreats were held to allow both faculties to work together in forming a framework of what this new association would look like; from this came a mission and vision statement, goals and objectives. By Fall 1996 subcommittees were in place to implement specific innovative changes in the faculty, student and administrative programs/processes at the CHS and NC State sites; student teachers from NC State were placed at CHS under the partnership arrangement for the first time in Fall 1997.

The positive responses generated by the CHS/NC State partnership and an interest in school partnerships from the UNC University System encouraged NC State to expand the partnership initiative to include the Wake County School System, where Cary High School is located, and to add two additional school systems, Franklin County and Johnston County. These three school systems and NC State established Triangle East Partners in Education (TEPIE) in Spring 1997.

Innovations in the Student Teaching Program at CHS

The formation of the CHS/NC State partnership allowed the two faculties to address some specific changes in the preservice program for students at NC State in science education and mathematics education for implementation in Fall Semester 1997. Several of these innovations were under consideration by the NC State faculty in the Department of Mathematics, Science and Technology Education at the time the partnership with CHS was established; the formation of the partnership allowed for the implementation of these changes more quickly and on a large scale.

The traditional program for senior students at NC State in preservice education includes a Professional Semester that consists of seven and one-half weeks on campus enrolled in "materials and methods of teaching" courses followed by 10 weeks of full-time student teaching. The on-campus courses are scheduled from 8:00 a.m. until 12:30 p.m. Week 3 and Week 6 of the Professional Semester each contain two days of on-site observations at the schools where the students will do their full-time student teaching. Usually the first observation days (in Week 3) is the first time that the student teachers have met their on-site cooperating teachers.

Due to the CHS/NC State partnership, the role of the student teacher during the Professional Semester has become longer and more complex; to denote these expanded responsibilities, the "partnership" student teachers are referred to as Interns. The partnership allowed the faculties at CHS and NC State to make several cooperative changes in the preservice Professional Semester.

1. Involvement of Interns in the Teacher Workdays - Public school teachers are typically required to attend a series of work days prior to the beginning of classes in the public school. Consequently the Interns had the opportunity to meet with their Cooperating Teachers (CT) before their involvement in the public school classes and work with them in the planning of classes for the fall semester. This required the Interns to return to NC state a week before their on-campus methods and materials classes began.

2. Interns Attend Opening Day in the Public Schools - The first day of the Professional Semester coincided with the opening day of the public schools. The Interns were required to spend Opening Day with their CT at the school site.

3. Interns Become Co-Teachers of 6th Period Class From the Beginning of the Professional Semester - Since the on-campus methods and materials classes are completed by 12:30 each day, the Interns return to CHS each day to participate in their CT's 6th period class; this is the last class of the day at CHS and run from approximately 1:30 to 2: 20.

<u>CHS Faculty Response to Partnership Innovations</u>

Eleven teachers at CHS served as Cooperating Teachers (CT) for the eleven NC State Interns in mathematics and science during Fall 1997. All of these teachers had previous experience as CTs and had participated in the traditional student teaching experience with other NC State students. Four of these teachers had been active participants in the planning of the CHS/NC State partnership; the others had minimal involvement. During and after the 1997 Professional Semesters, anticdotal information was gather from these teachers on their response to the partnership innovations. Additionally the CTs responded to a written survey given to them by their CHS faculty coordinator; the survey asked the CTs to comment on specific changes in the Professional Semester resulting from the CHS/NC State partnership. These date are reported below for each of the three selected partnership innovations.

Involvement in Teacher Workdays

All of the CTs thought this change in the program worked well. It provided a time for CTs and Interns to meet without the pressure of having classes to conduct. There was the opportunity for joint planning, making it easier for the Interns to visualize the role they were going to play in the classroom. This early planning made the CT and the Intern partners and co-teachers. One of the most important aspects was that the Interns saw themselves being recognized as professional teachers and as active members of the CHS faculty. It was difficult to distinguish between the Interns and other teachers who were new to the school. The Interns became part of the teaching/planning process, rather than apart from that process.

Attending Opening Day

This was the most acclaimed innovation for the partnership. Every CT valued this experienced for providing the Interns with the "before" picture for their internship. As one teacher commented, "I thought it was extremely beneficial for [the interns] to see how the year starts and then transforms." The Interns had a deeper appreciation of the changes in the high school students through the semester. Interns also had the opportunity to observe the different techniques used by teachers in establishing protocol on opening day, especially the importance of introducing the students to the subject area in a fun, interesting way rather than simply giving rules and establishing structures.

Co-teaching 6th Period

Of the three innovations this one received the most mixed reviews. Two of the 11 CTs "...didn't think it was particularly beneficial for [the Interns]." Five CTs specifically remarked on the positive value of the 6th period experience. Most of the Interns had to return to the university immediately after 6th period ended in order to carry out assignments from their on-campus classes. The discrepancy among the CTs views of the experience may be due to the expectation of some CTs that the intern would remain after class every day to plan for the next class. Also the relationship between the Interns and their CTs developed differently, some becoming stronger that others. The overall view toward the 6th period experience was positive; one teacher commented, "[The Interns] seemed so adjusted and ready to assume their teaching responsibilities because the already knew student names and general info. By the time they begin teaching, that (the teaching) was all they had to worry about." In one 6th period class students were surprised when the Intern left at the end of the semester; they thought she was a co-teacher.

Figure 1. Teacher Intern Outcomes of the Cary Project.

By participating in Teacher Planning Week, interns:
- were welcomed and viewed as part of whole school faculty
- were recognized as partners in the Partnership
- became acquainted with the physical layout & procedures of the school
- assisted in planning for courses they would teach
- knew prerequisite lessons of classes before beginning internship
- were able to link on-campus activities to planned lessons
- established a professional relationship with cooperating teacher
- experienced being a "real" teacher

By attending Opening Day, interns:
- saw how teachers introduced science to their students
- observed the Opening Day routine
- became acquainted with how management plans were developed with students
- met and were introduced to all their classes
- assisted the cooperating teachers in teaching the classes
- discovered the paper work required start the year

By assisting and teaching 6th period class throughout the semester, interns:
- observed the development of the class/teacher rapport
- established earlier contact with the students making it easier to teach the class full-time
- learned names and the patterns for the first class they would pick up
- added additional classes to their schedule sooner that other interns
- related incidents from class to members of the Methods course
- set the context for some Methods activities
- helped Methods students understand the application of class material

Adding on-campus time for reflection and portfolio development enabled the interns to:
- reflect on the total internship experience
- have extended discussion and analysis with fellow interns
- develop their portfolios through their reflections
- express the need for additional specific "methods" for this time
- find direct relationship between class material & their experiences
- celebrate their accomplishments through their portfolio presentations

All three of these partnership innovations were used again with the Fall 1998 Interns. With the faculty at CHS more familiar with the program, the CTs made greater use of these opportunities. The NC State faculty examined class assignments and reduce the requirements that would call for the Intern to specifically return to campus. Table 1 lists some outcomes for the Teacher Interns who participated in this project. Data on the Fall 1998 experience are still being evaluated. Closer counseling between the CTs, the Interns and the University Supervisors helped to facilitate the success of these and other changes in the CHS / NC State Partnership preservice preparation of teachers.

Smaller Pieces: Departmental Alliances

The innovations implemented in the CHS/University partnership allowed progress toward providing university interns with more, and longer, in-school experiences during the professional semester. The "Methods" class, however, was still held on the University campus; students did not have regular opportunities to interact with school students while learning pedagogical strategies and concepts. When the interns did reach the internship phase of the semester, they were often scattered throughout the large county-wide school district, having little access to the university supervisor or their peers. The prospect of creating a "center" for the development of prospective science teachers provided the incentive needed to promote the alliance between a high school science department and the university faculty member.

The Partnership Site

Avery High School (pseudonym), a large high school in the southeastern United States, was chosen as the site for the development of our science department-university partnership. Several factors contributed to the selection of AHS as the partnership site. Location was a primary concern. University students and faculty needed to be able to access the site with a minimum of travel time; AHS was a fifteen minute drive from the university. The size of the partner school and the number of available science faculty were also considerations as the development of a potential center for science teacher education would require a large faculty. AHS had a science faculty of sufficient number (18) to support a sizable cadre of prospective science teachers engaging in school-based field experiences. AHS was also an attractive site for the partnership because the teachers had a significant need and potential for professional development. The school had experienced a recurrent turn-over in science teachers, especially among not-yet-licensed first and second year teachers. The teachers' attempts to continue in self-directed professional development and their participation in state and national organizations were very limited. Among the faculty of 18 teachers, only two had completed a program that would educate them to mentor unlicensed science teachers in the school. Few of the teachers regularly volunteered to mentor teacher interns. Finally, the university faculty member was impressed with the need the school faculty had for the development of a positive, professional support system. AHS had experienced a "split" when the student population outgrew the available resources at the site. Ninth grade students were moved to a newly opened middle school for two years and then to a converted industrial complex during the following academic year. The faculty teaching courses targeted for ninth grade students moved from site-to-site with the students. Those faculty had limited opportunities to interact with their departmental peers who remained on the main campus. One of the underlying goals of the partnership was simply to provide a way to get the AHS teachers together in a collegial environment where they could focus on a positive, collaborative purpose.

Getting Started

The idea for the partnership was actually "seeded" during a conversation between the university faculty member and Tim (pseudonym), a chemistry teachers at AHS, about the possibility of implementing a science education "Methods" course on the high school campus. Tim, who had been supervising teacher interns in his classroom at the school, indicated an interest in participating in a more intensive, practical approach to the traditional "Methods" course. The university faculty member's conversations with Tim led to an interview with one of the school's assistant principals; several subsequent meetings were held to negotiate a plan for a project. The STEAM (Science Teacher Education and Mentoring) project, designed to develop and implement a collaborative professional development community on a high school campus, resulted from those interactions. Several specific goals drove the STEAM project's agenda:

1. To develop and implement an "on-site Methods" course for prospective high school physical science (chemistry, physics, and earth science) teachers.
2. To identify and develop a cadre of teachers who would act as mentors for teaching interns.
3. To provide instructional support for entry year and other nontenured classroom science teachers.

4. To develop a collaborative community for the continuing development of teachers across all levels of professional expertise (i.e. preservice and inservice public school teachers, and university faculty).

In February, 1998, after receiving approval and support from the AHS administration, informational flyers were sent to all the science teachers in the high school and a meeting was conducted at the monthly departmental faculty meeting. Eight teachers volunteered to participate in the project. The teachers represented all the content areas taught by the science department (biology, chemistry, physics, earth science, and physical science). The teaching experience of the participants ranged from 2 to 29 years. Four of the participating teachers had graduated from four-year teacher education programs where they had engaged in traditional methods/student teaching experiences. Four other science teachers had entered the profession through alternative routes, usually earning a degree in a particular science discipline and then working in industrial settings prior to coming to the teaching profession. The project "team" also included a professional facilitator, a research consultant, a university science education faculty member, and two senior-level students from the undergraduate science education program at the university. The director of teacher education at the university attended and participated in the project meetings.

The high school teachers met with the university members of the project team on four occasions during the Spring, 1998 semester. All meetings were held after school in Tim's classroom on the high school campus. The objectives of the four meeting sequence were to develop a sense of community among the university and high school participants and to begin a dialogue concerning the on-site Methods course that would be held on the high school campus in the following Fall semester. In preparation for the first two meetings, the teachers were asked to read Chapter 4 ("Standards for Professional Development for Teachers of Science") in the *National Science Education Standards*, (NRC, 1996) and the draft (www-based) version of the National Science Teachers association's "Standards for the Education of Teachers of Science." The teachers completed surveys developed by the university faculty member to communicate their responses to the readings. (Teacher time was compensated monetarily through a grant awarded by the university's partnership organization.)

The research consultant, university faculty member, and facilitator met prior to each meeting to examine the data generated from the prior sessions and to set the agenda for the upcoming interactions. The facilitator began each meeting with a clear idea of her goals and implemented the agreed-upon agenda. A summary of the focus of each meeting follows:

Meeting #1: What do you believe to be the primary purpose of an undergraduate level science teacher education program? What roles can inservice teachers play in the process?

Meetings #2 and #3: What roles do the cooperating teacher, teacher intern, and university supervisor play in the development of prospective teachers? What one thing, in your opinion, is of utmost importance in the development of prospective teachers?

Meeting #4: What are the uses of a methods course? What coordination between university and school faculty do you think the development and implementation of a methods course will require?

In addition to the four Spring meetings, the teachers were invited to confer with the university faculty member and the research consultant on two occasions during the ensuing summer months. In those meetings the teachers were encouraged to consider the specific elements that would be included in the Methods class. One of the then-graduated university student participants was hired by the high school and was assigned to work with the Methods class. The university faculty member and the chemistry teachers collaborated to develop parallel lesson plans that would encompass both the goals for the students in the chemistry class and the teacher interns.

The Methods Course

The Methods course was conducted from mid-August through mid-September in the Fall, 1998, semester. The teacher interns reported to the AHS campus to participate in the "work week" which preceded the first day of school. During that time the interns met with their cooperating teachers, worked with the chemistry teacher to prepare for the instruction that would occur in the chemistry class, and participated in seminars with the university instructors. Preparation for the beginning of the school year included setting up the classroom environment (bulletin boards, seating arrangements, etc.), developing instructional materials and assessments, and mixing reagents and gathering supplies for the laboratory activities. During the seminar sessions the interns began to examine instructional practices (i.e., assessment and discussion techniques) and lesson planning.

The teacher interns participated in the classroom-based Methods course for approximately five weeks. The following schedule was implemented:

11:45 -12:15	Final preparations and debriefing for the chemistry class agenda
12:20 - 1:15	Participation in the academic chemistry class
1:30 - 4:00	Seminar and preparations for the upcoming chemistry classes

During the chemistry class sessions the TIs made observations and facilitated small group discussions and laboratory activities. Observations, concerns, and suggestions were discussed in the seminar sessions that followed the chemistry class. The seminar sessions were also used to allow the teacher interns to further develop their own skills (discussion techniques, understanding students' conceptions, lesson planning, etc.) and to help the classroom teacher develop quizzes and tests and prepare for the laboratory activities.

Initial reports about the project indicate that the Methods course was well-received by the participating high school students who appeared to enjoy the extra attention afforded them by the presence of the teacher interns. The university teacher interns, however, had varied opinions about the structure and benefits of the course. Some of the TIs believed that the workload required to integrate preparations for the chemistry class with the demands of the university Methods class was excessive. The classroom teacher, a first year teacher who gave up her planning period each day to participate in the after-chemistry class seminar session, reported that she benefited from the interactions she had with the university instructor and the teacher interns.

Using Inquiry Projects in Partnership Schools

UNCW's Professional Development System is a nationally recognized educational reform effort involving a school of education, ten school systems, and fifty professional development schools in southeastern North Carolina. Drawing heavily on a systems approach, PDS organizers utilized theory and research in organizational reform, professional development of educators, and curricular/instructional supervision to inform the design and implementation of each generation of our collaboration with schools in our region. We related to schools initially in ways described in both Goodlad's model of Partnership Schools (1993) and the Holmes model of the Professional Development School (1986). From that point, we have situated those site-specific partnerships within the context of a system of partnerships. We are now in the third round of contractual agreements with the ten school systems. Those agreements define the roles and responsibilities of each member of the PDS. We say that our professional development system works for us because it is our system we have a shared ownership and we seek to meet our collective goals. The connection of shared ownership and the affirmation of collective goals are likely idiosyncratic and unique to the particular collection of people, programs, and communities in our system. What is applicable more broadly are the guiding tenets we have embraced and refine throughout our partnership efforts.

The UNCW PDS works because of true collaboration through a dynamic process promoting respect, inquiry, and leadership. This process embraces professional culture through valuing a developmental perspective of our people, purposes, and programs and thereby respecting the differing levels of experience and readiness among members of the system. That developmental view is facilitated through inquiry into our practice; we look closely at what we are doing and pay attention to outcomes, responsively changing our thinking and our practice by looking at the collected data within appropriate contexts. Further, we have learned that it is not enough to have an understanding of developmental process, nor even adopt a habit of inquiry we must also have leaders at each part of our system who share a common vision and take risks to bring that vision to reality. Finally, we have realized and celebrated a lack of closure; we will never be finished because each lesson we learn teaches us new questions. We are resolved to look for progress in our growth, rather than seeking a sense of accomplishment in ending that growth.

Inquiry in Professional Development

There is a clear need for inquiry within the context of professional development efforts (Byrd & McIntyre, 1999). Inquiry can be defined as a search for information and insight through documented collection and analyses of data. Inquiry projects assigned to teacher interns during the internship experience and inquiry projects conducted by practicing teachers individually and collaboratively with interns and other teachers are showing promise as a means to facilitate thoughtful analysis and change in teacher practice. The inquiry project is seen as a means of documenting and thereby analyzing the decision-making processes inherent in teaching and connecting those decisions to the collection means and sources of the data used to make and evaluate those decisions. Many teachers have stated that they do what they do because they know it works. Inquiry projects require a more thoughtful analysis of exactly what they are doing and how they are deciding that what works. The practice described here is implementation of the

Teacher-Directed Classroom Inquiry Project (Rogers, 1998) consisting of planning and reporting guides. The planning guide helps teachers to select an inquiry topic, consider additional information needed to focus on a particular inquiry, choose data sources and means of collection most likely to match inquiry, determine how those data can be analyzed to address the inquiry, and acquire appropriate approval (especially important for our teacher interns). The report guide leads teachers through the process of stating the inquiry and any appropriate background information; telling the procedure, findings, and conclusions of the project; explaining further implications of the project from the teacher s perspective, and stating references for those who read the report. These inquiry projects are being shared among teacher interns, partnership teachers, and other LEA and university educators to promote discussion of issues associated with UNCW s Professional Development System.

Summary

The initial efforts to develop partner relationships with the public schools are already bearing fruit with respect to changes in North Carolina State University's teacher education programs. The ongoing dialogues between school and university faculty are also providing opportunities for deeper levels of collaboration than we have experienced in the past. The alliances allow university personnel and school personnel across all levels of authority (classroom teacher, superintendent, university vice chancellor, etc.) to come together for a common purpose--to improve the development of prospective teachers and to help school children be more successful. The CHS/NCSU partnership has provided a small, doable "model" environment to examine the negotiations necessary to bring people with seemingly different agendas together to achieve a collaborative mission. That alliance has already led to changes in the university's teacher education program schedule. The STEAM project is yet another attempt to impact the classrooms of individual teachers and their students while at the same time providing rich, interactive environments in which university teacher interns may actively participate in and professionally reflect upon the work of teaching. The inquiry projects used in the UNCW system provide an opportunity for teacher interns and partnership teachers to engage in activities that allow them to reflect on their beliefs and practices. Those collaborations have been successful in building collegiality and enhancing the professional developments of all the participants.

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TEAM PROJECTS: A TASTE OF REAL SCIENCE IN OUR CONTENT/METHODS COURSE

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We have designed a hybrid content/methods course for preparing physical science teachers. This 3-credit-hour physics course is jointly taught by two professors - one from engineering and one from secondary science education. The objectives include giving future teachers realistic experiences in the pursuit of solutions to problems where no answers are provided by the textbook or instructor. Using the course theme of energy in the home and automobile, we discuss heat transfer, home energy consumption, battery storage, solar photovoltaic arrays, and other basic energy concepts. Each lesson introduces a problem, offers demonstrations of key concepts, asks students for applications from their own experiences, and ends with a quest for new solutions.

At the mid-point of the course we divide students into teams of three and assign them a project that requires synthesis and analysis of course content. Examples of these projects include (a) testing and scale-up of a solar photovoltaic array panel, (b) construction and energy audit of a scale model house to minimize heat losses, (c) exploration of several methods of heating water in search of the most effective, (d) efficiency and durability of residential sources of light, and (e) a quest for the most effective way to cool a six-pack of carbonated drinks. In each case, the team is given the following instructions:

> The final project is designed to challenge you to apply some of the science and engineering principles we have studied in this class. You will work with two others to study a problem and reach a conclusion supported by your own data. The descriptions below are intended to "draw a circle around the problem", not to fully delineate all the details. Thus, you must examine the problem statement carefully, consult with your partner, seek clarification where it is needed, and ask for any equipment you cannot locate yourselves. Of the 100 possible points for each problem, 60 will be awarded for simply doing what is specified in the written description below. The remaining 40 percent will be awarded for "creative sciencing", defined as applying your best means of solving the problem using ingenuity and common sense. There are no right answers in the back of the book. We do not even know the answers. But there are good answers! Your job is to find them, test them, and document them in your report. Your grade will be based on both the written report and the oral presentation {@ 50 points each}. All team members must take part in the entire process of library research, construction,

testing, and graphing results. All team members must sign the cover sheet of the report stating that you either have contributed equally to the final product or declaring your actual contribution. Project reports are due on ______. Your team would be wise to begin work at once and allow plenty of time for the natural frustrations that are an inevitable part of applied science.

This video/paper presentation (see Appendix A for video outline excerpt; see Appendix B for index to entire video) will describe the results of our team project approach to preparing better science teachers, noting that many of them do not otherwise get a real taste of the frustrations and joys of authentic science projects (Linn & Clark, 1997). We feel this is a good way of helping teachers meet the National Research Council standards with their own students. We seek to prepare science teachers who will engineer learning environments in their own classrooms that avoid "looking for the same answer as the one in the back of the teacher's manual." Project approaches in the classroom can help achieve this.

Our future plans for the course include CD-ROM and web page development to go with printed materials for distribution to other institutions. We are working on export of several course modules for use in our state-wide "Science in Motion" mobile van outreach program.

Figures 1 through 3 provide example project descriptions as given to student teams for this 5-week effort:

Figure 1

How many ways can I heat water?

Project managers : <<names of team members>>

You are to compare two methods of heating water – electric resistance coil and a second, non-electric method. Use a simple, 120-volt immersion coil heater to heat 1000 cu. cm. of water from 20 deg. Celsius to 50 deg. Celsius. Calculate the efficiency of this operation. Do this three times and take the average of your efficiency calculations to be more sure of your answer. Now repeat the heating of 1000 cu.cm. of water through a similar temperature change, but your only source of heat must be non-electric. Again calculate the overall efficiency. You may use any second method of heating, but you must explain where heat is going, and account for differences in measured efficiencies. Repeat this process three times and take the average of your efficiency results. Compare both the energy input and output to produce the specified temperature changes using each energy source.

Your final report must contain all collected data for all trials. Display this in tables and graphs, and show all efficiency calculations. Explain how you controlled for error of heat losses. Recommend in your report the "better" way to heat water for your bathroom based on (a) economy, (b) availability, and (c) wise use of resources. Do some reading and use common sense. Explain your recommendations.

Figure 2

Solar photo voltaic array panel

Project managers : <<names of team members>>

Monitor a photo-voltaic panel over three 24-hour cycles. You are to determine using a light meter how much solar radiant energy strikes the panel. You will simultaneously monitor the energy and power output from the solar array. Produce graphs that link the energy input and energy output. Calculate the overall efficiency of the panel for producing electricity. Correlate power output with local conditions over each 24-hour cycle. Recommend uses for this energy conversion device. What are its limitations?

Your final report must provide graphical evidence for the potential uses you recommend for solar energy conversion to electricity. Why is this the preferred choice for energy conversion in deep space probes? Using the data from his monthly statements, how large would this type of panel need to be to supply the electrical needs of Bill Baird's house in Auburn? Your report must also include information about solar photo-voltaic energy conversions that come from your own group's library investigation of this topic.

Figure 3

Keep the heat

Project managers : <<names of team members>>

Build a house with a single room of 3,500 sq. cm. floor space or less. Wall space must be about 7,200 sq. cm., with 15% of this used for windows. Wall thickness must be less than or equal to 2.0 cm. Use shingles for roof covering. Use a single type of wall insulation. Use plastic wrap for windows. Heat your house with a single 40-watt heat source, placed in the center of the house and not contacting any wall or floor. Monitor the inside and outside air temperatures over two 24-hour day-cycles, and calculate heat loss through the walls, windows, and ceiling (attic). Your house must occupy a foundation in Haley 2462 during the "winter" season, but the object is to keep the maximum amount of heat inside the living space. Temperature difference between inside and outside should be equal to or greater than 10 deg. Celsius. Building materials should be cardboard, fiberglass, plastic wrap, and fiberglass shingles.

Your final report must describe the building construction, energy input and loss, three cycles of 24 hour temperatures, and recommendations for next design based on your findings. Include information on home energy conservation of space heating. Include at least eight infrared photos taken of your building with the internal heat source "on" but all room lights off. [We can provide camera and infrared film.] Where was heat escaping most rapidly? What are some design changes that you recommend for reducing heat losses?

Note

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Appendix A

Video outline

The 10-minute video provides a short collection of scenes selected from the Spring 1998 edition of our course.

1. Faculty from the sciences and engineering can collaborate with faculty from education in preparing and teaching quality content courses for teachers. The central theme of our course is "energy in our personal lives", especially the home and car. We apply current technology and recent physics developments to develop the ideas of our course.

Scenes of Baird & Zee teaching the course, beginning w/ calc. of body surface area. Mutual concern for improved science classroom instruction led to course design. Zee with electric car, solar photovoltaic array, steam power from home pressure cooker. Baird with electric pickle.

2. Such team-taught courses have the advantage of providing multiple perspectives on content and pedagogy for teachers. We try to demonstrate the learning cycle in each class meeting of our course.

Scenes showing how instructors demonstrate good teaching style. Frequent questions, hands-on approach, etc.

3. The preparation of science teachers should include classroom experiences and assignments that follow the (1995) NSES standards:

* concrete experiences should precede abstract concepts;
* frequent, hands-on encounters with science enhance conceptual learning;
* seek connections with science-technology-society themes in the classroom;
* promote collaborative student learning through peer teaching;

* questioning strategies promote inquiry and encourage life-long learning;

* fewer concepts presented in greater depth lead to better mastery of content.

Selected scenes that show the above. Zee reasons out an equation with help from class.

4. Physics content in our course is selected to connect with the theme of "energy in our personal lives."

Baird with cross-section of wall from home. Inquiry about heat transfer through roof into attic.

5. Use of the learning cycle in each lesson facilitates content learning while demonstrating good teaching style.

Engage -
Explore -
Explain -
Elaborate -
Evaluate -

6. We try to use current technology to deliver our message in class.

Representative of Science in Motion brings equipment to collect data on solar flux.

Student shows how to handle a spreadsheet on his laptop computer.

7. Small class size and continuous interactivity help produce active learners, who go on to become student-centered teachers.

Ralph carries the power supply out to show students how hot the resister is.
Baird reasoning about thermostat setting and resulting costs of home heating.

8. Each student is expected to play an active role in each class.

Students working problems on board.

9. Learners construct meaning from personal experiences with new knowledge, and must fit this into meaningful understanding of the subject. Students solve problems on the board, demonstrate spreadsheets on laptop computers, assist in each demonstration, and present their final projects to the assembled class and instructors. In these ways they construct meaning from their experiences, and fit this meaning into pre-existing understanding of physics concepts.

Male student working problem on board.
Students explaining their final projects to the class.

10. In their final projects, teams of three students explore a problem, collect essential data, make sense of their results, and present their conclusions to other teams. The assigned questions are

open-ended; even the instructors do not have a "correct" answer. For some students, this is the first time they have tackled a problem of this type and produced a final report of their own research. These projects apply physics concepts to everyday problems as students cooperate to study an open-ended question and produce an engineering report.

More scenes of final project presentations, especially solar panel and heating water.

Following this short segment is a longer collection of scenes (one hour and 28 min.) taken from each week of the ten-week course. A printed index is provided below.

Appendix B

The rest of this tape is a selection of scenes from the course in Spring 1998. In the following outline of these scenes, remember that Dr. Zee is Engineering professor and Dr. Baird is the Education professor. Approximate start times are given in hours:minutes:seconds.

Start Time	Scene
0:00:00	Dr. Zee makes a "tin man" of himself for estimating surface area
0:02:35	-as above with a student helping measure Dr. Zee's arm
0:04:12	An experiment testing efficiency of an immersion coil heater
0:05:05	-ongoing experiment
0:05:49	-ongoing experiment
0:06:45	Dr. Baird teaching
0:07:22	Description of efficiency
0:08:10	Dr. Zee describes why kilowatt hours are used by utilities
0:09:46	A student demonstrates computer spreadsheet use
0:10:47	Dr. Zee "kills himself" with an electrical outlet
0:13:52	Dr. Zee makes steam in a heating efficiency experiment
0:14:56	-further discussion of the efficiency
0:17:00	Dr. Baird discusses boiling temperature with the class
0:17:57	Dr. Zee and a student measure kinetic energy in water from faucet
0:18:27	-that water power is used to lift a weight
0:19:18	Dr. Zee discusses with students
0:19:58	A student working an assigned problem on the board
0:20:11	Dr. Zee discusses Ohm's law
0:20:59	-continued discussion, with an experiment to measure resistance
0:22:22	-continued work on resistance with a heated resistor
0:26:33	-more on resistance
0:27:45	Heater wire as an example of a metal with a different resistivity
0:28:08	-more with heater wire
0:31:14	A student working an assigned problem on the board
0:31:31	Dr. Zee and the class create a formula relating resistance to temperature
0:33:52	Dr. Zee and the class devise a way to measure the length of coiled wire
0:35:46	Review of some concepts and problems presented to this point
0:36:14	A student working an assigned problem on the board
0:36:51	Dr. Baird introduces the electric pickle lesson
0:37:15	-light flux from a candle is measured
0:37:52	-light flux from a lightbulb is measured

0:38:30	-students help set up the electric pickle
0:39:12	-the electric pickle glows
0:39:58	-the electric pickle smokes
0:40:28	A student working an assigned problem on the board
0:40:54	Dr. Zee describes how mass cancels to simplify a waterfall problem
0:41:43	Dr. Zee describes an electric vehicle that is actually on the market
0:42:22	-calculating range and power for the electric vehicle
0:43:08	Solar cells are introduced
0:44:06	Light flux from a lightbulb is measured again
0:44:36	Dr. Zee and the class discuss an experiment where they heat water
0:45:26	-Dr. Zee and a guest use probes and a computer for the heating exp.
0:46:29	-the experiment in progress
0:47:05	Dr. Baird leads a discussion on energy costs
0:49:55	Dr. Zee describes methods of concentrating natural gas
0:52:28	Introduction of thermal energy transfer topics
0:52:55	Students and Dr. Zee test some materials as thermal conductors
0:53:38	A wall model is presented that will be used for a heat transfer experiment
0:54:59	Dr. Zee diagrams heat conduction and questions students
0:56:22	Dr. Zee works a heat resistance problem
0:57:56	An experiment on heat transfer through the wall model
1:01:02	Dr. Baird discusses thermostat settings and national standards
1:01:49	A student working an assigned problem on the board
1:02:38	Dr. Baird and the class work on figuring out what emissivity implies
1:03:52	Dr. Baird describes interaction of roof and sunlight for heat transfer
1:05:28	Dr. Baird describes double-pane glass
1:06:54	Student project -- heat retention in a house
1:08:57	-house project continued
1:09:16	Student project -- comparing ways to heat water -- sterno
1:13:32	-heat water continued -- propane
1:18:05	-heat water continued -- electricity
1:23:23	Student project -- using a solar panel
1:25:06	-solar panel continued

ENHANCING THE *SCIENCE* IN ELEMENTARY SCIENCE METHODS: A COLLABORATIVE EFFORT BETWEEN SCIENCE EDUCATION AND ENTOMOLOGY

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Background & Purpose

It has been suggested that children's attitudes and interests in science are greatly influenced by their experiences with science in the elementary school. Children begin school with a natural curiosity about the world in which they live; however, by the time they complete the elementary grades many of them have developed a dislike for science (Beiswenger, Stepans & McClurg, 1998; Hall, 1992). Sadly, science teaching and learning is an all-too-often neglected aspect of the elementary curriculum.

Because they tend to have a limited background in science, elementary teachers often lack confidence in their own ability to understand and teach science successfully. These negative attitudes can greatly influence their effectiveness as teachers of science (Kramer, 1988). For example, science is typically taught at the end of the school day (if at all), and activities are usually textbook-based. Rarely are there opportunities for meaningful inquiry (Beiswenger, Stepans & McClurg, 1998), exploration, and question-driven investigations. In addition, it is not uncommon for teachers to actually transmit a dislike of science to students (McDermott, 1990).

Teachers' subject matter knowledge is a particularly important issue in science education in that it influences instructional practices across subject areas and at different grade levels (Brophy, 1991). Recent studies have reported that many prospective teachers do not have even the most basic understanding of their disciplines as they begin their teacher preparation programs (Ball 1990; Ball & McDiarmid, 1990; Cochran & Jones 1998). In general, the subject matter knowledge of prospective teachers has been characterized as unorganized, superficial, and inaccurate (Guess-Newsome & Lederman, 1993; Lederman & Latz, 1993). When it comes to science, prospective elementary teachers' knowledge has been described as limited, narrow in perspective, and characterized by a lack of understanding of the nature of science (Anderson & Mitchener, 1994; Scharmann, 1988; Wenner, 1993). In addition to their limited science subject matter knowledge, elementary teachers often hold the same misconceptions and alternative frameworks about science as their students (Hashweh, 1987; Hollon, Anderson & Roth, 1991; Smith & Neale, 1989).

College and university science programs have remained essentially unchanged for decades (Yager & Penick, 1990), as have the science content requirements of teacher preparation programs (Zeitler, 1984). The typical science credit requirement for prospective elementary teachers consists of two to three courses across the biological, physical, and earth sciences. In truth, we know very little about how these courses prepare students for careers in the sciences, let alone science teaching (Yager & Penick, 1990).

Most subject matter courses for teaching science are offered within academic departments where prospective science teachers generally take standard departmental courses. Many science faculty seem to believe that the effectiveness of a prospective teacher will be determined by the number and rigor of courses taken in the discipline (McDermott, 1990). Aside from teaching these courses, faculty in the sciences typically have no involvement in teacher preparation programs. This is not surprising given that the education of prospective teachers is considered peripheral to the mission of science departments.

What is apparent and of concern is that the ways in which science is portrayed in undergraduate courses do not accurately represent authentic science (Anderson & Mitchener, 1994), especially regarding the nature of science. Traditional science content courses are typically taught in a large, lecture-style setting with a separate, verification-format laboratory. Rarely do these courses provide prospective teachers with opportunities to design and engage in inquiry-oriented, scientific investigations. To make matters worse, the scientific concepts and relationships that prospective elementary teachers are usually exposed to are not representative of or connected to those that they will likely be expected to teach (Cochran & Jones, 1998).

Elementary science teaching has been characterized by a heavy science process component (Zeitler, 1984) that incorporates observing, classifying, hypothesizing, and making inferences. In light of recent reform efforts in science education, there is an increased emphasis on engaging children in doing scientific investigations -- asking scientific questions, investigating aspects of the world around them, and using observations to construct reasonable explanations for the questions posed (National Research Council, 1996). Unfortunately, elementary teachers themselves lack these types of inquiry-based experiences as learners of science. The lecture-based content courses that prospective elementary teachers take generally encourage passive learning and focus on the recall of scientific information. Moreover, the breadth of topics covered in the typical college course allows little time for acquiring a sound grasp of the underlying concepts. Undergraduates become accustomed to receiving knowledge, rather than helping to generate it (McDermott, 1990) and rarely have opportunities to engage in meaningful activities that incorporate science content and inquiry skills.

Similarly, laboratory experiences, when required, do not address the needs of prospective elementary teachers either. The format is usually based on the verification of known principles. Students have little opportunity to make observations and perform the reasoning involved in formulating these principles (McDermott, 1990). In addition, the laboratory equipment used at universities is often not available in school districts. No attempt is made to help prospective teachers plan laboratory experiences that utilize simple materials and apparatus.

Another potential drawback of science content courses is that instructors, often scientists, rarely model pedagogical approaches that emphasize teaching science for understanding, which is currently at the forefront of science education reform (NRC, 1996). Teachers are expected to identify their students' prior knowledge and skills; use appropriate strategies to enable the children to confront their prior knowledge and develop process skills; and engage students in assessing what they have learned (Harlen, 1998). This form of teaching utilizes multiple instructional strategies such as cooperative group work, opportunities to discuss and debate ideas, and classroom activities that focus and support student inquiry. Rarely are these strategies part of large lecture science classes that serve as examples of pedagogy whether intended or not. It is widely accepted that prospective teachers learn more than just content from content courses (Cochran & Jones, 1998; Hauslein et al., 1992; NRC, 1996). Learning to teach is a complex process that is influenced by the experiences that teachers themselves have as learners (Britzman, 1986; Holt-Reynolds, 1992). As a result, within the context of reform, teachers are once again being asked to teach in ways that are inconsistent with their prior science learning and instructional models.

In response to these issues, educators have recommended that teacher preparation programs be designed specifically to assist preservice teachers in constructing robust subject matter knowledge, as well as preparing them to teach that subject matter for understanding (Borko & Putnam, 1994; Cochran & Jones, 1998; Tobin, Kahle, & Fraser, 1990; Zembal, 1996; Zembal-Saul, Starr & Krajcik, in press). The purpose of this contributed paper is to provide an overview of one such effort – a unique elementary science methods course and related field experience that developed out of an ongoing collaboration between Science Education and the Department of Entomology at The Pennsylvania State University. This partnership was aimed at providing prospective elementary teachers with meaningful opportunities to learn life science concepts using insects as models, engage in scientific investigations under the guidance of entomology faculty and graduate students, explore children's ideas about science, and consider implications for teaching and learning science for understanding. What follows is a description of the collaboration and related course experiences.

Elementary Science Teaching & Learning Course

At The Pennsylvania State University, elementary education majors are required to take three science content courses -- one each in the life, physical and earth sciences -- prior to enrolling in the elementary science teaching and learning course (methods), which is typically taken during the last semester prior to student teaching. Most of these courses are offered within the College of Science and are characterized by many of the same limitations described previously.

In light of what is known about the science subject matter preparation of preservice teachers, the elementary science teaching and learning course has been designed around several central areas of emphasis. First, prospective teachers are actively engaged in learning science throughout the course. A conceptual change orientation drives instruction; concepts are selected based on the *National Science Education Standards* (NRC, 1996) K-4/6-8 content guidelines; and inexpensive materials that are available at Wal-Mart or the local grocery store are used. The purpose of this strategy is for preservice teachers to experience, as learners, a more conceptual approach to science teaching and learning -- one that is consistent with contemporary reform efforts in science education. At the end of each semester, many education students report that this course was their first experience learning science in this way.

Reflection is another critical aspect of the course. Preservice teachers are supported in their attempts to engage in critical reflection in a number of areas, including their past and present experiences as science learners, their beliefs about the nature of science and scientific inquiry, their emerging *theories* regarding teaching science for understanding and the role of children's ideas/thinking, and their experiences *testing-out* these theories with elementary children in school settings.

The science teaching and learning course is one of three subject-specific methods courses and complementary field experience taken during what is known as the Discipline Inquiry (DI) Block. As mentioned previously, this block is typically taken during the last semester prior to student teaching. Beginning in the fourth or fifth week of the semester, education students are in schools approximately two days every week.

For several years the DI Block had been offered during the summer, presenting the challenges associated with providing a quality program in the context of a condensed meeting schedule and field placement restrictions. Interestingly, it was this challenge during the summer of 1998 that resulted in the creative and fruitful collaboration with the Department of Entomology described here.

The Science Education – Entomology Connection

The faculty of the College of Agricultural Sciences were natural collaborators in education due in part to their shared mission of outreach and public education. The Department of Entomology, in particular, has been actively engaged in sponsoring educational programs, such as The Great Insect Fair (annual community-based outreach and education event), Bug Camp for Teachers (summer course for practicing teachers), and Bug Camp for Kids (summer program for elementary children) for a number of years. When the challenge of providing a summer version of the elementary science teaching and learning course arose, science education and entomology faculty were already working together to develop an applied life science course for prospective elementary teachers using insects as models. The entomology faculty were eager to provide assistance, viewing it as an opportunity to learn more about the education majors for which the applied life science course was being developed. As a result, two week-long summer education programs for elementary children, Bug Camp for Kids and Advanced Bug Camp, were integrated into the summer version of the DI Block, making possible interactions among prospective elementary teachers and children around science content. These experiences were complemented by a school-based summer enrichment program in a local school district.

Bug Camp for Kids

Bug Camp for Kids, which was in its fourth year of implementation, was a week-long day camp attended by approximately forty-five children, ranging in age from eight to twelve. Campers participated in daily field studies to observe and collect insects. In addition, they participated in a variety of engaging laboratory investigations that used insects as models to learn a broad range of biological, ecological, and environmental concepts. Instructors placed a heavy emphasis on using observations of insects to generate questions. In addition, the findings of field studies and investigations were reinforced through simulations, role playing, insect *games* and songs. The roles of the preservice teachers included conducting pre/post content interviews with children based on the program outcomes developed by Bug Camp coordinators; *adopting* groups of students and facilitating their learning activities; and creating a multimedia artifact (electronic slide show) that chronicled the children's experiences throughout the week. During their involvement in the camp, prospective teachers kept a semi-structured journal that challenged them to consider children's learning, as well as their own subject matter learning, and to reflect on implications for teaching science in the context of elementary schools.

Advanced Bug Camp

The Bug Camp experience was immediately followed by another week-long entomology program for children, Advanced Bug Camp (ABC). Unlike Bug Camp for Kids, which was an established program, ABC was offered for the first time in the summer of 1998. It was developed as a result of the success of Bug Camp. That is, there was a perceived need to offer new and more challenging science learning experiences for veteran Bug Campers, some of whom had attended Bug Camp for two and three consecutive summers. Therefore, ABC was designed to engage young insect lovers (ages 10-12) in scientific inquiry projects using insects. Campers began the week by visiting a number of laboratories where research on insects was being conducted. Then, with the assistance of entomology and education mentors, children worked in pairs to design and conduct investigations related to questions they developed about insect physiology, behavior, etc.

Instructors emphasized the role of observation and questioning in science, experimental design considerations (e.g., variables, repeatability, data collection, etc.), the role of evidence in developing explanations, and interactions within a scientific community. Great efforts were taken to create a community of young scientists. For example, each day ended with a round table discussion in which groups shared their progress, defended their findings with evidence, and generated questions for further exploration. The week culminated with a research conference in which children presented their projects to the group in a more formal setting. Again, children were encouraged to end their presentations with questions for future research.

Education students took on a much more central and active role in the Advanced Bug Camp experience. They participated as active members of a research team. These teams consisted of a pair of children, a pair of education students, and an entomologist. The preservice teachers were responsible for conducting pre/post interviews with children that focused on the nature of science and scientific inquiry, facilitating and participating in the inquiry-based investigations, and providing leadership with technology (e.g., multimedia research presentations). Throughout the week, the prospective teachers documented the investigation in which they participated, analyzed children's ideas about the nature of science, and considered implications for teaching science in the context of elementary schools, which included making connections to the National Science Education Standards (K-4 and 6-8 Inquiry and Life Science content standards).

As might be expected, a great deal of preparation was necessary to support the implementation of such an ambitious project. Of these preparations, an orientation session for mentors turned out to be critical to the success of Advanced Bug Camp. During this session, entomology mentors (faculty and graduate students) were introduced to education mentors (elementary education students). These introductions included an opportunity to share concerns about the upcoming program. Without exception, entomology mentors expressed their worries about working with children and education mentors shared their uneasiness with science content related to insects. One prospective elementary teacher eased some of the tension by coining the summer catch-phrase, "We won't squash the bugs if you don't squash the kids!"

The orientation session also engaged mentors in an activity designed to raise considerations associated with assisting children in designing scientific investigations. These interactions among mentors were crucial in establishing the potential contributions that each individual would make to their research team.

<u>School-Based Enrichment Program</u>

Immediately following the bug camp experiences, preservice teachers spent four weeks in a school-based summer enrichment program for children in first through fifth grades, the emphasis of which was reading and mathematics. Whereas the science teaching and learning course was heavily integrated with the bug camps and conducted on-site in the Department of Entomology, education students attended the school-based enrichment program each morning and returned to the university in the afternoons to attend their methods courses.

Although science was not central to the summer enrichment program, the preservice elementary teachers were responsible for planning and implementing a two-day culminating event that involved teaching with insects. Preparing for this event provided a context for experiences within the science teaching and learning course. For example, prior to planning instruction, education students investigated children's ideas/thinking about science content related to insects. Similarly, attempts to enact their instructional plans provided the basis for critical reflection on practice.

Analysis of preservice teachers' instruction revealed several patterns. In general, the activities they prepared were student-centered and engaging -- children were active participants in the learning process. Instruction was developmentally appropriate, and a number of attempts were made to integrate children's literature, music and art in meaningful ways. Not surprisingly, many Bug Camp activities were modified and used in some way, and having children generate questions from their observations of insects was common. Unfortunately, issues with preservice teachers' science subject matter knowledge were evident, and attempts to engage children in inquiry fell short of resembling Advanced Bug Camp.

Lessons Learned

As would be expected, limited experience engaging in scientific inquiry during Advanced Bug Camp was not sufficient to alter preservice teachers' beliefs or influence their thinking about designing science instruction. However, evidence from artifacts collected in the science teaching and learning course suggests that participation in the scientific inquiry project was valuable in other ways (see Zembal-Saul, Boardman, Severs & Dana, 1999). First, engaging in scientific inquiry provided an opportunity for prospective teachers to learn science in a way that they had never experienced previously -- a way that represented the authentic nature of science. When asked to reflect on that experience by considering connections to the National Science Education Standards (NSES) (NRC, 1996), several students commented that the entomology faculty had done an effective job of incorporating the inquiry standards into their program. They were surprised to learn that the entomologists actually knew very little about the NSES document. This fueled discussion regarding the nature of science and scientific inquiry and its role in school science, which provided a context for education students to reconsider the goals of contemporary reform efforts in science education.

Another important aspect of engaging preservice elementary teachers in scientific inquiry stems from the model of implementation used in Advanced Bug Camp. By working as a member of the research team, the education students were essentially *lab partners* with children. This gave them an opportunity to explore children's ideas about science content and the nature of science, and to monitor children's thinking as they engaged in learning science via inquiry. Because an entomologist was available to aid with content and experimental design issues, the prospective teachers were able to focus on issues of learning -- both their own and that of children. As they reflected, many of the education students acknowledged that the ABC experience changed their views about what elementary children are capable of accomplishing when provided with appropriate support and guidance.

Finally, the collaboration between entomology and education was successful for two reasons. First, the strong emphasis on education embedded within the mission of the college in which the Department of Entomology resides allowed the collaboration to progress with institutional support for the faculty and graduate students involved. It is the experience of the authors that this is rarely the case when dealing with colleges of science. Second, the collaboration was an equitable one. Everyone involved had something to contribute that was vital to the success of the summer programs for children. Likewise, everyone was involved in learning something valuable which contributed to their own development as a result of their involvement. An added benefit was that the balance in roles emerged naturally from the design of the program.

In conclusion, much work remains to be done in order to minimize the gap between the vision of reform and the reality of classrooms. While elementary science methods courses attempt to assist preservice teachers in learning to teach science for understanding, it comes as too little too late. Education students need multiple opportunities to experience learning science in more conceptual ways that better represent the authentic nature of science prior to their advanced coursework in teacher education programs. The professional development of practicing teachers needs to be considered concurrently if there is to be any hope of providing preservice teachers with opportunities to translate their emerging ideas about teaching and learning into practice. Although the challenge is daunting, it is our contention that collaborative efforts, such as the one described here, will play a pivotal role in improving the situation and demonstrating that teacher preparation and development is the responsibility of the university community, not merely that of colleges of education.

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THE TEXARKANA PRESERVICE SCIENCE IMPROVEMENT PROJECT

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The Texarkana Preservice Science Improvement Project (TPSIP--http://is.tc.cc.tx.us/~dallard/tpsip/tpsip.html) was an effort to improve the training of preservice elementary teachers in science in the Texarkana, Texas, region. It was a collaborative venture involving personnel from Texarkana College (a 2-year college), Texas A&M University-Texarkana (an upper-division university sharing a campus with Texarkana College), and local public and private schools. TPSIP addressed three content areas: physical science, chemistry, and life science. An action team of elementary school teachers, undergraduate elementary education majors, and college science faculty focused on each content area.

Each team developed a module with five hours of science activities. These modules consist of lesson plans and kits of materials. The modules were field-tested by undergraduate elementary education majors with elementary school children during May, 1998. They were revised after the field test and then used to conduct a weeklong science institute for children at a local elementary school during June, 1998. After that the modules were utilized in science courses taken by elementary education majors at Texarkana College. Duplicate copies of the modules were also assembled for each school district involved in the program. Their elementary school teachers will be able to use these with their classes.

Funding

Funding for the TPSIP was provided by the Texas Statewide Systemic Initiative for Math and Science (TSSI--http://macdns.cc.utexas.edu/ssi/) Preservice Elementary Science Preparation Program. The TPSIP received 2 grants over the project time period. The first grant was a planning grant of $7,000. The second grant was an implementation grant of $30,000. The TSSI is funded by the National Science Foundation. The Texarkana College project was one of seven projects funded by the TSSI to work with preservice teachers. The other programs funded were at The Fort Worth Museum of Science & History, Southwest Texas State University, West Texas A&M University, Howard Payne University, Blinn College--Bryan Campus, and the University of Texas at Dallas. Information on all of these projects can be found at http://www2.tltc.ttu.edu/thomas/research/pesp/Pespteam.html.

Guidelines

All of the projects were developed according to a set of guidelines developed by the TSSI Preservice Elementary Science Action Team. These guidelines consisted of five major points: (1) Collaboration, (2) Science Content and Process (3) Student-Centered Teaching, (4) Inquiry-Based Teaching and Learning, and (5) Continuous Growth (Stuessy & Thomas, 1998). The funded projects were required to meet these guidelines in the development and implementation of the programs.

Stages of the Texarkana Project

Planning -- Summer 1997

College science faculty, public school administrators, and elementary teachers meet three times with invited facilitators from around the state. These meetings focused on examples of preservice science preparation programs at other colleges and universities, inquiry-based teaching, the National Science Education Standards (National Research Council, 1996), the Texas state standards (TEKS--Texas Essential Knowledge and Skills) (Texas Education Agency, 1998), and Project 2061 guidelines and Benchmarks (American Association for the Advancement of Science, 1990 and 1993).

Phase I -- Fall 1997

College faculty and elementary teachers met to develop topics for the modules. They were split into three action teams, one each for physical science, chemistry, and biology. The action teams decided to use water as theme for module development. Water provides many unique opportunities to integrate chemistry, physical science, biology, and additionally earth science. The action teams decided to use the Texas Watch Water Quality Monitoring Program (http://www.tnrcc.texas.gov/water/quality/data/txwatch/index.html) as one of the major activities to organize the modules. This turned out to be an excellent choice for a theme.

Phase II -- Spring 1998

College, elementary, and preservice teachers learned about developing units using the learning cycle model. TPSIP participants attended a workshop on inquiry-based teaching using the Learning Cycle on February 6, 1998. The workshop was conducted by Dr. Charles Barman from Indiana University/Purdue University at Indianapolis. The participants were very enthusiastic and the workshop was a great success.

Teams of preservice, inservice, and college science teachers met to develop modules for the topics specified. These modules included lesson plans and equipment kits. Modules were field-tested by preservice teachers, under the supervision of elementary and college science teachers, in elementary classrooms in May 1998. Brochures were prepared and recruitment began for elementary school students to attend the Summer Institute.

Phase III -- Summer 1998

The action teams meet to assemble the module kits. The kits contained all of the materials necessary to teach the concepts and lesson plans for each activity included.
The summer institute was called the "Summer Science Splash". Twenty-four students from local public and private school (grades 3-5) applied for the Summer Science Splash. The "Splash" was conducted June 15-19, 1998, from 1:00 - 4:00 p.m. at Spring Lake Park and Pine Street Middle School in Texarkana, Texas. The first day of the "Splash" was a field trip to Spring Lake in Texarkana. The students performed water quality tests on the lake water and also collected specimens to make a "Pond in a Jar". The remainder of the week's activities took place at Pine Street Middle School. During this time the students were led through activities in Life Science, Physical Science, and Chemistry. All of the activities focused on some aspect of water. Preservice, inservice, and college science teachers led the activities. Photographs and other

information from the project is available on the World Wide Web at

http://is.tc.cc.tx.us/~dallard/tpsip/tpsip.html.

Phase IV -- Summer 1998

The modules underwent further revision and were then in final form for use in the college science classes and by elementary teachers.

Phase V -- Fall 1998

Modules were (and continue to be) used by college teachers, elementary teachers, and preservice teachers.

Conclusion

The TPSIP was a very important step in the evolution of the elementary science teacher preparation at Texarkana College and Texas A&M University-Texarkana. The most important facet of the project was the educational process that the college science teachers were exposed to. They became familiar with aspects of science education that they had previously never considered. Most were classically trained in their subject area and had never had a course in science teaching methods. They were made aware of inquiry-based techniques, the National Science Education Standards, the Texas Essential Knowledge and Skills, and the Project 2061 Benchmarks. They met with and discussed problems of teaching science with inservice elementary teachers. The project has significantly changed the way several of the college science teachers teach their classes for elementary education majors (and other classes as well). This change is seen in the final evaluation of the project. There is less lecture and more inquiry-based instruction taking place in many of the college science classes taught by project participants.

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ASSESSING THE IMPACT OF A TEACHER ENHANCEMENT PROGRAM ON CLASSROOM ENVIRONMENT

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Systemic reform is a key component of the science education agenda and is central to the *National Science Education Standards* (National Research Council, 1996). Ongoing professional development for classroom teachers is an area of emphasis in these standards, which define a new direction for effective science instruction. Incorporating a constructivist approach to teaching and learning, the focus is on more student-centered and active learning environments. To effectively use these techniques, teachers must think in ways substantially different from the manner in which most of them were taught (Borko & Putnam, 1995). Just as students learn in an active environment, so too must teachers develop their conceptual base in an active environment if they are to promote such environments for their students. They must experience the learning they want their students to have (Loucks-Horsley & Stiegelbauer, 1991).

Experiencing science learning as an active, collaborative process is documented as an effective way for teachers to develop an understanding of why it is important for their students to learn this way if every learner is to have maximum opportunity. It also helps them understand which concepts are most likely to cause difficulty for their students or are most fundamental, and which ones are most effectively taught by various means (Loucks-Horsley, 1995). The most effective science education institutes combine development of conceptual and content knowledge with small group activities, use of manipulatives, and immersion in doing science (Ruskas & Luczak, 1995). Teachers expand their conceptual knowledge as they concurrently become acquainted with materials and activities that provide students with concrete and representational experiences of fundamental concepts. Professional literature supports this as one strategy for improving the classroom environment for under-represented groups in science (Harris, 1995).

The overall goal of the enhancement program was to improve the teaching of life science and biology as an inquiry-oriented and socially relevant discipline in rural Minnesota schools. Teams of elementary, middle, and high school teachers from selected districts spent six weeks in a residential workshop program during the summer, followed by weekend sessions during the academic year. Workshop participants then served as a cadre of in-service instructors for their own and nearby districts.

Science educators, college biology instructors, and other biology professionals employed an activities-based approach to learning science, teaching methodology, and science processes, with the goal of improving science instruction at participants' schools and, via the ripple effect, at surrounding schools. The primary anticipated outcome would be to provide participants with the concepts and content, skills, and hands-on teaching strategies necessary to teach science as an integration of science, technology, and social issues. As the result of a survey of local teachers, the enhancement workshops focused on the areas of freshwater wetland ecology, genetics, and microbiology.

Inservice workshop evaluation typically focuses on gains in content knowledge or cognitive development of teachers and/or their students. While this was important, we were also interested in examining the impact of the enhancement program in terms of its effect on teachers' instruction and classroom environment, as well as to assess the program's impact beyond the participants' own classrooms.

Methods

At the beginning of each summer workshop, participants were administered the short form of the Individualized Classroom Environment Questionnaire (ICEQ) (Fraser & Fisher, 1986; Rentoul & Fisher, 1979). The ICEQ assesses a variety of items which distinguish "traditional" teacher-centered classrooms from those evidencing a preponderance of individualized, student-centered instruction. Responses are on a 5-point Likert scale and are distributed equally across five categories: Personalization (PE), Participation (PA), Independence (IND), Investigation (INV), and Differentiation (DF). Category descriptions are provided in Table 1.

Table 1
Category Descriptors
Individualized Classroom Environment Questionnaire

Personalization (PE)	Emphasis on opportunities for individual students to interact with the teacher and on concern for the personal welfare and social growth of the individual.
Participation (PA)	Extent to which students are encouraged to participate, rather than be passive learners.
Independence (IND)	Extent to which students are allowed to make decisions and have control over their own learning and behavior.
Investigation (INV)	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.
Differentiation (DF)	Emphasis on the selective treatment of students based upon ability, learning style, work rate, and personal interests.

Participants were initially asked to focus specifically on their classroom of the previous year and to report their perceptions of the environment as it actually existed. At the conclusion of the workshop, participants were again administered the ICEQ and asked to report what they would prefer the environment to be like in their ideal classroom. At the conclusion of each workshop, participants were also surveyed as to the activities which they intended to implement during the school year, ways in which they planned to impact other teachers within and outside their district, and any challenges they perceived to implementing the curriculum ideas in their classrooms.

At the conclusion of the school year, the ICEQ was again administered to the participants, who were asked to report their perceptions of the actual classroom environment during the previous academic year. Teachers were also surveyed and interviewed to assess the manner in which the program had impacted their teaching. Responses on the ICEQ and the survey were compared to those obtained on the instruments administered during the summer workshops.

Results

There were significant changes ($p < 0.05$) in participants' perceptions of the actual classroom environment between the beginning of the workshop and the end of the following school year, and these changes more closely resembled their preferred classroom environment as reported on the end-of-workshop ICEQ (Table 2). In addition to significant changes in overall classroom environment, changes in the specific categories of Independence, Investigation, and Differentiation were significant in their own right ($p < 0.05$).

Table 2
Mean scores on ICEQ
Pre vs. Post and Pre vs. Delayed Post significant at $p < 0.05$

	PE	PA	IND	INV	DF
Pre-Workshop	4.25	4.24	2.13	3.13	2.94
Post-Workshop	4.71	4.85	3.12	4.52	3.92
Delayed Post-Workshop	4.68	4.74	2.98	4.33	3.72

During interviews a number of teachers indicated that they had made a conscious effort to bring about a change in their classroom environment as a result of participation in the workshops and follow-up activities. In particular, there was an increased emphasis on opportunities for individual students to interact with the teacher, an increase in the extent to which students were allowed to make decisions regarding their learning, and an increased emphasis on the skills and processes of inquiry and their use in problem solving and investigation. These were all important objectives of the enhancement program. Observations of the classrooms by workshop faculty members during the follow-up sessions supported the changes indicated by the ICEQ results.

Both in interviews and on the surveys, participants noted a renewed enthusiasm for teaching activity-based science and increased confidence in stepping outside the bounds of a textbook. Eighty-three percent (83%) of the teachers reported "great" or "considerable" change in their teaching methods and course content as a result of participation in the enhancement program. Areas in which at least 65% of the participants reported significant changes included use of more "real world" problems and collaborative activities, greater student involvement in discussion, more use of local environmental problems and resources as a class focal point, and greater use of available technology in the classroom.

All the teachers (100%) reported using a minimum of 10 activities developed during the summer workshops, and 75% reported using 20 or more of these teaching ideas in their classes. All but one workshop participant had presented in-service programs for other teachers in their building, district, and/or neighboring districts. These programs averaged 18 contact hours, with each participant reaching an average of 14 other teachers. Follow-up surveys with a random sample of in-service participants indicated 54% had implemented at least five of these activities.

Conclusion

The workshops were intended to improve biology education in isolated rural schools by (a) increasing the use of hands-on, process-oriented activities in science classes, (b) raising the confidence level of science teachers, and (c) impacting other teachers and districts through a cadre of teachers providing in-service programs. These results indicate that the enhancement program substantially met its objectives.

Teachers were more confident and better prepared to move beyond the restrictions of a textbook-centered mode of instruction. Teachers are building connections to other schools and to other grades within their own district. The desired ripple effect is occurring as program teachers reach out and educate other teachers. Teachers are engaging their students in real-world investigations suited to the local resources. And teachers are changing their classroom learning environment, due in part to their participation in the program.

The most encouraging aspect of these results is that changes occurred in the actual environment within the teachers' classrooms, particularly in the categories of Independence and Investigation. These were areas of emphasis for the enhancement workshops which related directly to the implementation of a more inquiry-oriented, process-based approach to science teaching and learning. Teachers consistently indicated in the interviews that they felt more confident in their ability to use the "hands-on, minds-on" approach after the summer workshops, and this was reflected in their increased use of such an approach in their classroom.

Teachers involved in the program are engaging their students in real-world investigations and interpretation of data. They exhibit increased enthusiasm for teaching and increased confidence in their ability to step outside the bounds of the textbook or laboratory manual to implement more process-oriented activities. The success of the program is indicated by teachers changing their classroom instruction to more closely align with current ideas of how students learn, as well as reaching out to other teachers during formal and informal in-service activities. Students in at least two schools even successfully influenced local environmental review processes, collecting data and presenting their results to the county commissioners. In at least this instance—and we believe in most instances—teacher enhancement workshops can have a positive impact on the education of our youth.

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TEACHER SUPPORT SPECIALIST IN SCIENCE (TS^3): SOCIALIZING PROSPECTIVE SECONDARY TEACHERS INTO THE PROFESSION

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In 1990, the Georgia Department of Education initiated the Teacher Support Specialist (TSS) Program[1], an inservice program that prepares veteran teachers to provide the individual support and mentoring so desperately needed by student teachers and early career teachers. While extremely successful, the TSS Program falls short in providing the subject specific information and experiences that would help veteran teachers do a better job of supporting beginning teachers. To be most effective in working with their new colleagues, veteran science teachers need to know (a) about the needs and problems of today's beginning science teachers, (b) how to work with these beginning teachers as adult learners, (c) the supervisory models and strategies that can be applied to science learning situations, and (d) recent advances in the science disciplines studied by beginning teachers in their college and university classes. These needs of veteran science teachers were coupled with the requirements for TSS certification in the 1998 Teacher Support Specialist in Science (TS^3) project.

This paper describes the initial phases of the Eisenhower funded TS^3 project carried out at the University of Georgia in 1998 and reports the findings of preliminary evaluation efforts. Because the project is still being implemented, all project activities have yet to be evaluated and the overall benefits of the project are still being determined.

Project Description

The purpose of the project was to prepare a cadre of secondary teachers capable of providing the subject specific instructional support and mentoring needed by science student teachers and early career science teachers. The plan called for this to be accomplished through sustained contact with a project staff that included Regional Education Service Agency personnel, university scientists and science educators, and veteran science teachers (grades 7-12) who are experienced mentors. Specifically, the project was designed to help secondary science teachers to: (a) become knowledgeable of

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effective practices and principles in science teaching, classroom observation and conferencing, adult learning, professional ethics, and reflective teaching; (b) become knowledgeable of recent advances in the sciences; (c) reflect on and improve their efforts to support and mentor beginning science teachers; and (d) establish collaborative relationships with other Teacher Support Specialists in Science, Teacher Support Specialist trainers, and scientists and science educators from the University of Georgia.

The project began in March, 1998 and will run through May, 1999. To date, the Preparation and Instruction phases of the project have been completed. The Sustained Contact phase is ongoing and the Presentation phase will culminate in February, 1999. The schedule of project events is presented in Figure 1.

The *Preparation* phase involved assembling a project staff, selecting teacher participants, assembling instructional materials, and planning for course and sustained contact activities. Course planning involved evaluating instructional materials to augment the TSS program resources, locating new materials, and meeting with scientists to plan science content update sessions.

During the *Instruction* phase, led by Koballa, Gustafson and Keys, the teacher teams participated in a 50-hour course for which they will receive 5 staff development unit (SDU) credits. The summer course included sessions on the problems and needs of beginning science teachers, working with adult learners, supervisory models and skills, learning styles, reflective teaching, elements of effective science teaching, and legal and professional issues in science teaching. Science content sessions led by university scientists were also part of the summer course. The culminating experience of the course was the development of an action plan by each teacher for supporting and mentoring science practicum students during fall semester 1998.

During the *Sustained Contact* phase, the teachers participated in six afterschool sessions and worked intensively with University of Georgia students during the fall practicum experience as specified in their action plans. The afterschool sessions were intended to supplement the summer coursework and involve teachers in instructional activities regarding their mentoring of university students and early career teachers. The sessions provided them with opportunities to discuss concerns and resolve problems related to the implementation of their action plans. During this phase, the project evaluator and one other member of the project staff visited the school sites. The staff member, who also taught one of the two secondary science methods courses in which the university practicum students were enrolled, observed some lessons and facilitated reflective debriefing sessions with mentor-student teams. The teachers received 5 staff development unit (SDU) credits for their participation in this phase of the project.

Figure 1. Project Schedule

<u>Preparation Phase</u> March-June, 1998	Planning and participant team selection Assembling project staff, including veteran teachers
<u>Instruction Phase</u> June 22-July 3	Class sessions from 8:30 a.m. to 1:00 p.m. June 22 - Introduction to Science-Specific TSS June 23 - Problems and Needs of Beginning Science Teachers Action Plan Development (veteran teachers) June 24 - Science Teachers as Adult Learners Science Update Session (UGA scientist) June 25 - Legal, Professional and Ethical Issues in Science Teaching Action Plan Development (veteran teachers) June 26 - Learning Styles and Science Teaching June 29 - Elements of Effective Science Teaching June 30 - Promoting Professional Growth By Reflective Teaching Action Plan Development (veteran teachers) July 1 - Models of Supervision Science Update Session (UGA scientist) July 2 - Supervisory Skills in Science Teaching and Learning Action Plan Development (veteran teachers) July 3 - Action Plan Presentations and Preparing for Sustained Contact (veteran teachers)
<u>Sustained Contact Phase</u> Sept '98-May '99	Sustained contact sessions from 4:45 to 7:00 p.m. Sept 15 - Issues and Concerns of Mentoring University Students Sept 29 - Applying Models of Supervision Oct 13 - Practicing and Enhancing Supervisory Skills Oct 27 - Addressing Learning Styles Nov 10 - Considering Effective Teaching in Science Nov 24 - Program Assessment and Preparation for GSTA (Each session's activities will be geared to help the teams to reflect on the understandings constructed during the summer and implement their action plans. Audio and video tapes of participants' mentoring sessions will be used to aid reflection. Student teachers will be encouraged to participate in these sessions. Topics of the sessions may change depending on the participants needs and concerns.) Project staff will visit each teacher team at their school at least twice to gauge the success of their implementation efforts.
<u>Presentation Phase</u> February, 1999	Teachers will present their personal cases of working with student teachers at the GSTA meeting.

The *Presentation* phase of the project will culminate in February, 1999 at the annual meeting of the Georgia Science Teachers Association (GSTA). At this meeting, teachers will present highlights of their project-related experiences. It is planned that the teachers will discuss their personal growth in mentoring and supervision, knowledge constructed about methods and strategies for working with science education students and early career science teachers, and relay issues and concerns unique to mentoring and supervision in science.

Evaluation of Participants' Reactions to the Project

The participants' reaction to the TS^3 project (thus far) is revealed in analyses of three sources of data. First, the participants completed questionnaires prior to and following the summer TS^3 course. Secondly, the evaluator (Kemp) conducted semi-structured interviews with three of the participants during the fall semester as they were mentoring student or practicum teachers. All three teachers had had practicum students and student teachers prior to participating in the TS^3 project. And finally, the evaluator acted as a participant-observer by attending the summer course and fall sessions. He fully participated in the classes, including reading the assigned literature and talking informally with other participants during breaks. He also took notes about the activities and responses of participants during the meetings. The participants were informed about the evaluator's role during the first few minutes of the first meeting, and were reminded of his role several times during subsequent meetings. Even so, the participants seemed to fully embrace the evaluator as one of their own, or occasionally saw him as an intermediary between them and the course instructors.

The participants' overall response to the program has been very positive and highly favorable. When asked to rate their "overall satisfaction with the TS^3 summer course," all but one of the teachers rated the course a "6" or "7," on a seven point scale with "7" being strongly agree, giving an average of score of 6.56 ($\pm$1.01). Some of the teachers' comments about the course include:

- One of the BEST courses ever!
- I am very glad I took this course.
- I really thought it was very helpful.
- I know other teachers who thought their [regular] TSS training was a waste of time. I am very satisfied and feel positive about our training.

Thus, most of the participants enjoyed the course and felt they had improved their knowledge and skills related to preservice and first-year teacher supervision as a result of their participation.

In terms of specifics, the teachers felt that they had learned many valuable skills to help them supervise and mentor student teachers and first-year teachers of science. On the post-summer questionnaires, teachers indicated the summer course helped them improve their abilities related to helping student teachers improve their teaching, discussing issues with student teachers, evaluating student teacher effectiveness, working with college supervisors, and practicing classroom observation techniques. The post-summer questionnaire, or post-survey, had a seven-point scale, with "7" being "strongly agree." On one item the teachers (n=9) said they felt their ability to work with student teachers (6.56 ± 1.01) and first year teachers (6.33 ± 1.12) had improved as a result of their participation in the summer course. This perception of increased ability carried over into the fall semester. During an interview, one teacher remarked, "The TSSS training has been an "eye-opening" experience. It helped me see how to analyze student teachers and focus on certain, important things." Another teacher said:

> Before I just thought, well, I've got to take this person from whatever stage they are in their teacher preparation, and move them down the line and just try to make them a better rounded teacher. It was just kind of slip-shod, flying by the seat of my pants. But now I'm much more aware of things that I can do to help the preparations, and work with the supervisor, also. I'm aware of roles that I can play. Whereas before it was, "Okay, let's just do the best we can here and see if we can get you ready for a teaching career." So I think the training this summer did help me a lot in being aware of sequencing, process, skill development, those sorts of things. What each person needs will vary with the student teacher, but my appreciation for the total picture and all the aspects of it are stronger now than they were before.

One of the aspects of the program that helped teachers be more systematic in their supervision was an "action plan" they developed during the summer. Most of them had never actually outlined what they wanted to help student teachers learn to do, even though most of them had supervised pre-service teachers before. As one participant said, "the action plan has got to be the key to how it works." Another remarked, "My action plan was very helpful. I think I accomplished 90% or more of it."

Teachers achieved a better understanding of the university's way of developing pre-service teachers as a result of the TS^3 program, and felt more confident about working with the university supervisors. One teacher said, "I now understand what goes on at the university better, although I am still somewhat nebulous. Carolyn especially provided us with a frame of reference." Another one remarked:

> So, when I [got] a student teacher, I just thought they all came from the same bag up there. But they weren't! So, knowing how these people are being trained, and how these different programs relate to each other was ... helpful to me. ... I just had no concept of where these people came from. They were assigned to me, and I was going to make them welcome, and we were going to do the best we could, but I had no idea concept. So, that part of it's been helpful to me, too--understanding the system and how UGA does all that.

On the post-survey there was an average response of 6.11 ($\pm$ 1.27) for the statement "As a result of my participation in this summer course, I feel that I have improved my knowledge and skills concerning ... what student teachers are currently being taught at the university." Teachers also rated their post-summer course ability to work with college supervisors very highly (6.67 $\pm$ 0.71).

One of the aspects that most participants enjoyed were the two scientists brought in as guest speakers during the summer course. However, even though they found the presentations interesting, a few of the participants did not feel the information would be useful to them in their teaching or mentoring. Their comments included:

- I thoroughly enjoyed Dr. ____ and his presentation--it was very informative and useful.
- Speaker handled presentation <u>very</u> well--without making me feel "stupid."
- Interesting info on a personal level--not beneficial to use w/ students (other than knowing about the Outreach Program)
- They were very interesting, but did not give me much to use in my class.
- I enjoyed the opportunity to stretch my own understanding of the topics without feeling intimidated by my ignorance!

Although the teachers enjoyed the presentations, they did not feel that they had improved their science content knowledge much during the summer. On a post-survey questionnaire, the teachers agreement averaged only 3.22 ($\pm$ 2.33) for the statement "As a result of my participation in this summer course, I feel that I have improved ... my science content knowledge." In fact, the only questions on the post-survey which did not receive positive agreement (5 or better on a 7 point scale) were those that related to the amount of science content learned during the summer.

The participants not only learned how to supervise pre-service or first-year teachers, they also reported learning how to be a better teacher for their own students as a result of participating in the TS^3 course. On the post-survey, the teachers strongly agreed with the statement "As a result of my participation in this summer course, I feel that I have improved ... my ability to work with my own students" (average of 6.11 $\pm$ 1.17). They also responded with an average of 5.44 ($\pm$ 1.81) to the statement regarding their improvement of knowledge and skills related to "modern science teaching methods." In the fall interviews, teachers made the following comments:

- The program helped me improve my own teaching methods.
- One thing the summer course did was help me understand how to formally evaluate a lesson.
- I am now more self-reflective. The training made me think about what I'm doing.

Other teachers also agreed they had learned about reflective teaching. On the post-survey questionnaire, there was an average response of 5.89 $\pm$ (1.69) for the statement "As a result of my participation in this summer course, I feel that I have improved my knowledge and skills concerning ... reflective teaching techniques."

Overall, only one of the teachers who completed the post-surveys responded neutrally (mostly giving 4's) instead of positively to the majority of questions. In his written remarks, this teacher said "I didn't hear much that I already didn't know." The evaluator observed that the staff were only occasionally successful in fully engaging this particular person during presentations or activities. This person appears to have a learning style which differed from the other participants and the staff. This observation was supported during one of the summer activities in which the participants assessed their learning styles using the True Colors profile (published by TriPhoenix Publishing Company, Inc., 1990). According to the person's own assessment, he or she probably learns best by doing and experiencing, and would prefer to be autonomous rather than directed by others. Therefore, this teacher may have benefited more from trying out on his/her own the information and skills presented during the summer course and fall seminars. However, this teacher has not been interviewed since the summer course, so no data are currently available to evaluate the long-term impressions of the TS^3 program on this individual.

Thus, all but one of the participants were enthusiastic about their newfound knowledge and abilities related to mentoring and supervision of pre-service teachers and first-year teachers of science. The participants felt they had learned how to be more systematic in helping novice teachers develop their skills. They felt more knowledgeable about the university's teacher education program, and how they fit into the "big" picture of science teacher development. And not least of all, the majority of the participants felt they had become better teachers as the direct result of participating in this science-specific Teacher Support Specialist program.

Summary

The TS^3 project was funded by the Eisenhower, Title II program and prepared a cadre of 11 secondary science teachers capable of providing the subject specific instructional support and mentoring needed by science student teachers and early career science teachers. The project coupled the science specific needs of secondary teachers with the requirement of the Georgia TSS program in a 100-hour experience that included both summer workshop and sustained contact activities. University of Georgia scientists and science educators, secondary science teachers, and RESA personnel were involved in program planning and instruction. While still in its first year of implementation, the project has doubled the number of TSS certified secondary science teachers in the 13 school systems served by Northeast Georgia RESA and has provided opportunities for area secondary science teachers and university science educators to discuss important issues of science teacher education. The discussions are contributing ideas for ongoing efforts to reform science education field experiences at the University of Georgia.

CONNECTING SCIENCE, MATHEMATICS, AND HUMAN HEALTH: APPLICATIONS OF THE GRAPHING CALCULATOR IN TEACHER PROFESSIONAL DEVELOPMENT AND STUDENT ACADEMIC ENRICHMENT

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The Health Sciences and Technology Academy (HSTA) (http://nt-hsta.hsc.wvu.edu/health), administered through West Virginia University (WVU), provides professional development to science teachers (n ~ 48) who partner with higher education faculty in a science and math enrichment program for financially disadvantaged and African-American students (n ~ 450) (Rye, 1998, Bock, 1996). The long-range goal of HSTA is to increase the number of underrepresented students in West Virginia who complete a post-secondary degree in the health sciences or secondary science teaching and remain in West Virginia as primary care givers or teachers. With the assistance of Eisenhower Professional Development Program funding, HSTA has included a focus on human nutrition for science and math enrichment, and in doing so, has incorporated the use of graphing calculators. The graphing calculator has been applied to data sets on the nutrient composition of food to facilitate understandings about experimental design and other cross-disciplinary concepts, and how math and science connect to human health. Driving questions are posed about nutrient intake and health in the context of examining and analyzing these data sets. Human nutrition content and applications of the graphing calculator to that subject matter, as illustrated in this session, provides one context for secondary teachers and teacher educators to collaborate towards integrating science and math instruction.

Background

Human nutrition is grounded in the principals of biology and chemistry (Spallholz, 1989) and is rich in opportunities to apply mathematical concepts (Rye, in press). Accordingly, a focus on human nutrition provides for the development of cross-disciplinary science concepts and reveals the integrated nature of science and mathematics. Moreover, it provides for the types of learning experiences necessary for a "lived curriculum," as advocated by Hurd (1997). Post-secondary faculty in mathematics, anatomy, chemistry, and teacher education have created HSTA Summer Institute experiences for HSTA teachers and "year 3" HSTA students that integrate studies of food composition, osteoporosis, and cardiovascular disease with the use of the Casio^{Æ} graphing calculator (Casio, 1998). The calculators are applied to generate descriptive statistics, mean and median box and whisker plots, and scatter plots, which are examined to develop understandings about such concepts as percentile, correlation, linear regression, and dependent and independent variable. Past funding has been sufficient to allow teachers and students to keep the calculators, making them available for use during the subsequent school year.

Following are descriptions of HSTA Summer Institute experiences that apply the graphing calculator to human nutrition content. The "Fruity Investigation" was utilized in the 1996 and 1997 Summer Institutes and is described fully elsewhere (Rye, 1997). The "Calcium Intake and Bone Health" experience utilized in the 1997 Summer Institute emanated, in part, from the pre-pilot testing of a lesson within the theme of "special concerns in nutrition," subsequently published in the *Secondary Level Interdisciplinary Curriculum* (Campbell & Meyers, 1997). Portions of the third description, "Dietary Factors and Cardiovascular Disease," were utilized during the 1997 and 1998 HSTA Summer Institutes.

Fruity Investigation

This investigation seeks to determine the sugar concentration of a solution at which a grape will become buoyant. Box and whisker plots of the data are generated to illustrate the range of values produced by each small group that completes the experiment, and to discuss the concepts of median, percentile, natural variance, and experimental error. Hypotheses also can be set forth about the sugar concentration of different types of grapes (e.g., white as opposed to red), and the independent samples t-test can be applied to the data generated from experimentally determining the sugar concentration in randomly selected samples of these grapes. Most of the data shown in Table 1 was generated by the students who completed this experiment. The "percent mass as sugar of solution at buoyancy" approximates the actual sugar concentration of the grapes--approximately 18% according to food composition tables (e.g., Pennington, 1998). Further discussion can be generated about "body composition" (percent mass as water) of grapes (about 80%) as opposed to humans (50 to 60%), which leads to an appreciation of water as the nutrient needed in the greatest quantity by humans.

Table 1
Fruity Investigation Data and Respective Calculations: Percent Sugar Solution at Which Red and White Seedless Grapes Become Buoyant

	Mass (g) of Sugar Added to Water to Achieve Buoyancy		Mass (g) of Sugar Solution at Buoyancy		Percent (%) Mass as Sugar of Solution at Buoyancy[a]	
Group	Red Grape	White Grape	Red Grape	White Grape	Red Grape	White Grape
1	11	11.5	69.7	70.8	15.8	16.2
2	11.5	12	81.6	81.7	14.1	14.7
3	14	15	75	76	18.7	19.7
4	11.5	12.5	70.3	75.5	16.4	16.6
5	15.5	14.5	66.2	65.2	23.4	22.2
6	10	9	72.9	72.8	13.7	12.4
7	10	12	72.9	72.8	13.7	16.5
8	15	18	84	87	17.9	20.7
9	16	17.5	76.5	76.1	20.9	23
10	11.5	12.5	72.1	72.5	16	17.2

[a]Percent Mass as Sugar calculation: (Mass of Sucrose Added to Achieve Buoyancy/Mass of Sugar Solution at Buoyancy) * 100. Example for Group 1, Red Grape: (11/69.7) * 100 = 15.8%

Calcium Intake and Bone Health

This experience in human anatomy includes examining normal and osteoporotic bone, and learning about risk factors for osteoporosis. Amongst the nutrition-related risk factors is a diet that is chronically inadequate in calcium (Ca). Data sets of the energy value (kcal) and Ca content of various types of food, such as dairy and green vegetables (see Table 2 for samples) are examined and manipulated to answer questions about (a) the range of Ca present per serving and on a Ca per kcal basis and (b) the extent to which various foods satisfy recommended dietary allowances for Ca (e.g., 1200 mg/day for males and females, ages 11-24 years). Bioavailability constants also can be applied to food composition data in order to examine relationships between Ca in the food as opposed to the amount absorbed (Sizer & Whitney, 1997). For example, from 1 cup cooked broccoli, 38 mg of Ca (72 mg Ca per cup * .53 bioavailability) are absorbed whereas 95 mg of Ca (298 mg Ca per cup * .32 bioavailability) are absorbed from 1 cup 2% low-fat milk. Thus, taking into consideration the kcal values of and the Ca bioavailability from each of these foods, a revelation unfolds: The broccoli turns out to be a better source of Ca (on a per kcal basis) than does the 2% low-fat milk: 38 mg Ca/44 kcal = .86 mg Ca per kcal of broccoli; 95 mg Ca/121 kcal = .79 mg Ca per kcal of 2% low-fat milk. The previous exercise allows students to "look beyond" the Nutrition Facts on food labels and illustrates the complexity that underlies human systems and nutritional needs.

The experience continues through a chemistry investigation (Campbell & Meyers, 1997) where various dairy products are titrated for calcium, and descriptive statistics and box and whisker plots of the data are generated and discussed. Findings are compared to Nutrition Facts on the food label.

Table 2
Calorie (Kcal) and Calcium (Ca)[a] Content of 1 Cup Servings of Select Dairy Products and Green Vegetables

Food (1 cup each)	Kcal	Ca (mg)
Milk, Whole	150	290
Milk, 2 % Low-fat	121	298
Milk, 1% Low-fat	102	300
Milk, Non-fat	86	301
Yogurt, Vanilla, Low-fat	194	388
Asparagus (from frozen, cooked & chopped)	50	42
Broccoli (from fresh, cooked and chopped)	44	72
Brussel Sprouts (from fresh, cooked)	60	56
Cabbage (raw, shredded)	17	33
Lettuce, loose-leaf (chopped)	10	38

[a]Kcal and Ca values obtained from Sizer & Whitney (1997).

Dietary Factors in Cardiovascular Disease

The food composition data provided by this experience allows students to think about food intake from the perspective of the health of the cardiovascular system. For example, in the human anatomy component of the Summer Institute, students were asked to consider how a heart attack and stroke affect an individual's health and lifestyle. Relative to the latter, dietary intake becomes an important consideration. Students examine the nutrient composition of various types of animal products--such as red meat and dairy (see Table 3 for sample)--to determine if relationships existed between fat and kcal content or between fat and cholesterol content. Linear regression reveals that there is a strong and positive correlation between fat and kcal in both types of food: $r = .998$ for red meat and $r = .820$ for the dairy foods. However, the relationships between fat and cholesterol are dissimilar amongst the dairy foods and meats: There is a strong positive correlation ($r = .997$) in the former (as fat is reduced, the cholesterol content of dairy food appears to decrease by the same proportion), but only a weak and negative correlation ($r = -.293$) in the latter (reducing fat appears to have little impact on cholesterol content of meat).

Data sets also were constructed for "Voracious Carnivore," "Moo Cow," and "Flatulent Flatus"--names that humorously reflected the diet (meat, dairy, or legumes, respectively) of three fictitious characters. For these data sets, box and whiskers plots and scatter plots can be generated, and linear regressions can be performed, in association with questions such as "Who has the greatest range of total fat in their diet?" "Does there appear to be any relationship between kcal and total fat in these diets?" "If Moo Cow and Voracious Carnivore ate only the low fat items in their diet, who would obtain the most cholesterol and why?"

Chemistry experiences are added to the above through a "chips lab." Here, the fat and sodium content of "unknown" snack chip samples are quantified through laboratory analyses, e.g., for sodium, the distilled water "wash" of crushed chips is titrated with a $AgNO_3$ solution. Analyses of the new fat free potato chips yielded a "surprising" result: Students were able to extract a measurable amount of fat from the sample. This finding allowed for discussion about bioavailability and food technology: The "fat" used to prepare these chips--actually a sucrose polyester known as olestra that has some structural similarity to fat--is non-absorbable, and thus unavailable from a metabolic standpoint (Sizer & Whitney, 1997).

Table 3
Approximate Kcal, Fat, and Cholesterol Content[a] of Select Cooked Red Meats and Dairy Products

Food & Amount	Kcal	Fat (g)	Cholesterol (mg)
Beef, Chuck Roast, Lean & Fat, 4 oz	394	29	112
Beef, Round Roast, Lean, 4 oz	249	11	109
Pork, Shoulder Roast, Lean & Fat, 4 oz	373	26	124
Pork, Shoulder Roast, Lean, 4 oz	277	14	127
Venison, Roast, 4 oz	179	4	127
Milk, Whole, 1 cup	150	8	33
Milk, 2 % Low-fat, 1 cup	121	5	18
Milk, Non-fat, 1 cup	86	0.4	4
Yogurt, Vanilla, Low-fat, 1 cup	194	3	11
Ice Cream, Vanilla (~10% fat), 1 cup	267	15	59

[a]Kcal, fat, & cholesterol values obtained from West Diet Analysis (1997) and Sizer & Whitney (1997).

Implications

Teacher professional development efforts that bring together mathematics and science, such as those described above, support achievement of the National Science Education Standards (NSES)(National Research Council, 1996). At the program level, these standards convey that such coordination "provides opportunity to advance instruction in science beyond the purely descriptive" (p. 214) and "reinforces the perspective of investigation and experimentation that is emphasized in the National Council of Teachers of Mathematics standards" (p. 218). Further, human nutrition subject matter provides an authentic context for learning science and mathematics and the opportunity to develop student understandings within the NSES content standards of "Life Science" and "Science in Personal and Social Perspectives." Applications of the graphing calculator in this context contribute to teachers' and students' competence in the use of learning technologies.

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Co-Teaching Science and Mathematics Methods Courses

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The teaching that we describe in this paper is part of a master's degree program leading to elementary teacher certification. Within this program, the development of literacy skills remains a central focus of teacher preparation, and integration tends to mean the subsuming of other subjects by literacy instruction. For that reason, we have been struggling against integration in order to ensure the integrity of our disciplines - mathematics and science. A number of factors have caused us to rethink our roles in the program. First, we also teach in an integrated secondary teacher certification program in Mathematics, Science and Technology Education (MSAT) that provides us with another model of integration, one in which the study of each discipline is strengthened by its integration with the others. Second, we have concerns about the quality of the math and science instruction that graduates of our elementary certification program might be offering their students and wish to explore alternative approaches to the integration of content.

The freedom to rethink our roles was facilitated recently when the administrative structures in the College of Education at The Ohio State University were reorganized. A consequence of this reorganization was that our teacher education programs were also adapted to fit the new administrative structures of the College of Education. Within the School of Teaching and Learning, the faculty formed three sections that offer M.Ed. teacher education programs. We (Beeth and McNeal) each are members of two of these sections, Integrated Teaching and Learning (ITL) which offers elementary certification and Mathematics, Science, and Technology Education (MSAT) which offers middle and secondary certification. The ITL section takes integration as one of its themes, where "integration" is broadly construed as the integration of teaching and learning, the integration of diverse students within one classroom, and the integration of subject matter, such as math and science. The M.Ed. programs that ITL runs prepare elementary teachers (K-8) with these forms of integration in mind. On the other hand, the MSAT section created a unique M.Ed. program that prepares prospective middle and secondary school teachers to integrate math, science, and technology into their teaching. Thus, our work as teacher educators in ITL and MSAT takes place within a climate of integration. We (Beeth and McNeal) had broached the idea of integrating math and science to each other before this, but it was not until a colleague in drama education called us together to describe our courses to him that we realized how much common ground there might be.

The work that we describe here is work-in-progress as we explore a variety of questions about ways to integrate our science and math methods courses. Questions include: Are there principles of integration that we can use when planning the integration of our courses? How might these principles help our prospective teachers think about teaching in an integrated fashion? How much do we want to integrate (e.g., should we become one course, or come together only occasionally)? When and in what ways is it appropriate to integrate and when not? What roles do the strengths of our individual courses play in an integrated structure? As we attempt to provide our prospective teachers with situations in which math and science can be talked about together, we are attentive to themes that emerge in these discussions that might inform our future plans. Finally, as mentioned above, this work is literally "in progress" as the two courses are still under way and we are reporting on the first half of the coursework while we plan the second half.

The Methods Classes Prior to Integration

Each methods class meets weekly for two and a half hours over two ten week quarters, Autumn and Winter. We requested from our colleagues that the science and math methods classes be scheduled the same day in order to facilitate our efforts at integration. This report reflects only those activities that took place during the Autumn Quarter.

Science Methods Class -- Beeth

The goals of the elementary science methods courses are: 1) to motivate prospective teachers to want to teach science, 2) to confront prospective teachers' views of the nature of scientific activities and the implications these views have for teaching and learning science, and 3) to teach some fundamental science concepts. Beeth exposes prospective teachers to a model of instruction (Peterson & Jungck, 1988) that involves them in POSING problems about natural phenomena, PROBING for answers that explain a problem, and PERSUADING their peers that they have a sufficient answer to the question posed (referred to as the "3 P's" approach). Throughout this course prospective teachers participate in discussions designed to confront their notions of the nature of scientific activity and the implications that their views have for teaching and learning about science (see Moscovici & Nelson, 1998; Rutherford, 1987). Prospective teachers are expected to select teaching resources and plan instruction that is consistent with their developing views of the nature of science. The following excerpts from a former prospective teacher evaluation of the science methods course indicate the extent to which the first goal for this course was accomplished.

> I enjoyed the hands-on activities and most importantly, the instructors were able to improve my attitude and comfort level about science.

The second goal for these courses, to confront prospective teachers' views of the nature of scientific activities and the implications these views have for teaching and learning science, is as important as motivating them to include science in their instruction. Although many of the elementary and middle school students these prospective teachers work with are innately inquisitive about the natural world, capitalizing on this inquisitiveness is possible only if a teacher is well prepared to do so. Beeth's approach to helping prospective teachers in this course learn to think through these issues involved challenging their beliefs about the nature of science as an intellectual activity and modeling science instruction during his instruction. During this course Beeth modeled the 3 P's approach to science instruction (Peterson & Jungck, 1988). This "3 P's" model of science that Beeth presents starts with real world phenomena of interest to the learner. It includes an expectation that the learner will draw on his or her existing knowledge, additional resources such as library materials, the knowledge and expertise of other students, and the assistance of adults to collect information, analyze data, and present conclusions that provide an answer to the problem posed. This model places a heavy emphasis on the need to communicate the results of an investigation of the natural world in a persuasive manner (i.e., persuade peers). Developing the ability to probe problems and persuading peers are two characteristics of the 3-P's model of science instruction that stand in sharp contrast to more traditional presentations of a "scientific method."

Implemented in an elementary classroom, the 3 P's model allows teachers and students the opportunity to participate in many of the physical and intellectual aspects of science rather than just learning about the science done in the past (i.e., the science of "dead white men"). This approach also includes a number of added benefits for the classroom teacher. One benefit of this model is that learners must communicate the rationale for what was done and what they learned, as opposed to merely following directions supplied on a worksheet to fill in predetermined blanks or data tables. This allows teachers opportunities to reinforce the necessity for teaching written, oral, and visual communication skills -- basic literacy skills that elementary school teachers traditionally teach well and ones they can reinforce in the context of student-designed investigations in science. Another benefit of this model is that it removes the apprehension some teachers feel regarding knowing too little science content in order to teach a subject well. Using a 3-P's approach, students generated their own problems and the solutions to them. While learning science content is an expectation of the model, it is not an expectation that students at this age will possess "the received view" of any particular body of scientific knowledge.

An additional benefit of the 3 P's model to an elementary school teacher is that he or she can address aspects of science that are external to the science content itself. For example, how does the background of an investigator effect the outcome of an investigation? It is well known historically that the nationality of an investigator does influence what they identified as a problem to be solved, who they considered to be colleagues working on similar problems, and how data are presented. For example, evolutionary biology is filled with instances of scientists working along nationalistic lines (e.g., followers of Frenchman George Cuvier attempting to prove the intellectual superiority of white male Europeans). In a similar vein, the influence of elementary and middle school age students' past experiences, as well as their current beliefs, attitudes, and values, effect the interpretations they make about investigating the natural world. The influences of individual factors such as these can be used to discuss issues related to social aspects of learning science (e.g., who did this science?, where did it occur?, and why did they get to do it at that time?). More contemporary issues of science might also be discussed such as would the availability of better technology affect your science investigation, and if so, how?

Another benefit of 3 P's instruction is that it relies on the group to determine what is accepted and what is not. Since persuasion of peers is a requirement of this instruction, the group establishes norms for what counts as an acceptable explanation without dismissing the possibility that an individual may have his or her own ideas. Investigations presented within the scientific tradition do require that multiple investigations produce the same results if the conclusions are to be considered valid. This is not to imply that scientists are somehow seekers of an objective truth. It is meant to communicate that socially accepted standards of scientific inquiry do exist, regardless of the background of a particular scientist. Generating these standards is a significant aspect of the learning that can occur when a 3-P's approach is followed. The statement that follows is indicative of the impact that this model of instruction had on prospective teachers in the science methods course.

> I felt I learned a lot about how science is done and I feel it's an important concept for kids to learn.

The final goal of instruction in this methods course is to teach some science content. Granted, teachers at all levels can always benefit by learning additional science content. Throughout the course, lessons were chosen to included content that focused on fundamental concepts in science. Prospective teachers explored the concept of density by placing cans of carbonated soda in water to determine why some sank while others floated. They also observed and described physical variation in human genetic traits followed by a lesson on genetics (Soderberg, 1992). After learning to plant and grow Wisconsin Fast Plants©, prospective teachers posed problems about plant growth and which factors we could investigate in the classroom. Beeth selected science content for this program only if it engaged students in learning processes he associated with science (exemplified by the 3 P's model of instruction) and it had the potential to be highly motivating to the prospective teachers.

At the beginning of each class period, Beeth provided prospective teachers with examples of prepared instructional programs and references to the availability of free or inexpensive instructional resources. On the last class day, he talked about local, state, and national science teacher organizations and encouraged prospective teachers to continue pursuing a knowledge of science through formal means, such as taking a science content course, and informal means such as attending bird or flower hikes in local parks. Science content was not the main focus of Beeth's instruction since it is quite literally impossible to cover the amount that prospective teachers might need. Although Beeth sacrificed breadth of coverage, prospective teachers, like the one below, did indicate that they had learned some concepts well enough to teach them.

> I enjoyed many of the experiments and group activities we did in class and hope to use some in my own classroom, especially the marshmallow meiosis which illustrated how traits are passed from one generation to the next.

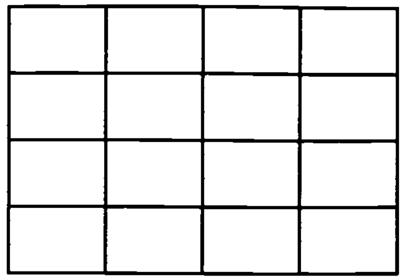
Evaluations of the science methods courses by the prospective teachers indicate substantial accomplishment of Beeth's instructional goals. So why mess with a good thing? Why begin the process of integrating science and mathematics when things seemed, from the prospective teacher's point of view, to be going so well? A partial answer to this question is that science instruction, even at its best, would not help our prospective teachers experience the integration of these subjects, and we felt that this experience was essential for them. Although most of the faculty in the ITL programs say they do integrate multiple subjects, no one had yet taken the steps that would capitalize on what we all thought could be an even better experience for our prospective teachers.

Mathematics Methods Class -- McNeal

McNeal views learning to teach as a lifelong process of personal reflection on theory, practice, and their interrelationship and explicitly states that this course "will not teach you how to teach mathematics ... This course ... aims instead to teach you how to LEARN about teaching and learning mathematics" (McNeal, Ed T & L 708 syllabus). The main goals of this two-quarter course are to support prospective teachers in: 1) examining their assumptions about mathematics, mathematics teaching and learning; 2) learning about current issues in mathematics education; 3) listening to and observing students' thinking; 4) planning lessons that build on what students' know; 5) evaluating their own lessons in terms of what learning occurred; and 6) viewing teaching as inquiry -- there are dilemmas in taking a problem solving approach to mathematics instruction that each individual teacher must resolve in the particular context of his or her school and community. The first three goals form the primary thrust of the Autumn Quarter, while the last three are emphasized in the Winter Quarter.

Along with asking prospective teachers to describe their relationship to mathematics and to read articles that provoke them to think about what it means to understand mathematics, McNeal engages prospective teachers in doing mathematics and then in reflecting on that experience in the hope that these activities will challenge some of the ideas that prospective teachers often bring to their thinking about teaching. For example, most prospective teachers believe that mathematical problems are solved by applying a best procedure (usually one expressed as a formula) to generate a single answer. Their experiences in mathematics class were often limited to listening to the teacher present a procedure, then practicing that procedure, and having their answers validated by the teacher. In McNeal's class, prospective teachers solve a carefully selected problem in pairs and then participate in a discussion of the solution methods used. For example, the "squares problem" in Figure 1 was the first problem introduced in the math methods course (see Table 2). Initially, prospective teachers often see only 16 squares, then recognize the outside border of the grid as another square and their exploration takes off. The object of this problem was to help prospective teachers recognize the existence of a variety of solution methods and problem interpretations to an apparently straightforward problem. In moving on to an 8 by 8 grid, prospective teachers usually want to generate a more systematic method of counting, or of computing, the number of squares. This elicits a search for patterns and the generation of formulae to express those patterns. McNeal facilitates the discussion to highlight the variety of methods and the different interpretations taken, and simultaneously makes a concerted effort to avoid evaluating the prospective teachers' answers as right or wrong. By these means, McNeal challenges the prospective teachers' current conceptions of mathematics, mathematics teaching and mathematics learning.

Figure 1.
The "squares problem."
How many squares do you see in this picture?
If we call this a 4 by 4 grid, how many squares would there be in an 8 by 8 grid?



Over the 10-week quarter, the class moves from these foundations (discussion of and about mathematics, the goals of teaching mathematics, and factors that help and hinder mathematical learning) into more specific discussion of children's ways of thinking about and doing the mathematics of counting, place value, addition, subtraction, multiplication, and division. Discussion of the connections among these mathematical ideas and operations is generated once again by engaging the prospective teachers in doing mathematics. They are introduced to counting in base 8 and asked to operate completely within that system as they solve arithmetic problems as if they were children. Rather than requiring prospective teachers to role play, the base 8 system challenges them to rethink basic arithmetic, counting, and place value. The computational strategies generated by the prospective teachers often replicate methods that young children use to solve arithmetic problems and hence these experiences help prospective teachers to understand both the learning experiences of children and the mathematics involved in the operations that seem self-evident to them as adults. Other topics in mathematics, such as fractions and data analysis, are dealt with in the Winter Quarter, using similar pedagogical strategies.

<u>Looking for a Workable and Reasonable Integrated Structure</u>

We began our joint planning by meeting to discuss our current, separate course goals and assignments in order to find common themes and/or activities from which to begin the process of integration. This included discussion of what we would mean by "integration". For instance, McNeal was initially considering integrated assignments (assignments that would count for both courses) as well as combined class sessions.

As we outlined the goals discussed in the previous sections, we found that our separate courses developed parallel strands of discussion on the nature of math and science in the early weeks of the quarter. Not surprisingly, each separate methods course also included some work on children's development of subject matter understanding and lesson planning. Because of similarities in our own conceptions of science and mathematics that included a focus on inquiry and the relationship of each to the other (math as a useful tool for scientific investigation and science as an application of math), we planned to engage the prospective teachers in activities that would exemplify integrated lessons.

We also found that our course emphases were complementary in that Beeth had prospective teachers begin planning lessons in the Autumn Quarter, then moved to a focus on children's conceptions of science in the Winter Quarter while McNeal did the reverse, making lesson planning a major area of discussion in the winter, after focusing most heavily on children's conceptions of mathematical objects and operations in the autumn. This complementarity had two effects on our thinking about integration: First, it meant that our assignments did not readily mesh so we abandoned that idea, and second, it suggested another way of thinking about the integration of our courses. Furthermore, we thought that prospective teachers, like elementary students, might benefit from working on lesson planning and learning about children's subject-specific conceptions over time. By engaging prospective teachers in thinking simultaneously about lesson planning and about children's learning over time, but not in the same content domain, we hoped to allow them some room for depth and enrichment. Specifically, we hoped that prospective teachers' developing ideas about planning science lessons might enrich their math lessons and that their developing awareness of how to look and listen to children's mathematical understandings might inform their thinking about children's scientific conceptions.

By thinking of the two courses as interwoven rather than running in parallel or as one joint course, we came up with a simple structure. Out of a total of ten sessions in autumn, we decided on three non-consecutive joint sessions around the following activities: discussion of prospective teachers' understandings of the nature of math and science, and two activities that integrated math and science (a technology lab and an investigation of density). The simplicity of this structure, one that was not radically different from the usual, neither consumed too much of our energy and time in integration, nor detracted from meeting the goals of our separate courses. Table 1 displays the planned integration of joint sessions with existing math and science lessons. Reading the second, third, and fourth columns shows the math syllabus, and reading the sixth, seventh, and eighth columns shows the science syllabus. The middle column (Science and Mathematics) shows the topics for the integrated sessions.

Table 1
Planned Integration of Math and Science Courses

Date	Math class topics	Math class activities	Math assignments	**Science and Mathematics**	Science topics	Science class activities	Science assignments
Week One 9/29	Assumptions and expectations about math, teaching, & learning based on your prior experiences	squares problem in-class write up of mathematical thinking	Holt (131-191)		Your past experiences in science	Fast Plants	
Week Two 10/6	Conceptual vs. procedural knowledge; How we learn ; Goals of math education	in-class write up of mathematical thinking	Skemp Erlwanger Due: Reflection		Your past experiences in science		Peterson (1988) Science autobiography due
Week Three 10/13	Beliefs about what math is; Comparison to math in school	meet in morning with science	Tate Standards Due: First field journal; Reflection	**Discussion: compare and contrast: what is science? what is math?**	Posing authentic questions		Rutherford (1987)
Week Four 10/20	Writing in math; Looking at children's math	video; discuss 1st field journal; prep for 2nd field journal	Wilde Pengelly O'Brien Due: Reflection on math/science		Posing authentic questions		Watson (1990)

Week Five 10/27	Technology in math class; Integrating math and science	meet in a.m. with science	Curcio & Folkson; Penniman; Isaacs & Kelso Due: Reflection; Second field journal	**Calculator-based graphing; Ideas for integrating science/math; using technology in the classroom**	Role of Science in the Elementary School	Magic or Science?	web links
Week Six 11/3	Children's arithmetic; Counting; Word Problems	Base 8; Cognitively Guided Instruction (CGI)	Cobb & Merkel; Carpenter et al. Due: Reflection on math/science		Role of Science in the Elementary School	Sinking and Floating	Instructional resources due
Week Seven 11/10	Hands-on to generalized formula/strategy	meet in a.m. with science	addition/subtraction readings; finish Holt Due: Reflection	**Density lab; Discussion of ways to build a formula**	Integration of Science et al.	Sinking and floating	Hewson (1998)
Week Eight 11/17	Continue counting; Addition & subtraction; Place value	more base 8; text pages; context of learning	Labinowicz Due: Lesson plan, transcript; Reflection on math/science		Integration of Science et al.		McLeod (n.d.) Science lessons due
Week Nine 11/24	Multiplication & Division	more base 8; word problems	Kamii; Burns Due: Reflection		Learning Science Concepts	Marshmallow Meiosis	Gatto (1993)
Week Ten 12/1			Ball Due: Reflection; Child study		Learning Science Concepts		Soderberg (1992)

What Really Happened

Our first joint session took place in the third week and dealt with the prospective teachers' conceptions of the nature of mathematics and science. We planned this to follow two weeks of instruction in each separate course. As can be seen in Table 2, during this time, we were laying the foundations for discussing the nature of mathematics or science, independent of one another. Our intention was then to bring our courses together to see what sense the prospective teachers would make of the two disciplines. We facilitated discussion around similarities and differences in the nature of math and science in the hope that this would enrich their understanding of each discipline separately and help the prospective teachers begin to develop a sense of the relationship of each to the other. An analysis of this discussion follows below.

Our second planned session was the technology lab. We invited two teachers who teach velocity and acceleration to Kindergarten students using a calculator-based lab to model this activity, and hence the integration of math and science, to the prospective teachers. Because we were unable to coordinate our schedules during the Autumn Quarter, this did not occur. We hope to make this work in the Winter.

Our third planned session was the density lab conducted by Beeth. The intent was to develop both a definition of density and an understanding of density as a mathematical relationship between mass and volume. The prospective teachers explored the concept of density by placing cans of carbonated soda in water to determine which sank or floated. The difficulties we experienced in trying to teach this joint session will be discussed in the final section of this paper.

Table 2
What actually occurred.

Date	Math class topics	Math class activities	Math assignments	**Science and Mathematics**	Science topics	Science class activities	Science assignments
Week One 9/29	Assumptions & expectations; Relation to prior experiences	squares problem math writing	Holt (131-191)		Your past experiences in science	Fast Plants	
Week Two 10/6	Conceptual vs. procedural knowledge; How we learn; Goals	discussed squares; discussed readings	Skemp Erlwanger Due: Reflection		Your past experiences in science		Peterson (1988) Due: Auto-biography
Week Three 10/13	Beliefs about what math is; Comparison to math in school	met in a.m. with science	Tate Standards Due: 1st field journal; Reflection	**Discussion: compare and contrast: what is science? what is math?**	Posing authentic questions		Rutherford (1987)
Week Four 10/20	Writing in math; Looking at children's math	discussed Standards; shared observations; clear lake problem	clear lake Wilde O'Brien Due: Reflection on math/science		Posing authentic questions		Watson (1990)
Week Five 10/27	Integrating math and science	met in a.m. with science	Campbell et al. Finish Holt Due: 2nd field journal	**Density lab -- hands-on experiments; discussed meaning of density**	Role of Science in the Elementary School	Magic or Science?	web links

Week Six 11/3	Children's arithmetic; Counting	base 8; CGI	Cobb & Merkel; Carpenter et al.		Role of Science in the Elementary School	Sinking and Floating	Instructional resources due
Week Seven 11/10	Continue counting; met in a.m. <u>without</u> science	base 8 activities; discussed basic facts; video of children's addition strategies	Due: Reflection		Integration of Science et al.		Hewson (1998)
Week Eight 11/17	Addition & subtraction; Place value; Word problems	text pages; base 8 activities; video of subtraction strategies; shared lessons	Labinowicz Due: Lesson plan & transcript		Integration of Science et al.		McLeod (n.d.) Science lessons due
Week Nine 11/24	Multiplication & Division	solving 59 x 69 mentally; mult. & div. word problems	Kamii; Burns Due: Reflection		Learning Science Concepts	Marshmallow Meiosis	Gatto (1993)
Week Ten 12/1	Word problems & CGI; Dilemmas in teaching	solved word problems by modeling; shared case studies; discussed dilemmas	Ball Due: Child study		Learning Science Concepts		Soderberg (1992)

Discussion of the Nature of Science and Math

Prior to the joint discussion of the nature of science and math, Beeth had asked the prospective teachers to choose a definition of science from among six possibilities (see Figure 2). While McNeal had engaged the prospective teachers in doing non-routine mathematical problems and in discussing how these experiences differed from their prior experiences with mathematics as described in an earlier section, she had not engaged the prospective teachers in explicit discussion of the nature of math. When Beeth shared the science definitions with McNeal during the planning sessions, McNeal thought they would be provocative in a discussion of the nature of mathematics. On the morning of our joint session, half of the class was asked to look at the definitions again and to choose any that they felt applied to science. The other half of the class was asked to consider the question, "What is math?", and were encouraged to use the list of definitions of science to assist them. We then facilitated a discussion comparing and contrasting their definitions of both, but beginning with some of the group's definitions of math.

Figure 2
Definitions of science presented in Beeth's class

SCIENCE IS:

• A BODY OF KNOWLEDGE that includes the names of organisms and their parts, the laws that govern the natural world, and theoretical ideas.

Learners of science should know as much of this body of knowledge as possible -- the anatomy and physiology of objects in the natural world.

• GENERATING NEW KNOWLEDGE about the natural world -- scientists discover new organisms and find out things not previously known.

Learners should understand the methods and procedures used by scientists when they set out to discover new things.

• A SET OF IDEAS (i.e., concepts) that allow people to explain how the natural world works.

A learner should be able to persuade others that he or she understands the natural world, and that his or her understanding is compelling.

• SOLVING PROBLEMS that are important to an individual or significant social problems such as reducing the impacts of pollution, finding cures for diseases or making better/more efficient products.

Learners should be able to apply their understandings of science problem solving to improve the quality of their lives.

• ONE PART IN THE HISTORY OF HUMAN DEVELOPMENT -- science has a long history, a complex sociology, and a deep philosophy.

What is important is that a learner understands the conditions under which scientific knowledge is generated, and how the production of this knowledge impacts the lives of non-scientists.

• A CHANGING SET OF IDEAS -- scientists will study the same natural objects and phenomena they always have but how we think about the natural world today needs to be an open question (i.e., changes in scientific ideas about the relationships between earth and sun have drastically changed the way we think).

A learner should understand that all scientific knowledge is tentative, and, when changes occur, how and why that knowledge changed. Upon what criteria or new information does the scientific community change its ideas?

This was a lively and lengthy discussion, lasting about an hour and a half. Over that time, the prospective teachers' ideas seemed to move from one word definitions of math (illustrated immediately below) to much more complex definitions of math (and science as well). This development occurred through a variety of connections made by the prospective teachers. They initially drew on experiences with math in their everyday lives prior to entering the program, such as learning percussion or dance, in order to exemplify their definitions. Later they began to make connections to experiences from our courses such as the "squares problem".

CL: We said that math is critical thinking, problem solving, reasoning and patterning. Math isn't a set of changing ideas -- the process changes but the product is not negotiable . . . Math is patterning, then we thought of math as musical because of my experiences playing percussion. I thought in eighths and sixteenths.
AN: (from another group) Yes, I had that experience with dance!
MP: (questioning CL's group) Does the product or answer ever change?
EG: [mentions that there can be different answers to the squares problem and other open-ended problems]
JN: Some answers aren't the same because the assumptions are different.
EG: For the purpose of communication, there has to be <u>some</u> stuff that is understood.

Embedded in this conversation is the prospective teachers' belief that the purpose of mathematics is to obtain correct answers. For the prospective teachers, this represents an unchanging, or absolutist, view of mathematics. As the conversation continued, they contrasted their view of the nature of mathematics to their view of science that they indicated was a changing set of ideas.

> BA: I saw math before this as finality, one answer, but maybe infinite ways to solve. If there's more than one answer, then I don't want to learn math. It doesn't make sense to me that there could be more than one answer.
> MP: That goes back to how we were instructed, how secure we feel with one answer. We weren't allowed to explore.

The prospective teachers' statements here suggest that they are beginning to see their ideas and feelings about the nature of mathematics as related to their prior experiences. They continue to build this connection as the conversation is switched to one group's ideas of the nature of science.

> AH: [Our group] thinks science is a changing set of ideas. We are still thinking about the same things as 100 years ago, but changing the answers. We are changing the methods too.
> Beeth: You seem to be saying that it's OK for science to change. Is it not OK for math ideas to change?
> MB: It might be OK for math to change, but I would need some kind of proof. Science has data to show [that the ideas should change.]
> NR: It would be hard to replicate a science experiment if math changed as well.
> ME: Science is much more complex. Math is more concrete, I mean, 2 + 2 = 4.
> EG: We don't want to see math as a process because it's uncomfortable.
> Bednar [a Clinical Educator assigned to the science methods course]: I see lots of parallels between math and science. You can have different answers in math. 1 + 1 could be 10 if each 1 is 5 things clumped together. It's not simple for children at all. Both [math and science] are process-oriented. Educators need to look at how we view [math and science] or what views we pass along.
> HM: We have to be careful when we say that science is a changing set of ideas because lots doesn't change.
> SB: We're used to science changing. I can see science has changed, but I can't see this in math.

The prospective teachers' statements about the nature of science indicate their understanding that it is a changing set of ideas, and that this view of science fits with their experiences. This stands in stark contrast with their view of mathematics as expressed earlier. Dissatisfied with the idea that science and math might be different, the prospective teachers shifted the conversation to the implications of their understandings of the nature of math and science for school science and math.

> SH: I think math and science ask different questions. In math we [teachers] tend to ask the same questions over and over, but in science, we are more open-ended. I resist math because I don't want people to tell me what the question is, I want to ask my own. [If I hadn't read the Tate article] I never would have thought to pose a question like how to show the effect of liquor stores in my neighborhood.

MP: I think it's a difference in higher level math versus elementary. In elementary math, there are different processes, but the same answer. In elementary science, the questions are more open.
MB: Is Pluto still a planet? If it isn't, a change like that will affect how we teach science.
Beeth: In science we seem to think it's OK to have two ideas, like the behavior of light being like both a particle and a wave. Science is willing to live with this duality.
AF: Even if we let children ask their own questions, there are still right answers.
SH: There is lots that can trouble the factuality.
Beeth: Is science much less precise than math? All questions are possible.
SH: Math should be that way.
McNeal: Maybe we need to make a distinction between school math and math as a discipline. My husband [a mathematician] seems to feel that he can ask any question that he wants!
HM: In school, math worksheets only have problems like 5 + 2. We see math as just numbers, there is no context. In science, the question tends to be "why?" In math, the question tends to be "what is the answer?"

Implications for Further Co-Teaching of Science and Math

In having this discussion around the definitions of math and science, we were trying to give prospective teachers some tools (e.g., definitions of science and the squares problem) for talking about a kind of math and science that they may not have experienced. As instructors, we were also hoping to create dissatisfaction in them about their beliefs about math and science. We noted that the prospective teachers drew on the single example of the squares problem for discussing mathematics, but were able to generate multiple contexts/problems for discussing science (e.g., Pluto, genetics, light) from their own experience. This seems to have been sufficient for the prospective teachers to move from rhetorical statements about science and math, to thinking about their own experiences, to feeling dissatisfied with their current views, and to considering how they would teach math and science.

We were very pleased with the value of this discussion of the nature of science and math. We saw a parallel between the existence of multiple definitions of science with the multiple solution methods for a given math problem. It seemed that contrasting math with science enabled the prospective teachers to look more closely at mathematics as a discipline, recognize their own views of mathematics as absolutist, and finally, of the relationship these views had to their prior experiences.

Despite the value above, we experienced a number of difficulties with co-teaching these courses. Among these were our lack of knowledge of each other's teaching styles. This showed up most readily during the density lab. In discussing and then choosing to do this lab, we thought we saw interconnections between the science and the math that would be easy for us to bring out jointly. This did not happen. Although the lab was successful in terms of learning for the prospective teachers (based on their written reflections on this experience), Beeth taught this lab as he had taught it in the past with little input from McNeal. In the process of writing this paper, we were finally able to articulate our miscommunication around this lab. McNeal had been expecting an activity that would engage the prospective teachers in empirically deriving a formula and had continually interpreted Beeth's description of the lab as such. We now understand that the formula for density is a logically derived from definitions, rather than empirically from data. This distinction between how formulas are derived will help us choose activities in the future that demonstrate both types of interconnections.

This was our first stab at integration -- our prospective teachers are still trying to figure it out, so are we . . .

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A BRIEF HISTORY OF THE COLLABORATIVE VISION FOR SCIENCE & MATHEMATICS EDUCATION AT MICHIGAN STATE UNIVERSITY

Don Duggan-Haas, Michigan State University
Edward Smith, Michigan State University
James Miller, Michigan State University

The Collaborative Vision for Science & Mathematics Education (CVSME) is a loosely coupled organization that has improved communication and fostered collaboration among faculty in the Colleges of Education and Natural Science. The improved communication and collaboration is intended to improve mathematics and science teaching and learning from kindergarten through graduate school. We believe we are making strides towards these goals. This paper will briefly describe the history of the organization, some of its accomplishments, and identify characteristics that have both fostered and frustrated the collaborative work.

Precursors

Program Structures

Several factors preceded the formal establishment of this collaborative. There is a respected, long-standing and sizable science education faculty group in the College of Education. Every fall, virtually all of the science education faculty and graduate students participate in weekly seminars, and in the last two years, a small number of faculty from the College of Natural Science have joined these seminars. The theme of this course, Teacher Education 955, changes from year to year. In 1998, the focus was on the differences in culture between the two colleges.

Under the leadership of Clarence Suelter, The Division of Science and Mathematics (commonly referred to as "The Division") formed within the College of Natural Science serving as a point of contact for the College of Education. For the last two and a half years, The Division has been under the leadership of Jim Miller. In 1999, Joan Ferrini-Mundy will assume the directorship of The Division. The Division is the formal structure in which masters' degree programs for practicing science teachers are housed. The Division also includes two faculty, one tenure stream and one temporary, with joint appointments in the two colleges. Several other faculty and support staff serve bridging roles between the two colleges.

A Catalyst for Collaboration

In the Fall of 1994, Michigan State University hosted a meeting to review an early draft of Project 2061's *Blueprint for Science Literacy*, involving scientists and science educators from around the country. At that meeting, there was a heated exchange between physicist Dan Stump and science educator Tim Smith, both (unbeknownst to each other) of MSU.

Tim found the conversation worth continuing and talked further to Dan and discovered they were both from MSU. As a result of this conversation, Tim established the Science Education Brown Bag Lunch Group. This group has continued to meet regularly since 1994. The setting is always informal, sometimes without an established agenda, but usually focused around a particular reading or issue. Attendance typically varies between ten and twenty, and both colleges are always represented. Beginning in the fall of 1998, mathematicians and math educators with interests in issues affecting both mathematics and science education have joined the conversations.

Beginnings of CVSME

In 1996, College of Education Dean Carole Ames launched an initiative to fund several "themes" within the college. These themes were intended to foster "intellectual communities" within the College of Education and internal funding was available. This served as a catalyst for conversation among the science education faculty group, encouraged by Ed Smith. Continued conversation lead to the inclusion of mathematics within the "theme" proposal and to branching across the two colleges. An organizational meeting was held that lead to the writing of the internal proposal. Funding of $8,000/year was awarded beginning in January of 1997. This funding was used to hire Don Duggan-Haas as the project's graduate assistant. Funding also was used for large group meetings, the most recent of which was January 7, 1999.

A steering committee formed including a scientist, science educators, a mathematician, and math educators. The Steering Committee meets monthly while whole group meetings have typically taken place once a semester. These whole group meetings have lead to additional meetings of smaller groups, including those involved in substantial grant development activities (see below for information regarding accomplishments).

Following the first meeting, website development began as one vehicle for information dissemination. A listserv was also established now including over forty subscribers from the two colleges, the Michigan Department of Education and directors of the state's Math and Science Center Network. Both the website and the list have continued to slowly grow over the last two years. Much more information about CVSME and related projects and activities is available on the website at <http://ed-web3.educ.msu.edu/cvsme>.

Figure 1. The Aims of CVSME

What is The Collaborative Vision for Science & Mathematics Education?

The Collaborative Vision for Science and Mathematics Education is a new and unique group at Michigan State University. CVSME seeks to improve science and mathematics teaching at all levels. Begun under an initiative of the Dean in the College of Education, this group has received strong support from the College of Natural Science, and encompasses most of the research faculty in science and mathematics education in the two colleges. The current participants number more than forty and include staff members from the Michigan Department of Education.
The aims of this group include:

- Creating new images of what science and mathematics education might be
- Providing a forum for consideration of needs and priorities for work in science and math education, i.e., strategic planning
- Informing our faculty better of one another's work and of relevant developments at the national, state, regional and local levels
- Facilitating preparation of collaborative projects that interrelate multiple aspects of our work
- Communicating the scope and impact of our combined efforts to administrators and policy makers
- Focusing of institutional support for major proposals
- Providing an access point for queries, expressions of concern or proposals about science and math education
- Providing a more informed, timely, and effective voice on policy matters that arise
- Fostering an intellectual community for faculty and advanced graduate students

This group is in a position to work with others around the University in strategic planning for new and continuing initiatives.

The opening text of CVSME's website defines the aims of the organization. This is shown in Figure 1. The text was written in the spring of 1997, shortly after the first meeting. In the following pages, the success of CVSME in meeting these goals will be addressed.

CVSME's second meeting lead to the creation of two foci -- one targeting the improvement of K-12 teaching and learning in schools hosting MSU's teacher candidates field placements (Alliance Schools) and the second targeting the improvement of undergraduate teaching and learning in mathematics and science at MSU. Several smaller meetings followed for each of the two foci, leading to important collaborations in both areas. A small ($30,000) NASA NOVA Grant was awarded to reform non-majors biology classes. More information about this work can be found at <http://ed-web3.educ.msu.edu/cvsme/nova.htm>.

In 1998, several important projects with direct ties to CVSME were initiated. In the Spring of 1998, CVSME hosted its first colloquia, with Dr. Gerd Kortemeyer discussing the Learning OnLine project. This project involves using the World Wide Web for undergraduate science course content delivery. This colloquium also marked CVSME's entree into educational technology, the focus of the January 7, 1999 meeting.

Throughout the spring of 1998, a large grant writing team involving faculty, post doctoral fellows and graduates students from the Colleges of Natural Science and Education developed a Howard Hughes Medical Institute Grant proposal. A $1.6 million award was announced in the summer and work is underway ① to reform introductory biology courses for science majors, ② to expand opportunities for undergraduate research and ③ to expand faculty professional development programs. Information about this project can be found at <http://lecture.lite.msu.edu/~hughes/>.

Jane Rice, of the College of Natural Science, developed a physical science course for elementary teacher candidates that was taught in the fall of 1998. Throughout the course, she worked closely with science educators. The course is being taught again in the spring of 1999, and enrollment is full.

In the Fall of 1998, the scope of educational technology projects in the College of Education were largely unknown to CVSME participants. This came to light as a result of Steering

Committee meetings and meetings involving Ed Smith, Jim Miller and Don Duggan-Haas, and, eventually, faculty and educational specialists directly involved in educational technology. This lead to the January 7, 1999 meeting entitled, "Using Technology in Support of Science & Mathematics Education."

This meeting helped faculty involved in both science and science education understand the scope of educational technology projects underway in both colleges and to see how their work might support these efforts and to discuss new possibilities for collaborative efforts. As a result of this meeting, at least two significant new grant writing teams have formed.

An Overview of CVSME's Accomplishments

Although many factors are involved in the strengthening collaboration between educators and scientists at MSU, we believe that CVSME played an integral role in several major accomplishments. These include:

- A general improvement in awareness of projects and programs in the two colleges related to science and mathematics education. This is perhaps our most important success. Communication has improved through both formal and informal channels. CVSME's listserv, website and meetings have served as formal channels for the dissemination of information and have acted as catalysts for more informal channels.
- A recently awarded Howard Hughes Institute Grant for reconceptualizing the science majors' introductory biology course and to expand opportunities for undergraduate research. Course improvements will include reforming pedagogy and the increased use of multimedia in course instruction. The award amount is 1.6 million dollars.
- The development of The Division of Science and Mathematics Education's Educational Principles. The Educational Principles are posted on the Division's website at: <http://www.dsme.msu.edu/challenges.htm>, with some further explanatory text. These principles are intended to inform the teaching in college science classes with educational research.

- A new course for elementary science teacher candidates, developed by a scientist in collaboration with science educators.
- A substantial and growing website that offers a central location for information sharing related to science and mathematics teaching and learning from pre-school through graduate school. The URL is: <http://ed-web3.educ.msu.edu/cvsme>. The site includes descriptions of, and links to, projects and programs which involve university faculty and graduate students that are related science and mathematics teaching and learning. The projects included are a representative sample, not an exhaustive list.
- A listserv with approximately fifty subscribers where information relevant to science and mathematics education is shared within the university community. The listserv also provides a vehicle for the dissemination of an electronic newsletter, The CVSME Update. The newsletter is also archived on the website.
- A NASA funded NOVA grant that is intended to improve teaching and learning in a non-majors' biology class.
- CVSME sponsored colloquia related to the teaching and learning of science and mathematics that have been well attended by faculty from both the College of Education and the College of Natural Science.

All of the above were the result of scientists and science educators working together. CVSME helped provide avenues for these collaborations. The authors believe that there are lessons to be learned from the work of The Collaborative Vision for Science and Mathematics Education that are transferable to many institutions. The divide between scientists and science educators is nearly universal and the demand for reform of tertiary-level teaching is growing. CVSME is an appropriate response to these conditions that may offer a model for others to adapt to their own situations.

Table 1 lists websites that include more information on several of the projects related to CVSME. All of the listed URLs are included within CVSME's site. This is a partial list of URLs for projects and programs related to CVSME. All links below and many more may be found within the CVSME website.

Table 1.

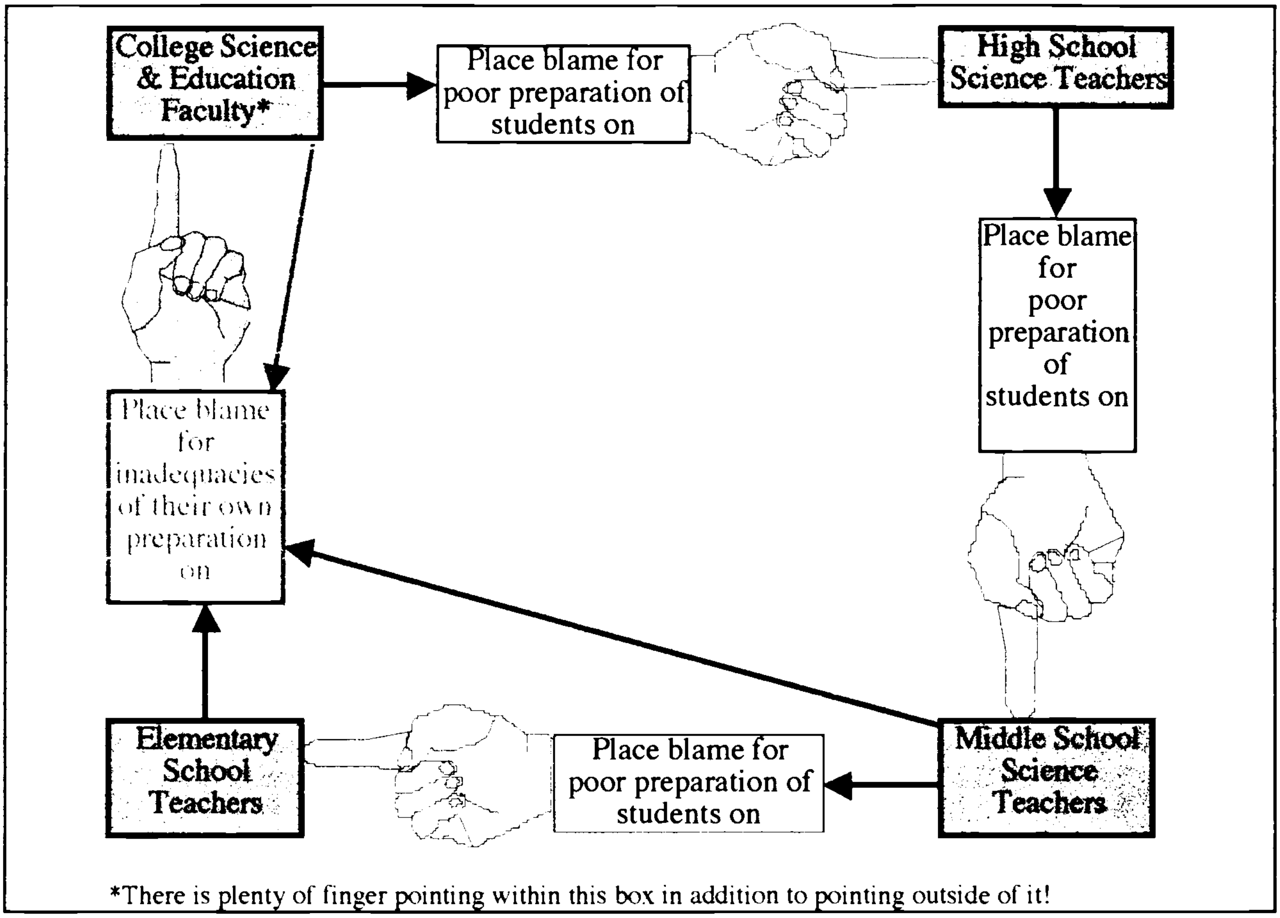
Websites related to The Collaborative Vision for Science & Mathematics Education	
Collaborative Vision for Science & Mathematics Education	http://ed-web3.educ.msu.edu/cvsme/
The Division of Science & Mathematics Education	http://www.dsme.msu.edu/
Michigan State University On Line Curriculum and Research Scholars (Howard Hughes Medical Institute grant project)	http://lecture.lite.msu.edu/~hughes/
The NOVA Project -- Implementing Innovative Teaching of Science at Michigan State University Using Integrative Studies Courses as a Springboard	http://ed-web3.educ.msu.edu/cvsme/nova.htm
The Division's Educational Principles	http://www.dsme.msu.edu/challenges.htm
The College of Education	http://www.educ.msu.edu/
The College of Natural Science	http://www.ns.msu.edu/
Michigan State University	http://www.msu.edu/

Obstacles Faced Along the Way

It is generally accepted that science education K-16 has serious problems in this country. Blame is placed in a variety of settings and when these arguments are viewed collectively, the 'blame path' is circular. College faculty despair about the quality of the pre-college preparation of their students (Seymour & Hewitt, 1997). High school teachers blame middle school teachers; middle school teachers blame elementary school teachers and elementary school teachers blame poor teaching in college for their lack of content knowledge (McDermott 1990). In addition to these links, all of the individuals included have been trained in college or university to do their current work, so blame may be pointed to college science preparation from anywhere within the cycle. This includes the college science professors themselves who have generally not seen consistently good models of teaching in their own professional preparation. (See Figure 2.)

Figure 2 shows one possible, "cycle of blame," for the problems of science teaching at many levels. The gray lines from college faculty back to college faculty is perhaps the least obvious and most important. Through this reflective arrow real change maybe generated. Of course this, of course, is a simplified model. What is the role of family? Of culture?

Figure 2. Cycle of Blame



Most salient to members of this collaborative is the finger-pointing within the box in the upper left hand corner of Figure 2 (this is not pictured). There is a fair amount of blame being assigned by both sets of academics both nationally and at MSU. This is perhaps the greatest obstacle we face.

Teachers at all levels must not simply respond to problems in teaching with statements beginning, "If only..." but must instead think in terms of, "If I..." or "If we..." (Fullan 1991). In other words, faculty must assume responsibility rather than place blame. Our discussions, particularly those in the Brown Bag Lunch group and in the Steering Committee, have generally moved beyond blaming. Those who are regular participants still engage in heated conversation, but they also recognize that other participants in the conversation have expertise that is valuable to the conversation and that all members of the conversation care deeply about teaching and learning.

This progress has been more noticeable in science than in mathematics, at least for undergraduate teaching. Sadly, the most outspoken member of the mathematics department representing CVSME and the only mathematician on the Steering Committee, Bill Fitzgerald, passed away in 1998. We have been unable to find a mathematician to take his place on the committee.

Many of the problems faced can be better understood if it recognized that there are huge cultural differences between the two colleges. There is a divide between the two cultures, similar to the one described by C.P. Snow (1959). These two cultures are defined by, and maintained through, the nature of interactions academics have with each other and with their students in each college. The differences perceived by students are delineated in Table 2.

It is not surprising that students see little relationship between their science and TE course work. It seems that every instructional characteristic of one program is reversed in the other. Unless otherwise noted, quotations are taken from New Teacher Interviews of MSU graduates. This table represents data from the Salish I Project and is adapted from (Duggan-Haas 1998).

The cultural divide is easily recognized by faculty in either college. There is plentiful anecdotal evidence of the divide, and less evidence on initiatives to narrow the divide. For example, the conversation between Tim Smith and Dan Stump that acted as a catalyst for the Brown Bag Lunch series highlighted the divide. Their work together over the four years since that discussion, and their work in other border-crossing activities indicates that the gap is being closed for these two individuals. Tim has been involved in the grant writing team for the successful grant proposal to Howard Hughes Medical Institute. He drafted what became the Educational Principles of The Division of Science and Mathematics Education as part of his work on the proposal. Dan has been involved in a science curriculum committee for a local district and in other curriculum development. Both have been regulars at the BBL gatherings for four years.

Table 2. New science teacher perceptions of teacher education and science coursework

Characteristic	Science	Teacher Education
Course Instruction	Lecture, "...mostly lecture. Not much labs, not great labs when we had them."	Group work/discussion, "I would say a little bit of everything besides lecture."
use of lecture	embrace	shun
use of cooperative learning	shun	embrace
class-size	large	small
Program purpose/goals	Goals are well-defined and understood: content; to learn facts	Goals are poorly defined or understood. Many different goals are identified.
textbook use	embrace	shun
Instructional Resources	Textbook	Readings — collections of articles
Methods of assessment	objective tests, mostly multiple-choice	written work before the internship, written work along with teaching performance during the internship.
Teacher-Student relationships	"By far, the commonest words used to describe encounters with S.M.E. [science, mathematics and engineering] faculty are 'unapproachable,' 'cold,' unavailable,' 'aloof,' indifferent,' and 'intimidating.'" (Seymour & Hewitt, p. 141)	personal; "Excellent," was a term used by half the participants to describe the faculty-student relationship in the Salish study.
Program components valued by new teachers	Research or research like experiences – two new teachers graduated from MSU reported such experiences; one as a volunteer, the other at a different institution. In most cases, these experiences were outside the formal program.	The full-year internship; the sequence of courses in TE related to their subject matter. In all cases, these experiences were part of the formal program.
	Partial Summary	
Classroom culture's relation to professional work	Undergraduate science courses do not generally reflect the work of scientists. Unfortunately, they may reflect the work of science teachers.	Undergraduate teacher education courses reflect what teachers should do (in the opinion of teacher education faculty) in their own classrooms.

What makes CVSME work (if it does)?

The system that is science and mathematics education is a complex adaptive system. Identifying the essential elements leading to this collaborative is an impossible task. Several initiatives came together at the same time that seemed to facilitate more pieces fitting together.

Perhaps this is what E.O. Wilson means by consilience, a jumping together of several factors. Perhaps it is synergy. While we have made progress, what lies ahead is a far greater challenge.

How can we measure our success? The aims established for CVSME (see Figure 1) are listed below. Each aim from Figure 1 (*italicized* below) is followed by a brief explanation of where CVSME stands in relation to that aim.

Creating new images of what science and mathematics education might be

This is perhaps best demonstrated through the work surrounding the January 7, 1999 meeting entitled, "Using Technology in Support of Science & Mathematics Education." This meeting focused on the thoughtful, pedagogic use of technology in K-12 mathematics and science education.. The meeting and the work both before and after the meeting has fostered discussion and collaboration between and among faculty involved in discipline specific work with those involved in educational technology. Increased clarity of what integration of technology into science and math at MSU might look like and how collaborative efforts might focused. In fact, concrete steps, including two proposals for new collaboratives, have been submitted.

Providing a forum for consideration of needs and priorities for work in science and math education, i.e., strategic planning

By strategic planning, we mean that projects are coordinated with each other and moving toward common goals. The two foci of CVSME explain our targets for reform – teaching and learning of science and mathematics for undergraduates at MSU (Focus 1) and teaching and learning of science and mathematics in schools hosting MSU teacher candidates (Focus 2). Strategic planning related to Focus 1 includes the development of grant proposals, such as the Howard Hughes Medical Institute (HHMI) grant funded for $1.6 million. The January 7, 1999 meeting is one example of such a forum for Focus 2. It also includes work within the teacher preparation program, which is expected to be the focus of a spring 1999 meeting.

Informing our faculty better of one another's work and of relevant developments at the national, state, regional and local levels

This is perhaps CVSME's greatest success. Through formal and informal meetings, the website and the listserv, faculty are far more aware of each others' work and are finding connections within each others' work. This is true not only between the colleges, but also within the colleges. We have found projects of which even faculty with related interests within the same college were not aware. Relevant projects and programs from other units, for example, the Office of Computing and Technology, have been able to communicate to faculty through these avenues. Additionally, the listserv and lunch group meeting have provided a forum for discussion of related issues at the state and national levels.

Facilitating preparation of collaborative projects that interrelate multiple aspects of our work

The HHMI grant is a very important collaborative project for both colleges and for our students. While this is not a direct outgrowth of CVSME, more recent proposals are a direct result. This includes proposals for a Technology Literacy Challenge Fund Grant proposal and a Rural Systemic Initiative grant proposal.

Communicating the scope and impact of our combined efforts to administrators and policy makers

The Dean's of both Colleges have attended CVSME meetings and funding continues from the Dean of the College of Education's office. The provost's office was involved in the HHMI proposal and is involved in the ongoing work related to the grant. Representatives from the Michigan Department of Education have been involved with CVSME through both electronic communication and participation in meetings. These are all indicators that the work of CVSME is valued by administrators and policy makers.

Focusing of institutional support for major proposals

Again, the HHMI grant and other proposals either recently submitted or under development have found CVSME's meetings and electronic communication avenues useful for proposal development. There is also an effort underway seeking Title II funds directed by Associate Dean of the College of Education, Robert Floden and involving faculty from both colleges.

Providing an access point for queries, expressions of concern or proposals about science and math education

It is clear that the listserv provides such an access point. Individuals from Michigan Department of Education, various mathematics and science centers in Mid-Michigan and other from outside the university have joined in both electronic and face-to-face communication through CVSME. Additionally, faculty and graduate students outside of the College of Education have been continually subscribing to the listserv. However, this access point has not been used to its full potential. It has served primarily to send information out rather than to respond to queries.

Providing a more informed, timely, and effective voice on policy matters that arise

Although the membership of CVSME has not seized every opportunity to speak to policy issues, it has, though the steering committee, endorsed the recruitment efforts for a new director of the Division and for implementation of Jane Rice's course. Also, important groundwork has been laid for playing roles in future policy work. This groundwork takes multiple forms – the very existence of CVSME, the electronic communications possible through the listserv and website and through steering committee and other meetings.

Fostering an intellectual community for faculty and advanced graduate students

The opportunities provided for open discussion and collaborative work have helped to foster the intellectual community that sits between the Colleges of Education and Natural Science. This includes discussions in the Brown Bag Lunch Group around critiques of national standards, state Science Education Frameworks and, more generally, about the nature of science.

CVSME has made considerable progress towards its goals. While it is difficult to determine what is causal in regards to this progress, we believe that CVSME has offered many avenues towards their fulfillment.

What elements have helped us towards our successes? This confluence of individual and administrative initiatives -- the Brown Bag Lunch Group coming together before the Dean of Education's "Theme Initiative," and Ed Smith's and Jim Miller's perseverance for several related initiatives to see themselves as related are all important pieces of the puzzle. There is also a broader stick-to-itiveness, what M. Scott Peck refers to as a willingness to "work through the chaos." (Peck 1998). Where there has been success, there has also been a willingness to work with colleagues that see the world in a different way and a willingness to listen and respect views other than our own.

For the past two years, we have worked to improve communication and collaboration among our colleagues. We are now beginning to study our work towards these goals. Our work has also lead to an important new goal -- to more directly connect the work in educational technology at MSU to work in science and mathematics education.

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RETHINKING THE PRESENTATION OF THE CASE STANDARDS FOR SCIENCE TEACHER PREPARATION[1]

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The Certification and Accreditation in Science Education (CASE) Network has done a commendable job in their development of Draft Standards for Science Teacher Preparation (CASE and Network 1998). The information on these pages is a response to the repeated requests of the CASE Network for feedback about those Standards and focuses on the presentation of the standards rather than the standards themselves. This paper primarily addresses the nature of the structure and presentation of the CASE Standards and suggests that the flexibility of electronic publishing be exploited to overcome problems associated with the ordered presentation of the standards used in the current draft.

Rationale for a Non-linear Presentation:

While the Standards are generally well-written, there are concerns about their presentation. In their current form, the Standards are numbered 1 through 10, with Content being Standard #1. While it is not directly stated that the order of the Standards is a rank order, it is problematic that Content is placed well ahead of Pedagogy (Standard #5). We believe that understanding content and understanding pedagogy are roughly equal in importance, and that these two standards are the most important.

[1] This feedback was written with much input from doctoral students in Jim Gallagher's Special Topics in Science Education: Current Reform in Science Education course at Michigan State University. The original version was written in the Spring of 1998.

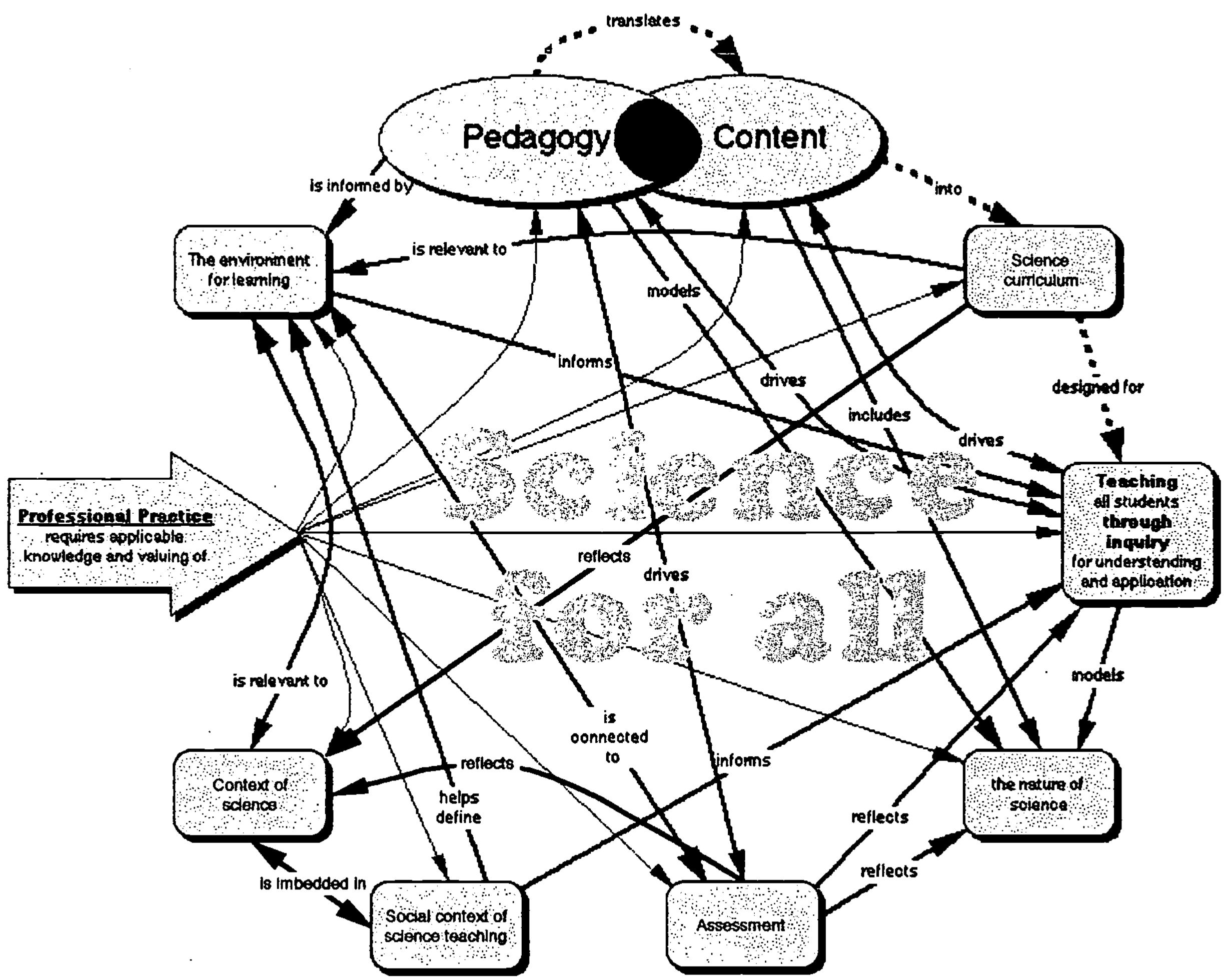
These two standards stand above the others -- pedagogy and content. Good pedagogy is impossible in the absence of deep knowledge of the subject to be taught. Similarly, strong content knowledge is of little value to teachers if it exists without understandings of how to help their students come to understand that knowledge. In order to be a good science teacher, it is necessary to have firmly established operational understandings in both pedagogy and science content. It is necessary to have pedagogical content knowledge (Shulman 1987). The other eight standards are included in the tight embrace of pedagogy and content. One cannot be successfully exercised without successful exercise of the other. Indeed, "How you teach is what you teach." (Human Rights 1998?)

As the Standards cannot be ranked in importance from 1 to 10, the publication of this document is well suited to electronic media - CD ROM and the World Wide Web. The electronic format allows a genuine cross-linking among standards that is lost when text is bound in printed pages. The schematic below shows some, though certainly not all, of the important linkages among the standards. Thus far, the Standards have been disseminated electronically and other information related to the Standards are available primarily in electronic format. Some electronic sources for information related to the Standards are shown in Table 1.

Table 1: Electronic Sources Related to the NSTA Standards for Science Teacher Preparation

Title & Description	URL
NSTA Draft Standards for Science Teacher Preparation	http://www.iuk.edu/faculty/sgilbert/nstastand.htm
Introduction to the newest version of the Draft Standards and the request for feedback	http://www.iuk.edu/faculty/sgilbert/draftstand.htm
Bill Baird's editorial in Volume 2, Issue #3 of the Electronic Journal of Science Education – A Progress report on the Certification and Accreditation in Science Education (CASE) performance standards for science teachers	http://unr.edu/homepage/jcannon/ejse/baird.html

Figure 1: Map of NSTA Standards for Science Teacher Education



Electronic publication offers a way around the problem of placing one Standard above another. Using hot-linked schematic representations of the relationships among Standards, the rank order implied by page order in a printed and bound document can be eliminated. Figure 1 shows such a representation, although obviously not hot linked from the printed page. In the electronic version of this diagram[2], each of the ten standards are hyperlinked to their

[2] This can be found online at: <http://www.msu.edu/~haasdona/NSTA_AETS.htm>. Text on this page by Don Duggan-Haas and Jim Gallagher. Graphics and web design for this page by Don Duggan-Haas with helpful

descriptions. In the electronic representation of the diagram, color is used and is another clear advantage of electronic publishing. The following description references colors used in the diagram in this form. The description and diagram would be made far more complex if other methods besides coloring were used to discuss and describe the diagram. It is therefore recommended that the reader access the electronic version of Figure 1 at http://www.msu.edu/~haasdona.

A more conceptual introduction

In addition to reformatting the structure of the CASE Standards presentation, the Standards for Science Teacher Presentation lack significant introductory and connective text to bring the discrete Standards into a coherent vision for science teacher preparation. There is some introductory text included with the November, 1998 draft of the Standards, however, this introduction is largely logistical in nature and the presentation would benefit from text that ties the individual standards together into a single, coherent document. The Introduction and Map of the Standards above are an attempt to tie the Standards together into a more coherent vision.

Again, the CASE Network is to be commended for their excellent work in development of The Standards for Science Teacher Preparation.

Introduction to the Standards

The NSTA/AETS Standards for Science Teacher Preparation are described by ten broad categories. It is necessary that new science teachers gain applicable knowledge and appreciation of each of the ten aspects of science teaching. Without competency in, and subscription to these

feedback from Jim Gallagher and fellow students in TE 991A, Special Topics in Science Education: Current Reform in Science Education, in the Spring of 1998.

NSTA/AETS Standards new teachers will not successfully teach all students for understanding and application utilizing a broad vision of science. These three ideas, teaching all students science; for understanding and application; utilizing a broad vision of science; plus one more key idea; that teaching less content allows for better understanding and more meaningful application are the heart and soul of the current reform efforts in science education reflected in the National Science Education Standards and Project 2061. (AAAS 1989; AAAS 1993; NRC 1996)

Science for All

Again, one of the several premises of the National Science Education Standards and Project 2061 is encapsulated in the phrase Science for All. This is a demanding goal. Many changes are needed in the education of science teachers if this goal is to be achieved, requiring increased sophistication in attitudes, professional knowledge, and skills in both teaching and interpersonal interactions.

Only a portion of science teachers have developed the knowledge, skills, and attitudes that are compatible with the goal of Science for All. Further, many science educators have little experience in helping prospective and practicing science teachers increase their capability of teaching all students science.

In order for science educators to be able to help science teachers develop the capabilities for teaching science for all, several actions are needed:

- Efforts need to be expanded to foster attitudes among scientists, science educators, and science teachers that scientific literacy is achievable for a broad spectrum of the population.

- Scientists, science educators, and science teachers should work diligently to develop interpersonal skills that will help to engage all students in learning science.
- Science educators and science teachers should work together to develop the professional knowledge and skills needed to foster scientific literacy among all students.
- Where research is needed to fill gaps in our knowledge about teaching science effectively to all students, science educators, psychologists, sociologists, scientists, and science teachers should join forces to design, conduct, and disseminate findings from their research.
- Relevant research should continue to be analyzed and recommendations from it made available to colleagues across the nation.

Science for All must become more than simply a slogan. It is essential that science educators lead others in the science education community in giving substance and positive action to this goal. The development of the NSTA/AETS Standards for Science Teacher Preparation is a step toward meeting these challenging goals.

Connections Among Standards

The diagram maps each of the ten standards, showing important connections among the standards. Each of the ten Standards, the brown text in the blue background, is linked to the appropriate web page (when accessed through the web[3]). The arrows included obviously do not represent every possible connection, but ones that we believe are most important.

[3] Again, a central point of this paper is that electronic publication should be taken advantage of for the publication of the NSTA Standards for Science Teacher Preparation. One of the advantages of publishing electronic is the cost free use of color. This description refers to colors used in the diagram available from the authors website.

The red arrows all flow from the standard for professional practice. Professional practice requires applicable knowledge and valuing of the information conveyed in each of the other nine standards. The purple dashed arrows should be read in sequence beginning with pedagogy: "Pedagogy translates content into science curriculum designed for teaching all students through inquiry for application and understanding." Thus, there are linear paths through and around this non-linear structure.

The dark gray arrows are important connections between individual standards other than professional practice. The authors make no claims that the links shown here is exhaustive or even necessarily the most important linkages. The point is to foster an understanding that each of the individual standards is dependent upon or influenced by other standards.

The links within the diagram are analogous to supports within a structure. The removal of any one of the standards makes the structure too weak to support science for all. In order for science teacher preparation programs to be effective, they must effectively address and assess each Standard. New science teachers should enter their classrooms with the understandings associated with each of the ten standards and with an understanding of the connections among these standards.

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REFLECTIONS ON TEACHER PHILOSOPHIES AND TEACHING STRATEGIES UPON CHILDREN'S COGNITIVE STRUCTURE DEVELOPMENT - REFLECTION II

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Introduction

Every classroom teacher has beliefs, whether articulated or not, on what makes a good teacher. "Good teachers know how to maintain order. Children need to make connections to past experiences. Time on task is a key element to increase learning. Children need to feel safe at school or no learning can occur." These philosophies vary greatly, but generally they attempt to answer a common question: "How can I as a teacher promote the best possible learning in my students?"

Do teacher philosophies - ideals and ideas in their heads - trickle down into the classroom? Do they do what they believe, or for whatever reasons are their classroom practices incompatible with their philosophies? And what difference does it make? No matter what the philosophy or practice, does either one effect student learning?

This paper will examine two related questions. First, does teacher philosophy effect classroom practice? Second, how does classroom practice effect student learning?

Philosophy

Teachers' philosophies consist of sets of beliefs about teaching and learning. Philosophies evolve from different sources. Teaching experiences, professional articles and research, curriculum experts, other teachers, personal likes and interests, and teacher preparation courses all help shape philosophy. As Caine and Caine (1997) describe it, there is another powerful influence on philosophy.

> Even people who might have different views of what they want education to accomplish often share deep beliefs about "school" and teaching, which are not grounded in a coherent theory of learning. Their unarticulated beliefs are grounded in the experiences that they have had with their own education. (p.8).

Just as philosophy has many influences, it also encompasses many components. One part of teacher philosophy which will be examined in this paper is direction of control. Who directs what happens in the classroom, from curriculum, delivery and assessment to schedule and physical layout? With a *teacher-directed* philosophy, the belief is that the teacher should control these aspects completely. If the philosophy is *student-directed*, children should have complete control. A *coalition* philosophy is a hybrid of the other two, where the teacher and student should share equally in decision making.

Figure 1: "Directedness of Teaching Philosophy and Practice" illustrates these three philosophy models. In summary, teachers who follow a teacher-directed teaching approach are likely to approach students with the notion of "I know a lot. Listen to me, do what I do, and you will learn a lot." Teachers ascribing to a coalition model take the more balanced approach of "I know a lot, but so do you. Tell me what you know and want, and I'll give you a few choices, as long as it fits into our schedule and goals." Student-directed teachers believe that "You know more about how your learn than I ever will be able to figure out. You need to run this classroom if you are going to be interested and learn."

Of course, these three columns represent the extremes, to which no teacher would fall all of the time. For example, no teacher, no matter how student-directed, would encourage a child to play with matches and then guide him toward dialing

Figure 1
Directedness of Teaching Philosophy and Practice

Teacher Directed	Coalition	Student directed
Good teachers □ tell students about important concepts/processes □ structure learning schedule	Good teachers □ tell and guide students to learn important concepts/processes □ let children have some input regarding learning schedule	Good teachers □ guide students to learn important concepts/processes □ allow each child to determine their own learning time
A well organized classroom □ has students separated from each other, all facing the teacher □ is organized by the teacher	A well organized classroom □ has flexible seating (for individuals or groups) □ is organized by the teacher and students	A well organized classroom □ has flexible seating (for individuals or groups) □ is organized by the students
Principles of teaching (Children learn best by) □ working the same way □ following the teacher's directions □ watching the teacher demonstrate and read about concept	Principles of teaching (Children learn best by) □ working in a limited variety of ways □ choosing what to work on from a limited variety of topics □ using objects in "hands-on" activities which are directed by the teacher	Principles of teaching (Children learn best by) □ working in the way that best suits each individual □ choosing what to work on and study from any topic □ using objects in "hands-on" activities which are directed by the individual student
Curriculum is based on □ state, district, and school requirements □ teacher interests □ what the teacher has done in the past	Curriculum is based on □ state, district, and school requirements □ teacher and student interests	Curriculum is based on □ what's developmentally appropriate □ interests of each individual student
Students are assessed through □ whole class pencil and paper tests	Students are assessed through □ whole class performance tests	Students are assessed through □ multiple assessments selected by individual students

"911". In some cases, explicit teacher-directed lecture is the best way to communicate important ideas. However, examining the extremes may shed light on all teaching philosophies.

Methodology

Four teachers (Teachers A, B, C, and D) participated in this study. All were classroom teachers in a primary school in suburban Chicago. Teachers B and D were veteran teachers, each having taught more than 15 years, and having been in education for their entire working lives. Teachers A and C were relative newcomers, having taught one year and four years respectively. Each of the newer teachers had recently switched careers from fields outside of education. Each teacher agreed to participate in a one-on-one interview with the researcher. To help articulate their philosophies, all four were interviewed using the "Teachers' Pedagogical Philosophy Interview" developed by Richardson and Simmons (1994). The researcher than compared each teachers' answers to Figure 1, in order to determine if the philosophies were teacher-directed, coalition, or student-directed.

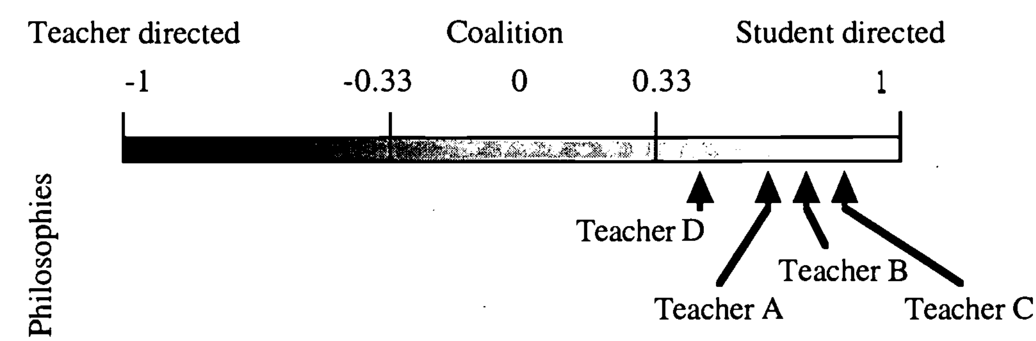
Data on Philosophy

In order to assign each philosophy to one of the directedness categories, answers were compared to Figure 1, and judged to be either a teacher-directed, coalition, or student-directed answer. Answers which didn't address directedness were not counted. Each teacher-directed answer was multiplied by -1, each coalition answer was multiplied by 0, and each student-directed answer was multiplied by 1. All of the numbers for each philosophy were then totaled and averaged (Figure 2). To determine overall directedness, each total was compared to the directedness scale (Figure 3), which is divided into equal thirds, each third corresponding to a philosophy. As Figures 2 and 3 both show, each of the four philosophies were judged to be student-directed, though to different degrees.

Figure 2
Summary of Philosophies

Teacher	Teacher directed answers x (-1)	Coalition answers x (0)	Student directed answers x (1)	Total / # of answers	Directedness
Teacher A	0	3	5	0.62	Student
Teacher B	0	2	6	0.75	Student
Teacher C	0	1	7	0.88	Student
Teacher D	1	1	4	0.50	Student

Figure 3
Directedness Scale of Philosophies



Data on Practice

In order to compare philosophies about teaching to actual classroom practices, each teacher was asked to prepare and present a science or math lesson. Each lesson was approximately 45 minutes in length. The researcher observed and took notes on each lesson.

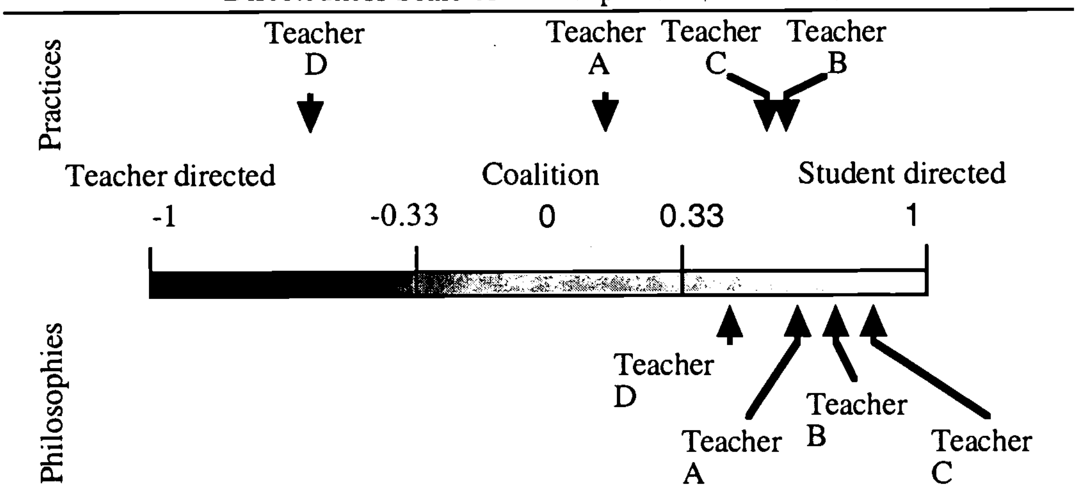
Similarly to how the philosophies were evaluated, the observational notes were compared to Figure 1 and judged to be either teacher-directed, coalition, or student-directed practices. Again, practices which didn't address directedness were not counted. A similar calculation process was applied. The results are summarized in Figure 4.

The data on practice was then overlaid on the philosophy directedness scale in order to compare philosophy with practice. See Figure 5. The data indicates that while two of the teachers (B and C) had philosophies matching practice, two (A and D) did not. Teachers B and C, whose philosophies were judged to be the most student directed, each taught a student-directed lesson. Teacher A had a student directed philosophy but taught more in a coalition manner. The philosophy of Teacher D was student directed, but less so than the other three. In contrast, her lesson was

Figure 4
Summary of Practices

Teacher	Teacher directed answers x (-1)	Coalition answers x (0)	Student directed answers x (1)	Total / # of answers	Directedness
Teacher A	0	5	1	0.17	Coalition
Teacher B	0	2	7	0.78	Student
Teacher C	0	2	5	0.71	Student
Teacher D	3	2	0	-0.60	Teacher

Figure 5
Directedness Scale of Philosophies and Practices



judged to be teacher-directed - quite far from her student-directed philosophy.

Conclusions and Implications

It is difficult to draw conclusions from this mixed data. In half of the cases philosophy matched practice, in the other half it didn't. Part of this may have been the limited amount of observation time. It's difficult to come to conclusions on practices when only one 45 minute lesson was observed. Still, as each teacher was asked to present a lesson for observation, it's unlikely that the philosophy behind the lesson would deviate too much from what is normally done.

In either case, it may be important for teachers to articulate their philosophies, if only to themselves. Study and comparison of philosophy and practice may help teachers conclude that what they believe is (or isn't) what they teach. This can lead to further analysis. "How did I come to believe this? Is it supported by research? Why don't I teach in the way that I feel is best? Are there outside influences - parents, principals, team members, districts - which make it difficult to follow my philosophy?" Such reflection is necessary if teachers are to grow professionally in a thoughtful manner.

Learning

Even though philosophy and practice don't always match, can a connection be found between practice and learning? How does the directedness of a teacher effect student learning? To answer this question, the researchers focused on one part of learning, the development of logical thought.

To develop true understanding of abstract scientific and mathematical concepts, students must possess appropriate logical structures. For example, teaching the concept of mammals to students who cannot yet classify consistently would be shortsighted, as those same students are developmentally unable to understand that dogs can belong to the group *pets* and to the group *mammals* at the same time. Students may be able to memorize what animals are mammals, but there can be no real understanding until collections and class inclusion ability is developed. Therefore, teachers must both teach concepts to which their students are developmentally capable of understanding, and provide for activities which develop these important cognitive structures.

Manipulatives in the Classroom

Piaget's theory of intellectual development describes how these logical abilities are constructed. Others have also concluded that the use of manipulatives seems to promote structure development (Cohen 1984; Phillips 1989; Phillips 1991; Heuser 1997). Many educators recognize the role manipulatives play in helping children visualize abstract ideas (Cole 1995; NCTM 1989; Ross and Kurtz 1993).

Despite the weight of evidence supporting the use of manipulatives, there is no consensus on how they should be used in the classroom. Teaching techniques for using manipulatives vary according to the source of direction. In the teacher-directed classroom, objects can be used purely for demonstration; the students can see the objects but can't touch or move them. Coalition teachers provide students access to manipulatives, but they direct what manipulatives are used, and how they are to be used. Examples of this second technique include many experiments and activities created by teachers or textbooks. A third, student-directed technique allows students to choose the kind of manipulatives and what to do with them. Students can select manipulatives and activities which meet their interests. Of course, there are numerous hybrids of these general techniques.

In which type of situation - teacher-directed, coalition, or student-directed - does using manipulatives most benefit students' development of cognitive structures? There has been little research directly comparing the degree of student control of manipulative use to cognitive growth. Gelman (1969) taught children how to conserve number using a a teacher-directed reward system. However, the process was time-consuming for teacher and students, and Crain (1992) questions the effect of such training on children's feelings, curiosity, and confidence. Cohen (1984) found that when children are encouraged to follow their own interests while manipulating objects, they learn more than when the teacher directs each movement.

Motivation theorists provide some support for allowing children to direct their own use of manipulatives. Providing children with opportunities to make their own choices may lead to increased learning, for three reasons. First, motivation to learn is increased when students are working on tasks which match their interests (McCombs, nd. 1998). Second, Phillips, Phillips, Melton, and Moore (1994) concluded that children generally choose activities which are developmentally appropriate to their abilities. Third, choice helps learners take more responsibility for their own learning and motivation (McCombs, nd. 1998).

Some educators are calling for science and math teaching techniques which incorporate more student-directed manipulative use. Such techniques would be rich in manipulatives appropriate to students' developmental needs (NCTM 1989; Cole 1995). Teachers would provide "...tasks that are likely to engage their students' interests." (NCTM 1991, p.27) through students being "... allowed to select from and engage in a wide assortment of activities with objects..." (Phillips 1992, p. A 10).

This manipulative-rich, choice-based environment would be framed around "...a curriculum of activity in which students are *doing* mathematics: estimating, measuring, manipulating objects, drawing pictures, making graphs and diagrams, collecting data, compiling lists and tables..." (Zemelman, Daniels and Hyde 1993, p. 77, italics mine). Similarly, the American Association for the Advancement of Science panels on scientific education (Rutherford and Ahlgren 1990) call for students to have "...many and varied opportunities for collecting, sorting, and cataloging: observing, note-taking, and sketching..." (p.188)

Individual studies have linked manipulative-based, student choice programs to increased understanding of ordering (Cohen 1984), place value (Phillips 1989), and collections (Heuser 1997).

Methodology

There seems to be some evidence, then, that students in a student-directed classroom would develop logical structures earlier and more completely than those exposed to teacher-directed practices. This study looks at the development of first and second grade children's understanding of four such structures - collections, class inclusion, ordinal relations, and conservation of number.

Sixty first and second grade students participated in this study. All were in the four classrooms of Teachers A,B,C, and D. Two classrooms (one first grade and one second grade) were designated as the experimental groups. The other two acted as the control group. A random sample of students in the control classrooms, and all of the students in the experimental classrooms was selected for this study. Random sampling of the control classrooms was needed due to a limited amount of time in which to perform the pretest and post test interviews.

The two control class teachers (Teachers A and D) followed the district mandated curriculum and taught science and mathematical concepts such as measurement and plants. Students were allowed to manipulate objects both in science and math class, but they responded primarily to teacher instructions for the whole class. For example, Teacher A directed her students to measure their partners' fingers using a tape measure. There was little student choice of either the type of objects to be used, or the kind of manipulation. All children were taught the same topic at the same time.

The two experimental classes (taught by teachers B and C) also taught the district mandated math and science curriculums. In addition, however, their students were allowed at least 20 minutes a day, two times per week, to choose their own sets of objects for exploration. The choice of what objects, and in what ways to manipulate those objects, was often directed by each individual student. The goals of the experimental group teachers was to have children learn collections, class inclusion, ordering, and conservation of number. Each of these structures are described in Reflection I.

This activity is called *object exploration.* It was outlined by Phillips (1996), who noted that in order to adapt Piaget's work into the classroom, teaching techniques must allow individual children to construct knowledge from hands-on experiences. For this study, each student in the experimental groups chose, from a wide selection of objects, a set which interested them. Students then were encouraged to follow their own interests, ideas and questions while exploring their objects. Children's actions reflected the wide range of interests and developmental levels. As one child was building with blocks, another developed a classification system for plastic dinosaurs. Two other students were counting their objects, but one was counting thirty bones while the other was counting thousands of base ten blocks. While each child was working, the teachers interacted with individual children, asking questions, guiding, making suggestions, and assessing progress, all in response to the actions which students were performing with their objects. Scientific and mathematical terminology was occasionally introduced by the teacher, in response to children's actions on their objects.

To determine each child's understanding of the four structures, one-on-one performance interviews (based on Phillips 1996) were administered to the children, both as a pretest at the beginning of the school year, and as a post-test at the end of the year. Due to student absences, several students did not take every test. Twelve graduate administered the interviews. Each graduate student was trained in using one of the interview protocols and in assigning children points for their answers. The points were based on a rubric that ranged from no understanding to complete understanding. Children rotated to different interviewers until they completed all four.

Results

While reviewing the pretest interview reporting sheets, the researchers noticed that the two graduate students administering the class inclusion interview used different scoring criteria. Additionally, there was not enough raw information recorded to rescore many of these interviews. Consequently, the class inclusion data was disqualified, and the interview was not given during the post tests.

The remaining pretest interview scores were compiled (Figures 6 - 8). Chi-square tests were applied to the data to determine if there were significant differences between the experimental and control groups on any of the other three structures.

Figure 6
Collections: Analysis of Pretest Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	19	10.5	21.0	68.4
Control	12	8.3	41.7	50.0
2nd Grade Total	31	9.7	29.0	61.3
1st Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	14	28.6	28.6	42.9
Control	9	0.0	44.4	55.6
1st Grade Total	23	17.4	34.8	47.8

Figure 7
Ordering: Analysis of Pretest Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	20	10.0	30.0	60.0
Control	11	0.0	36.4	63.6
2nd Grade Total	31	6.5	32.2	61.3
1st Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	13	30.8	38.5	30.8
Control	10	30.0	30.0	40.0
1st Grade Total	23	30.4	34.8	34.8

Figure 8
Conservation of Number: Analysis of Pretest Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2	% scoring 3
Experimental	20	5.0	35.0	25.0	35.0
Control	12	0.0	66.7	8.3	25.0
2nd Grade Total	32	3.1	46.9	18.7	31.3
1st Grade	n	% scoring 0	% scoring 1	% scoring 2	% scoring 3
Experimental	17	35.3	35.3	11.8	17.6
Control	9	22.2	33.3	22.2	22.8
1st Grade Total	26	30.8	34.6	15.4	19.2

There were no significant differences at the p-value = .05 level, and thus it was concluded that each group started off with a similar understanding of the structures.

The same statistical tests were applied to the post-test data (Figures 9 - 11). Again, there were no significant differences at the the p-value = .05 level for any of the three structures. It was concluded, as measured by the one-on-one interviews with the given scoring rubrics, that neither group gained more understand than the other in any of the structures.

Figure 9
Collections: Analysis of Post test Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	19	0.0	5.0	95.0
Control	12	0.0	0.0	100.0
1st Grade Total	31	0.0	3.1	96.9
1st Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	14	7.1	7.1	85.7
Control	9	0.0	22.2	77.8
2nd Grade Total	23	4.3	3.1	82.6

Figure 10
Ordering: Analysis of Post test Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	19	0.0	5.0	95.0
Control	12	0.0	0.0	100.0
1st Grade Total	31	0.0	3.2	96.8
1st Grade	n	% scoring 0	% scoring 1	% scoring 2
Experimental	13	30.8	7.7	61.5
Control	10	10.0	0.0	90.0
2nd Grade Total	23	21.7	4.3	73.9

Figure 11
Conservation of Number: Analysis of Post test Performance
between Experimental and Control Groups

2nd Grade	n	% scoring 0	% scoring 1	% scoring 2	% scoring 3
Experimental	20	0.0	35.0	15.0	50.0
Control	12	8.3	41.7	0.0	50.0
2nd Grade Total	32	3.1	37.5	9.4	50.0
1st Grade	n	% scoring 0	% scoring 1	% scoring 2	% scoring 3
Experimental	17	5.9	58.8	11.8	23.5
Control	9	0.0	33.3	22.2	44.4
1st Grade Total	26	3.8	50.0	15.4	30.8

Conclusions

Both general conclusions, and conclusions based on each specific structure can be drawn from this data. The experimental group teachers also drew conclusions based on the data and their experiences with object exploration.

General Conclusions

Why didn't the data support either the experimental or the control treatments? Two sets of conclusions can be drawn. The first addresses the limitations of the study methodology. First, a relatively small population requires dramatic differences between the groups in order to indicate significance. More subjects in both the experimental and control groups may be necessary to show significant differences in any future study. Second, more than 95% of the second grade students and 80% of the first graders in each group scored the maximum on the collections and ordering interviews. This is problematic because growth beyond the maximum of those particular interviews can not be measured. For example, suppose that throughout the year one group developed the ability to sort objects three ways using sophisticated criteria, while the other group was only able to sort objects two ways using simple criteria. If a perfect score on the interview required only sorting objects two ways using simple criteria, then each group would score similarly, even though one group had learned more. Future studies would have to use more difficult interviews to show true growth.

Aside from methodology limitations, we can speculate as to why object exploration appeared to be no more effective than teacher-directed techniques for developing logical structures. First, this study took place in a relatively affluent community, where children probably had more opportunities to work with toys and other objects at home than would a children from a community which is socioeconomically lower. An analysis of low socioeconomic students within this study may be enlightening.

Another reason may be that more social transmission is needed to develop these structures. Assuming two twenty minute weekly sessions, each teacher could practically meet with no more than 14 students per week. Cohen (1984) concluded that merely giving children access to objects is insufficient to develop structures. Rather, interaction with the teacher is essential. This seems to indicate the need for larger amounts of time for children to explore objects, and a smaller student to teacher ratio during these times. However, given that development of logical thought competes with other important intellectual and social development during the school day, greater time or more teachers may be impractical. One solution that hasn't been sufficiently studied is allowing students to provide the social interaction with each other. Despite a child's innate egocentrism, both Piaget (in Crain, 1982) and Phillips (1991) acknowledge that peer interaction can stimulate and challenge thinking, and is appropriate for some parts of logical thought development.

Structure Specific Conclusions

Collections

The data indicates that most students reach a minimal level of collections ability by the end of first grade, and almost all reach that point by the end of second grade. However, only half of the first grade students could sort at the beginning of the year, and therefore any concept requiring collections to understand is inappropriate for a significant portion of first grade students.

Ordering

A similar situation appears here. Almost all of the first and second grade students understood order at a minimal level on the post-tests. Less than half of the first grade students began the year with that understanding, however, and this should dissuade teachers from expecting first grade students to learn concepts which require students to order.

Conservation of Number

Data on conservation of number showed steady but unspectacular increase between pre and post tests, indicating that relatively little growth occurred for either grade level in either group. At the end of the school year, only half of the second grade students and less than a third of the first graders demonstrated a complete understanding of conservation of number. This may indicate that brain maturation beyond that of many nine year olds needs to take place before a student can conserve number. So, just because a child can count, doesn't mean that same child understands the permanent nature of number.

Teacher Conclusions

Despite the lack of statistically significant quantitative evidence, both experimental teachers enthusiastically supported this student-directed teaching technique. The format allowed them to introduce more advanced topics to children ready for greater challenge, and at the same time foster growth in less developmentally ready students. Object exploration seemed to promote excitement and positive attitudes toward learning among their students, which fit the teachers student-directed philosophies. Both of the experimental teachers felt that further study and development of object exploration was needed.

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GERMAN UNIVERSITY STUDENTS' THOUGHTS ABOUT THEIR SCIENCE TEACHER EDUCATION

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Much can be learned about a country's system of science teacher education by talking with persons preparing to become science teachers. To learn about the German system of science teacher education, we decided to talk with university students studying to become science teachers. Because our interest is in chemistry teaching we chose to interview participants in a seminar we were leading for prospective chemistry teachers at the Institute fur die Pädagogik der Naturwissenschaften (IPN) in Kiel Germany in Spring 1997. Our discussions with these university students both during and outside of the seminar provided us with considerable insights into gymnasium science teacher education. This paper first describes the German education system then goes on to discuss the German system of *Gymnasium* teacher education and the chemistry students' perceptions of this system as operationalized at one university. The description of the German education system is included to provide context for the discussion of teacher education. At different points in the paper some general comparisons are between secondary science teacher education in Germany and the USA.

The German Education System

Teacher education in Germany is closely aligned with the organizational structure of German schools. In most German schools, lessons are 45 minutes long and are taught only in the morning and early afternoon (Ries & Böhme, 1996). Pupils are typically given quite a lot of homework. From the second grade on marks that range from 1 (very good) to 6 (very bad) are given for each subject. If a pupil receives too many bad marks at the end of the term (typically three or more 5s), he or she is must repeat the grade. For this reason, pupils in the same class are not always the same age.

Kindergarten attendance for children ages 3 to 6 is voluntary. The kindergarten serves a child care and socialization function (Eurydice, 1991). At the age of 6, pupils enter *Grundschule* or primary school. After four years of school attendance, parents in consultation with teachers decide what type of secondary school their child will attend. The child's achievement and motivation toward school work are weighted heavily in the decision. About one-third of German children attend each of the three types of secondary schools: *Hauptschule, Realschule and Gymnasium* (Ries & Böhme, 1996).

Students interested in working as skilled laborers or in crafts such as carpentry or auto mechanics go on to a Hauptschule. They complete their studies at the end of grade 9 and then go on to serve a three or four year apprenticeship. Often the apprenticeship involves working four days a week and attending classes at a *Berufsschule* (vocational school) one day a week. Students wishing to pursue a careers such as nursing or work as a bank clerk or secretary will attend a Realschule after primary school. Schooling for these students continues through grade 10, with students then opting to enter either an apprenticeship program or a vocational college for further technical education.

Students who wish to become teachers must go to a Gymnasium through grade 13. The Gymnasium curriculum includes German language, mathematics, biology, chemistry, physics, geography, music, art, sport, and two foreign languages. During the last three years at the Gymnasium, students may choose to pursue an in-depth introduction to academic study in one of three areas: language and literature; social sciences; or mathematics, science and technology. With their graduation certificate, the *Abitur*, these students may go on to university or college. In recent years, a new school type has been opened in some regions of Germany. The *Gesamtschule* (comprehensive school) offers the same school subjects available to students who attend a Hauptschule, Realschule or Gymnasium in grades 5 through 9 (Archer & Peck, 1994).

Teacher Education

Routes into the teaching profession vary depending on the type of school. Kindergarten staff are not considered teachers (Döbrich & Kodron, 1992). They do not complete studies in teacher education. Teacher education is consider an academic career track and is available only at universities or teacher training colleges. Grundschule and Hauptschule teachers are educated at colleges of teacher education where they study for a minimum of three years. Their studies typically involve 98 semester hours of course work in three school subject areas (70-76 semester hours), with a healthy dose of education, psychology and sociology (22-28 semester hours) (Döbrich & Kodron, 1992). These teachers also do at least one week of field-based work each semester, plus two blocks of four weeks and one of eight weeks toward the end of their studies, all supervised by university mentors. Realschule teachers also study in colleges of education. They typically engage in in-depth study of two school subjects (80 semester hours) and education, psychology and sociology courses (18 semester hours) (Döbrich & Kodron, 1992). Prospective Realschule teachers have multiple school-based experiences similar to Grundschule and Hauptschule teachers.

Gymnasium teachers are educated at universities, and take from four to seven years to complete their studies. They study two subject areas in the content departments of the university (120-130 semester hours), theory of education in the department of pedagogy (8-18 semester hours), and participate in two four-week unsupervised school experiences (Döbrich & Kodron, 1992). One of these school experiences is at a primary school and the other is at a gymnasium. After completing university studies, prospective gymnasium teachers participate in a two year period of student teaching that is administered by the Institute for Practice and Theory in School (IPTS). Upon successful completion of student teaching, the student may then seek employment as a civil servant of the state.

Peter Nentwig's (1997) description provides a personal view of the experiences of a typical prospective Gymnasium teacher in Germany:

> John Average (who is not so average anymore, because only 40% of the teachers-to-be are male) is determined to become a teacher. He is now 19 years old

and has just finished High School with the "Abitur" after altogether 13 school years. Before he can enter a professional career, however, he has to serve his civil duties, i.e. to follow the army's draft for 10 months or join one of the Care Services for 13 months. (p. 2)

John will be in his 21st year when he enters a university. For a minimum of 4 years, but 5 or even more for the average John, he studies two subject areas and a little Education, Psychology and Philosophy, and has two practical terms of 4 weeks each in schools. After generally no less than six years, now at age 27, he passes the " 1. Staatsexamen", a university degree as a prerequisite for a teaching career. (p. 2)

Being himself, John passes with average grades, which means he will have to wait 6-12 months for an opening in the second phase of the teacher training (*Referendariat*, roughly translated as induction). With a little bit of luck he then gets a place in the programme. He is assigned to a school for 9-11 hours part-time teaching in his subjects under a mentor's supervision, visiting the mentor's classes for a few more hours and spending the rest of his time in seminars of the state's teacher training institution to learn the theory and practice of teaching. His teaching load remains more or less the same throughout the two years of the Referendariat, and so does his income of approximately DM 2.000. - per month (1.500.- net). He is assessed by his tutor and inspected from time to time by his trainers. After two years this induction phase is completed, and John is challenged with another examination, this time not by the university but by the state's authorities. (p. 2)

Having passed this, John Average is a fully examined teacher, age 30 or above, eager to get himself a teaching job in a school...if only he could find an opening, which is difficult for the average John these days. Many are turned away from the profession forever. With a huge bit of luck he will be employed by the State as a "beginning teacher", usually with a limited contract at first, which will give him an income of DM 3.942.- (2.125 - net) per month. Once he is in, however, his contract is likely to turn into the safe harbour of a full life-time employment after a few years. (p. 3)

Students' Perceptions of Their Teacher Education

The envisioned task of the university phase of teacher education is the "coordinated presentation of three knowledge forms - content knowledge, pedagogical content knowledge, and knowledge about teaching, schools, and about teaching as an occupation" (Terhart, 1995, p. 295). Our interviews with students enabled us to form judgments about the envisioned task of the university phase of chemistry teacher education at one German university. What we learned is that the system has both strengths and weaknesses. As expected, the students talked more about their concerns and the problems that they associate with the university phase of Gymnasium teacher education than about the strength of their experience.

At the university, prospective Gymnasium teachers are prepared as content experts. The students take the same courses that are required of chemistry diploma students, including inorganic and organic chemistry, and physical chemistry. This rigorous program of study ensures that Gymnasium teachers are well-prepared in the content that they will teach. Unlike programs of study at universities in the USA, students do not take courses to fulfill liberal arts requirements. Education in the liberal arts is completed as part of the students' gymnasium studies, prior to university admission. Students described the teaching in chemistry as mainly lecture and the laboratory experiences and as very regimented and prescriptive. Students were also critical of the advisement they received from chemistry professors. Several students told us that their chemistry professors are not interested in work with students preparing to become teachers and are unfamiliar with the university requirements for chemistry teacher education.

Prospective teachers take two courses in *Chemie Fackdidactik* as part of their university studies in chemistry. These courses are intended to teach students how to utilize their knowledge of chemistry in teaching. The students were very critical of these courses because, as they said, the courses are taught by a chemistry professor with little knowledge of schools and of appropriate chemistry learning experiences for adolescents.

Students interested in chemistry education participate in seminars in the Institute fur die Pädagogik der Naturwissenschaften, a science education research institute affiliated with the university. Students do not learn about the IPN from chemistry professors but from other students. While seminar attendance is voluntary, many prospective chemistry teachers participate in more than one seminar during their time at the university. Students find the seminars valuable in helping them prepare for teaching school chemistry. The topics and issues discussed in these voluntary seminars are topics typically addressed in science methods courses in the USA.

Two school-based experiences are part of the university education of prospective chemistry teachers. For most, the school-based experience is their first return to school since their days as pupils. Each experience lasts for four weeks, and must be done when university classes are not in session. One is in a Gymnasium and the second is in a primary school. The primary school experience is intended to help the prospective teachers learn about children and their educational experiences prior to entering the Gymnasium. In contrast to school-based experiences in teacher education programs in the USA, the students must find appropriate school placements without assistance from the university and there are no guidelines regarding the nature of the experience. Some students described the school experiences as enriching and very meaningful, while other reported that they were asked to do menial tasks that their host teacher did not want to do.

Assessment of student learning is more individualized at German universities than at universities in the USA. Examinations are given at the end of a student's university experience, and the exams tend to be oral rather than written. Prospective Gymnasium teachers are examined in their content areas and in pedagogy. The focus in pedagogy is on theoretical understandings, with little, if any, attention given to the application of pedagogical theory to chemistry teaching and learning. Students may study for six months or more in preparation for examinations. Examination times are scheduled with the professor and a representative of the Ministry of Education is present at the examination. The Ministry representative may or may not ask questions during the examination.

In summary, prospective gymnasium teachers were interviewed to determine their perceptions of their university teacher education experience. Our discussions with students suggest they are well prepared in chemistry content, but lack understandings and skills in areas they consider critical to successful Gymnasium teaching. The students characterized their university studies as theoretical and are hopeful that their two-year student teaching experience provides the practical knowledge that they feel they need. Most expressed a desire for a more integrated university experience that helps them link theoretical studies understandings with school-based practice.

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SCIENCE INTERNS' BELIEFS ABOUT THE NATURE OF SCIENCE AND TEACHING

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This study involves researching the emerging philosophy of science and teaching for eight preservice science teacher interns. The interns participated in a year long internship experience. The internship takes place during the final year of a five-year program. Each intern completed an undergraduate degree program in one of the sciences, and they completed an eighteen-hour block of education classes. In their undergraduate work they have spent hours in the classroom as a participant observer. During the internship year they worked with several different experienced teachers and with different age level students in various local schools. Each intern spent time in a middle level, junior high, and high school classroom. They also continued with course work during this period. The changes in their philosophy of science and teaching were tracked through an interview and subsequent opportunities at the middle and at the end of their teaching experience to edit the transcript of their interview.

The view of the teacher toward the nature of science is a major factor in determining the way that science teachers present material to students. This study was concerned with not only the way the interns' views evolved, but also with the way these philosophies affected their teaching. According to the National Science Education Standards, "The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned. All teachers of science have implicit and explicit beliefs about science, learning, and teaching" (National Research Council, 1996, p. 28). Brickhouse (1990) found in her study that "the teachers' understanding of what science is and how students learn science in schools formed a consistent system of beliefs for guiding classroom instruction" (p.60). This is important because, according to Brickhouse, "teacher education will make little impact on practice, if beginning teachers are unable to implement instruction consistent with their beliefs about science" (1990, p. 60).

Methodology

All of the MAT science interns during the 1997-98 school year were included in this study. There were three females and five males. Participation in this research was voluntary. The participants signed an informed consent form, and were able to drop out of the study at anytime. There were no incentives given to any of the participants.

The study of the interns' philosophy of teaching and science was conducted by the use of a standardized open-ended interview format. In this type of interview "the exact wording and sequence of questions is determined in advance" and "questions are asked in a completely open-ended format" (Patton, 1990, p. 289). The advantage to this type of interview is that each time the interviews are conducted the questions asked are exactly the same for each person and are written out in advance. Careful consideration was used in the preparation of the interview questions. Using a standardized open-ended interview format reduces interviewer effect, makes the interview systematic, and reduces the necessity for interviewer judgement during the interview. According to Patton, "The standardized open-ended interview also makes data analysis easier because it is possible to locate each respondent's answer to the same question rather quickly and to organize questions and answers that are similar" (1990, p. 285). Questions were aimed toward understanding the interns' philosophy of teaching, application of their philosophy of teaching to the classroom, philosophy of science, and how their philosophy of science translated into classroom practices. The interns were interviewed during the summer prior to the beginning of the school year, and the beginning of their field experience. All of the interviews were audio taped and then transcribed.

Questions used for the interview were adapted from the Salish I Research Project Teachers' Pedagogical Philosophy Interview First Year Teachers (Salish, 1997). The Salish I Research Project was sponsored by the U.S. Department of Education and the Office of Educational Research and Improvement. This project brought together nine institutions which prepare science and mathematics teachers to study influences on new teachers and their students. Salish II was a continuation of the work started in Salish I. In the Salish II project researchers from twelve universities used the findings of Salish I as background and defining materials for their research. This study is part of the Salish II research project.

The typed transcripts were returned to the interns in January. They were asked to review their responses and encouraged to revise their original responses to the interview questions by editing the transcripts. Changes to their original answers were to reflect changes in their views since the original interview. These revisions were then incorporated into the original transcript. The revised transcripts were returned to the interns at the completion of the school year in May. Again they were asked to edit the transcripts to reflect changes they had in their beliefs about teaching and science.

The analysis of data took place in several stages. First the data was open coded, allowing for the "naming and categorizing of phenomena through a close examination of the data" (Strauss and Corbin, 1990, p. 62). Axial coding, where connections are made after the open coding, and selective coding, where data is systematically related to other categories and those relationships are validated, was done with the aid of the NUD*IST software package. This software allows for all of the documents, transcripts and observation records to be searched simultaneously, reducing the possibility of missing a connection between the various responses from the interns.

Results

The students had widely varying views in their philosophies of teaching and incompletely developed concepts of a philosophy of science. The revisions of their original interviews were on the whole minor, with little change made by the midpoint of the year. The final revisions of the interviews by the interns, reflecting their end of year views added little to the overall view of their philosophies. Of the five interns who returned final revisions, only two made changes to their views, the others were minor grammar corrections.

For the eight interns, their idea of what science is and how they want the students to view science were fairly similar. They perceived science as a way of viewing the world around them. They looked at science as a scheme by which we make sense our surroundings. Of great importance to most of the interns was that students share their enthusiasm in the study of science. It is a love that they wish to pass on to their charges. About half of the interns were also concerned with the procedures of science. Science consists of studying the world using the systematic approach of the scientific method. Most did not view science as static, but looked at it as a process that could and did change over the course of time. A few of the interns' responses to the question of "what is science?" are:

> Intern #5
> Science is a way of thinking. I've been practicing this. But, science is a way of thinking, it's asking the how and the why. And when we think about science we are always asking questions and so the whole purpose of science is just to answer these questions. It's a way about finding the answers and we make hypotheses about something that we think is going to happen and so then we test what we think and then we have all this data that we gathered and then we draw conclusions based upon this data that we collected.

Intern #4
Refers to a body of knowledge as well as how that knowledge is gained. Science is science. It's a body of knowledge that has been discovered. Well, it's like always been there. The laws, of course what are the laws of physics? Like the laws of physics, they have always been there, but it has taken time and people to discover them. It's knowledge that is discovered as the result of studying problems. What is science? I don't know.

Intern #8
Oh boy. Science it's everything. Pretty much. It's a way of viewing the world. It is, although it is a subject area in school, and in school you might just study one part of science, or one area that is pretty specific, science encompasses everything. It, I guess, instead of saying it's a way of looking, well it is a way of looking, or perceiving, and, um, not analyzing, but synthesizing the situation and the things around you. Uh, it's like, I'm not sure because I am not a history major, but history is studying the past and possibly things that might happen in the future, where science is, you know, science is another way you can look at history and the things that happened in history and the way things happened in history. I mean you could apply it to anything, so it would be science encompasses everything and it is a way of interpreting and synthesizing and applying what you know.

Some responses from the interns to the question of how they want students to view science are:

Intern #4
Um, I think I would want them to view science as something interesting, something relevant, something possible that they can do. Um, I guess that's all for now.

Intern #5
Okay, not everyone is a scientist, so I would not try to make anyone love science. But I think that I would want them to have an understanding of what science is and the role it plays in everyday life and how the importance of it.

Intern #7
I would hope my students aren't so afraid of science, afraid of all the knowledge that can be gained, all of the information that's out there. Science every day is expanding. Hope's they find it inquisitive, hope that they are interested in finding out more. Science is so broad that you can teach one thing and hopefully it will spark their interest. And they can move on in their own interest and do their own research and maybe make a life out of some research area that they are interested in.

The concepts of facts, laws and theories were not well defined in the minds of the majority of the interns. Some of the ideas they voiced were that facts are measurable, unchanging, and truths. Facts deal with minute details, do not change over time, are hypotheses that have been proven, are testable, and are reliable. Laws are formed from facts, facts support laws, laws are not going to change, they explain relationships, and they are testable and verifiable. The hardest of these concepts for the interns to define was theory. Most interns expressed discomfort with their own definition of theory. Some used the idea that theories cannot be proven true, only false. Theories were viewed as changeable, as ideas, and as formed from laws. One intern stated that theories are beliefs. The inadequacy of the interns' interpretations can be seen in that some interns would start with a coherent answer when asked what facts, laws, and theories are in science, but this would quickly give way to confusion. Other seem to have heard definitions of facts, laws, and theories, but have not kept the concepts separated. Some examples of the interns' responses are:

Intern #3:
Theories is it's, um, if I can remember correctly, it's something that the scientist believes it needs a lot of evidence towards its correctness, but it can never be proved true, but it can be proved false. A fact is something that is accepted as, um, something that is accepted as correct, not false, not untrue, a fact is something that is can be proved through I guess statistics or something to that effect. Maybe. And a law is something like the law of thermodynamics, it is proved to be true in almost all cases and maybe it cannot be proved to be false, I am not real sure on that, It's also a guiding point for other aspects of science that are discussed that is not very clear.

Intern #2:
Facts are things that you find that are, um, true to the sense they can be proved by some sensory reading or UV. That would be a fact about a specific thing. A theory, I, ah, think this is again all based on the human sense and theory is again based on just what happens to matter and, uh, what happens to things in our realm of sensing, it can never be proved it can only be disproved. And that is something we discussed in class, um. Beyond a theory and that leading to a law is a mathematic, it seems that mathematically proved to occur in all circumstances, that is has occurred so far. I hope that, I think I've described about as well as I can.

Intern #6
I, er, ah, hmm. Theories depend on laws. Laws depend on facts. It's kind of a pancaked effect. Facts are ideas that, and theories, facts, theories a different word than what I wanna to use. Theories and hypothesis are ideas and, I think, facts are the hypotheses that have been proven. Uh, enough facts are gathered to come up with a law. The law, it can

explain a theory. A theory is always testable. It can be adapted or changed to explain it. I think of gas laws, coming to mind, you can prove them, the facts - certain characteristics prove the law. There's the gas theories, they're all intertwined, enough facts give you a law and the laws develop into a theory.

The interns seemed to agree on the idea that teaching should be based on respect for the students. This was manifested in answers that included: let the students know you care; show the students respect and honesty; offer education to all students; work with students from all backgrounds, learning styles, and beliefs; be honest with the students; and as a teacher you need to be flexible and accommodating. Some answers given by the interns are:

Intern #1
I think that the number one, the number one principle would be respect, because if you don't respect your students you are not going to get them to respect you. And I think you need to be honest. In subject matter, if you don't know something than I think you need to be honest and tell your students that you don't know that and be willing enough to investigate and find the answer for them, so I guess I would just say respect and honesty, I guess those are more morals than principles. That is my short concise answer.

Intern #3
I believe that teaching should be first based on educating the students despite who they are or where they are from. It's important to deal with each student differently because each and every student will have different learning styles, different beliefs, different systems. But teaching for first I mean mostly all important is to educate the children to help them to build a foundation for their lives. Same as above and to implement meaningful material that they will be able to apply to everyday life.

What should be taught in the schools, for most of the students would be government regulated through state frameworks. A few of the interns also felt that the textbooks should drive the curriculum to varying degrees. One intern felt that the teacher's background and knowledge area played an important role in what was taught.

Intern #2
You know, I don't think that that's my decision at all. I would hope that I would have a set of guidelines and wait. Um, I guess I would try to pick things most relevant to the regional and science issues at hand. Things that are popular right now, the rainforest is something I would leave out basically because it is so removed from what we are doing we could do so much more with our, our environmental issues at hand here in Arkansas.

> So I guess I would try to make it more reflective of the community and society where I am teaching is.
>
> Intern #6
> First off, what to teach and what not to teach wouldn't be a choice that I would probably have as a beginning teacher. I think the curriculum would be set forth for me. However, I think good common sense can go into saying what to teach and what not to teach. For example, the cloning project. I'm sure as a chemistry teacher I could show how different cells and different chemicals are reacting, however, getting into the rights and wrongs of it, that's not my department. That's the children's department. I don't think I should be able to decide what's right and what's wrong. I think that we should have all open viewpoints, but not make a clear decision. That comes into a moral dilemma, and I don't see myself handling the moral dilemmas right off the bat. Now if (a moral dilemma) should arise, like I said, I hope we could have viewpoints and let the children decide what they think is right and wrong. I don't want to say that my way is right and leave it at that or my way is wrong, and leave it at that. I think that we should - we're all open - we're all learning. That's kind of a scholar-practitioner, you learn as you go. But, as deciding as what to teach and what not to teach, I think just common sense would handle that situation.

A variety of ideas were expressed as to how students learn best. Most of the interns favored hands-on activities and manipulatives. Discussions were also popular with the interns, both as a teaching method and as a way of gauging student learning. One intern felt that worksheets were important for making the knowledge concrete to the students.

Several interns mentioned reflective writing as important for themselves and the students. For almost all of the interns, classrooms should be interesting inviting places with posters, plants, animals, and resources available. The interns felt that a stimulating environment, with place for the students to explore would be most appropriate to learning science.

Conclusions

Many opinions of the interns were very progressive and resembled several aspects of the National Science Education Standards. One very positive aspect of the interns' perspectives about teaching was their respect for the students. The idea of respecting the students is directly reflected in the National Science Education Standards, "Display and demand respect for the diverse ideas, skills, and experiences of all students" (National Research Council, 1996, p. 46). The view of the majority of the interns toward what should be taught in the classroom was based on the state mandated science frameworks. In the National Science Education Standards they also suggest frameworks, but stress the necessity to remain flexible to the changing needs of students to reflect topics from inquiries and experiences. It continues by stating that science content should "meet the interests, knowledge, understanding, abilities, and experiences of students" (National Research Council, 1996, p. 30). The use of discussion in the classroom is listed as one of the areas that requires emphasis in the classroom in the National Science Education Standards. This directly parallels the interns' view of discussions in the classroom. Finally, the interns viewed the classroom as a place that should provide a stimulating environment to be explored by the students. The National Science Education Standards suggest that this be taken one step further and that the students take a role in designing the learning environment, that the setting is supportive of scientific inquiry, that resources are available, and that the environment is safe.

The major concern raised by this investigation is that the interns do not have a well-developed concept of their own philosophies of science. Although they are developing sound teaching philosophies, if they do not fully understand the subject matter they are teaching, will the students be able to develop their own scientific philosophies and a greater understanding of the subject? In the National Science Education Standards it states, "Teachers can be effective guides for students learning science only if they have the opportunity to examine their own beliefs, as well as to develop an understanding of the tenets on which the Standards are based" (National Research Council, 1996, p. 28).

The methods used in this study should be revised for future investigations. When the interns were given back their original transcribed interviews, most did not see a need to change what they had written. In a study that is being conducted with this year's interns, the interns are being interviewed three times. This method is revealing greater changes in the responses of the interns.

Brickhouse suggested that further research be conducted "on teachers' development of pedagogical content knowledge in science in the context of teacher education, as teachers progress through courses in science and pedagogy and their clinical experience" (1990, p. 61). Helping preservice science teachers form an understanding of science and their own philosophies of science may be the key to the improvement of science education.

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THE RATIONALE PAPER: STRUCTURED REFLECTION FOR TEACHERS

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By definition, the very best teachers have significant impact on the learning of their students. Typically, these exceptional teachers have reasons for what they are doing; they have rationales. While these teachers have valid reasons for their actions, rarely do they have rationales that systematically build on their knowledge of research related to teaching, learning, and the discipline they are teaching. This paper describes the characteristics and value of a research-supported rationale for teaching, mechanisms for teaching others how to develop and maintain a personal teaching rationale, and how to use your own rationale to improve your teaching and the teaching of others.

The Ideal Teacher

Most of us have visions of the ideal teacher. In our imagination this exceptional person teaches masterfully, with every aspect of the classroom and students organized and considered in the learning process. Little is left to chance and, even though we may not see all of the instructional strategy, we do see the pieces coming together as seamlessly as a great concerto, with desired student learning as a final crescendo. Further, we might well describe this ideal teacher as one who not only teaches effectively but who understands well the role of the teacher and how this teaching and role today relate to yesterday and tomorrow. Our ideal teacher understands and probably uses the history and research behind the teaching we see. And, while we are dreaming, we might go so far as to ascribe to our exemplary teacher the desire and ability to explain her or his ideas while teaching others how to be just as skilled, rational, and knowledgeable.

If we are imagining the exceptional, why not go a step further and imagine how we might systematically help all teachers to be as described above? What would help all teachers attain the powerful heights of those teachers we know as the most outstanding? This paper focuses on one process that has shown itself to be a significant part of the arsenal of truly exceptional teachers -- developing and using a strong and personal research-supported rationale for teaching.

What Is A Rationale?

After teaching for two years, I was assigned a student teacher. I recall that at the beginning of the experience she asked me, "What is your philosophy of education?" Not ever having thought about it for more than a moment, I still easily recited some platitudes about motivation, encouragement, and being professional. It must have done the trick as she asked me no more on that subject and moved on to doing what student teachers often do, imitating their cooperating teacher. Then, while working with Professor Dorothy Schlitt at Florida State University a few years later, I was again confronted with my own understanding of what should be happening in classrooms. This time, however, I came to see the potent value and efficiency of developing a personal rationale to guide my teaching, to promote my understanding of the dynamics of the teaching and learning process, and for explaining my thoughts and actions to others.

Dorothy, easily the most masterful teacher educator I have ever known, had an equally powerful teacher education program. Following a quarter of observation in the local secondary schools, Dorothy had managed to create a science methods course that met full-time for the entire next quarter. During this quarter, students took no other courses! Then, they usually student taught the next quarter. With so much time, Dorothy (an early Piagetian and constructivist) was keen not only to have her students teach in a skilled manner, she wanted them to provide explanations of their classroom actions. She wanted them to have a rationale for teaching.

To Dorothy, "rationale for teaching" meant having articulate goals for students, justification for the content chosen for teaching, a clear description of the role of the teacher and students, and an evaluation plan for all aspects of the curriculum, including the teacher, students, and overall program. During the time I worked with Dorothy, she developed the rationale into a system whereby each student wrote a "Rationale Paper" (many confused "rationale" with "rational" with some attempting to write "Rational" Papers) and then defended it with her in an individual session.

Many of my early memories of those years were of sitting in a chair behind a student who was busily defending a rationale. I took notes, listening carefully as Dorothy asked a series of questions that caused the student defendant to think, respond, reflect, and eventually come to new understandings about their papers and their personal rationales. As Dorothy probed, she was also modeling the use of questions, wait-time, and response patterns to the student at hand. I was fascinated by how Dorothy's adept use of questions both allowed the student to stray to the limits of his or her knowledge (and, sometimes, to the chagrin of the student, beyond) and yet followed a highly predictable path. Equally amazing to me was that I could actually see the student's reasoning unfold, change, and, as the limits of knowledge were reached, how the reasoning began reverting to quite primitive levels. Even so, I truly marveled at the broad knowledge of her students and how adeptly they used the research of the time. These pre-service teachers certainly knew far more of the research literature than I knew as a high school teacher. At the same time as they were learning, I was formulating my own rationale and notions of how important a rationale was for any teacher.

While at first I saw the value of a rationale paper for assessment and in getting students to describe and reflect on their practices and defend them, later I found a number of additional positive effects. During the 27 years I have featured the rationale paper in my own teacher education programs, I have found that students who completed such papers:

- Took their goals for students more seriously
- Spent more time reflecting on their teaching practices
- Remembered and used the research literature more regularly and more effectively
- During student teaching and even beyond were more likely to remember their desired goals and roles from methods classes
- Found the rationale paper to be an impressive asset during job interviews
- Had a rational basis for selecting the content to be taught in their classes and for revising existing curriculum
- Better understood the respective roles of teachers and students

- Used their rationales for defending and evaluating their actions as teachers and curriculum developers
- Were able to influence other teachers because of their rationales

Clearly, I can say without hesitation that without the rationale paper as a major learning force in my classes my students would have learned less about teaching, would have been less well prepared, and probably would not have received as many accolades, awards, and impressive positions as they have. Had Dorothy Schlitt not introduced me to this one simple concept, a rationale paper that brought together all a student knew about teaching, I would have taught reasonably well but I would have had nowhere near the success I now look back on. For me, the rationale paper has been a cornerstone for my teaching, my program development, and for my personal education. I find it truly a concept worth pursuing.

The Rationale As A Teaching And Learning Tool

When I first began as a teacher educator, I viewed development of a rationale as an end point in my programmatic efforts. Initially I assigned the paper, collected and read it, and conducted a defense, not unlike what Dorothy Schlitt had done so effectively. In the more than many years since sitting at Dorothy's feet (so to speak), I have continually modified my vision of what I wanted to see in a rationale paper, developed new ways to get students to develop one most effectively, and learned to conduct the defense so that maximal learning took place. Today, I see the development, production, defense, and use of a research-supported rationale paper as the center piece of any exemplary and effective teacher education program. The balance of this paper will focus on a number of proven and essential aspects for using the rationale process as a core of a teacher education course or program.

Generating and Developing Goals for Students

"If you don't know where you are going, then you will probably get there" describes well the need for goals. In this case, it is goals for students, not teachers, that we speak of. Asking teachers to describe how or what they will teach prior to asking about their goals is as meaningless an exercise as asking a traveler what route will be followed prior to determining the destination.

We teach for specific, not random, outcomes. A rational teacher needs to begin with student goals. So, with this in mind, we begin with Generating Goals for students.

An effective way to begin is to assemble the teacher education class and ask, "What characteristics, attitudes, knowledge, and skills do you want your students to have after 13 years (K-12) of education? Run as a typical brainstorming session, where we write down verbatim what students offer and with no evaluation, this question usually generates 25 to 40 statements such as:

Students Will:

Solve problems

Be global citizens

Be creative

Have fun with science

Be able to communicate effectively

Work cooperatively

Identify problems

Be able to use laboratory equipment correctly

Know how to find information

Know how to learn

Understand basic concepts

Be able to use their knowledge

Be environmentally aware

Be positive and like the subject

Be able to self-assess

After having done this several hundred times with pre- and inservice teachers, scientists, and citizens (Penick and Bonnstetter, 1993) we find the list is almost always the same, regardless of the group generating it. For instance, the first suggestions are always very global (such as "be a global citizen") and often relate to attitudes. Many of the goals are expressed in a passive mode by stating "Be able to use laboratory equipment" rather than "Uses laboratory equipment." More surprising is that even groups of scientists rarely mention subject-specific knowledge as a goal. Never has anyone said "Know the first 20 elements of the periodic table" or "Recite the American Presidents in order." Sometimes, we even have to prod the participants in the brainstorming, saying something like, "Don't you want to include some content in here?" At that point, someone usually offers "Use knowledge." Some also get confused and offer teacher goals such as, "Encourage students" or "Teachers will be positive." If this happens, we just explain the difference between a student goal and a teacher goal and move on.

After generating the student goals usually we are left with a long list, half considered, highly redundant, and not clearly stated or heard. To overcome this, we now move on to Goal Development. Our purpose here is to narrow down the list of goals while, at the same time, developing consensus among the class group. Usually, we break the class up into groups of no more than six. Each group is told to "reduce the list of goals to 15 that you can all agree on." After much discussion and debate, the task is soon completed. Then, to bring the entire class together, we often repeat the instructions, reducing the target to ten goals, this time expecting the entire class to work as one group. Usually, they have little trouble with this task, often lumping several goals together, eliminating a few, and rewording most.

In additional to ending up with a fine list of ten goals for students, several delightful side-effects occur at this time as well. For instance, when assigned the consensus task every pair of eyes in the class usually looks to the instructor in unison, seeking the usual teacher refrain, "Now, class I would like you to.... When they look to us in this way, we merely walk out of the room or turn away wordlessly. Without fail, with no teacher to tell them what to do, a student will get up, take chalk in hand, and ask, "OK, where shall we start?" In this way, the students, not the instructors, are taking charge of what are supposed to be *their* goals for students. At the same time, the instructors are allowing for and seeing student leadership in action.

As the discussions ensue at each of the levels, the students are talking more than the instructor, providing another fine opportunity for students to realize that their input is valued and desired. During these conversations and debates, students have far more time than is traditional to make their points. Consistent with the research on wait-time, rather than each student making a single-sentence remark, we find that they speak in paragraphs, and on multiple occasions. They are truly communicating with each other. They also are finding out how difficult it is to conceptualize and communicate their complex ideas clearly and how frustrating it can be to teach others verbally. Finally, in the small groups in particular, students who would not routinely speak out in a large class setting often take full opportunity to present their ideas and to act as leaders.

In this process, we have helped students to construct their own goals and we as instructors have modeled the role of a constructivist teacher. Some students actually notice that this class has been very different, the instructor is different, and they are feeling pretty good about it all. But, the class is not yet over. Now that we have a list of ten or so agreed upon goals, the instructors inform the class that these ten goals will be considered to be the class goals for the semester and will also be among the goals that we, as instructors, have for our class of teacher education students. We use these goals continually, every day, primarily as a reflective device. For instance, when a student says, "In my class, we will have an activity every Monday," we can then ask, "How will that help you achieve your goals? or we might ask, "Which of your goals are you promoting with that idea?" Soon, students come to link lesson plans, classroom procedures, and teaching strategies with student goals. This is the beginning of a rationale for teaching and a mechanism for continuous teacher reflection on the teaching-learning process.

The Role of the Teacher

Having goals for students and reflecting on practice are necessary but not sufficient. For the rationale and the reflection to be more than random, for them to be focused in ways that lead to meaningful change, a teacher's rationale must also include the specifics of the role of the teacher. For instance, we know that master teachers teach quite effectively. If an ambitious and hopeful beginning teacher asks the master, "What makes you so effective?" the answer must be specific to be useful. If the teacher responds with, "Get the students involved," the beginning teacher has no more useful information than you would get if you ask a rich person how you, too, can be rich and they respond, "Make a lot of money!" or "Buy low, sell high." If we knew how to do anything with these words, we would not need the advice we were seeking. What we need instead are descriptions of skills to learn and practice, knowledge to understand, tasks to be accomplished, and roles to play.

Understanding and describing the role of the teacher requires knowing and understanding the patterns of teacher behavior desired, knowing how to describe the patterns, and understanding the effect of these patterns on students. To achieve this, teacher education students must learn to observe teaching and teachers systematically, perhaps using coding devices like the Teacher Assessment System (TAS) (Bonnstetter and Bonnstetter, 1986) or the Science Learning Inventory Categories (SLIC) (Shymansky and Penick, 1979). Many years ago, Ned Flanders noted that just learning to code a teacher's behavior actually influenced the observer's teaching behavior in a positive direction (Flanders, 1963). More importantly, as Dorothy Schlitt pointed out to me, how can two or more teachers hope to talk to each other about teaching unless they all know and understand a common language reflecting the actions and ideas of teaching? Learning to observe systematically teaches just that. We usually move our students into accepting a prepared version of a teacher coding instrument so that they do not have to create one themselves.

Unfortunately, just knowing what behaviors a teacher is exhibiting does not inform us about what is best to achieve the desired goals. For this, we must now move to a study of applicable research. Here, we often do an activity we call Roles and Goals. We begin by presenting teacher education students with research related to teaching. Often, we use a condensed form that Charles Matthews of Florida State University originally called Research Supported Statements (RSS). These short statements, taken verbatim from the literature, are representative of education research and thought. Examples of these RSS include, "When teachers wait 3 to 5 seconds after asking a question before they call on another student, rephrase the question, or answer themselves, then students tend to provide longer answers," or "Evaluation inhibits creativity." The RSS allow students to see quickly and simultaneously a number of pieces of relevant research that have applicability to teaching. Now, we are ready to begin.

First, we put students into small groups. Each group gets three of the class goals with which to work. Their task is to determine which identifiable behavior of the teacher is supported by the research as ultimately leading to the desired goal, which behaviors are contrary to the goal, and which seem to have no research pointing one way or the other. Now, each group is developing a matrix. When all the matrices of the class are brought together, a pattern begins emerging. For instance, if the goal under consideration is "Students will be creative," the research would indicate a need for avoiding evaluation and praise (Treffinger, 1978) while providing more open, accepting comments (Torrance, 1965). Creativity would not be supported by highly directive behavior (Payne, 1958) but would be enhanced by open-ended questions (Penick, 1993, 1994, Penick *et al*, 1996). Each goal eventually has a list of positive and negative behaviors such as these.

On combining the supported teacher roles from all of the student goals, a clear pattern will eventually emerge. For instance, virtually no goals will ever be supported by teachers rejecting student ideas, not providing adequate wait-time, or by using sarcasm. With these lists of positive and negative attributes, the teacher education students can now rationally (rather than arbitrarily) plan their teaching behaviors and strategies based on their goals and knowledge of the research literature. These teachers also now have a solid language and mechanism for communicating their ideas about teaching to others. They no longer have to speak just of their feelings as they design a desired classroom climate; instead, they can call on the research literature to support their ideas. As beginning teachers, having support for your ideas that may run counter to many traditional teachers can be quite useful and reassuring.

As students develop their rationales, they must continually reflect on their ideas in light of their goals and knowledge. This is what many exemplary teachers do consistently (Penick and Yager, 1983). Getting our students into such a habit will probably lead to effective and professional patterns as classroom teachers. In class and during reflective times, we move students toward considering each of their proposed actions and activities in light of their goals. If there is a match, they move ahead. If not, they must then either change what they propose or change their goals. Few choose to change the goals that by now seem rather essential to them.

But, as they say, talk is cheap. As an assignment, we tell students they must prepare a written rationale paper that includes:

- Goals for students
- A brief justification for those goals
- Specific teacher behaviors, patterns, and strategies that will lead to these goals
- How content will be chosen
- How the students, teacher, and curriculum will be assessed and evaluated.

Typically, these papers are about 5,000 words in length (a little longer than this paper) and require more work than students initially imagine. Many have told us that they spent more time on these papers that any other college paper they have turned in. When asked how that happened, they often respond with some variation of, "This paper is real; it's mine and it describes MY classroom and I want the best classroom I can have!" Most say they wished they had started sooner by keeping notes and quotes that would have been helpful. Others remember that we suggest just that at the beginning of the semester

Defending the Rationale

But, writing the paper is just part of our plan. During final exam week, we meet with each of our students individually for 90 minutes. During that meeting, we ask the student to defend the rationale paper that has occupied his or her thoughts for the semester. We typically begin the defense session by asking how the rationale would have been different if it had been written a year ago, before the present class. As the individuals talk about changes in the last semester, they almost always begin to relax, as they are the experts here, talking of their own. Then, we move into asking about specific goals and how they will achieve them. Some students have clear ideas and speak eloquently of their strategies in very specific terms. Others seem to have difficulty in expressing themselves, even though they seem to have the ideas written down. Finally, some seem to have either written the rationale paper for the instructors rather than as a personal statement. These students don't have a rationale and it shows rather quickly.

We view this rationale defense as 90 minutes of individual tutorial, an opportunity to find out where the student needs help and to offer it. For most students this works well and they leave with considerable clarification. Others just leave. We don't however, let them off lightly. During the defense we ask questions that should be answered. When they are not, we don't confront the first time. Instead, we will return and try from another perspective. If they have it, we move on. Sometimes we will find a lack and we will teach directly if it seems warranted. Other times we will ignore or merely guide them to a reasonable point. Over the years we have developed a number of strategies for making the defense effective.

Some Final Thoughts

For many years we had a sequence of courses through which our teacher education students moved as cohorts. In this sequence, students wrote a rational paper in the first and then revised is twice in the following two semesters, each time with a final defense. By the third time, each student had spent more time defending a rationale paper than our doctoral students had spent defending their dissertations. After three such experiences, students develop abilities to express and support their educational ideas, they learn something about writing, and they have a document of which they can be proud.

And proud they are as they present their rationale papers to cooperating teachers, principals when they interview, and to their parents as evidence of money well-spent. Some have used successfully their rationales as a core for grants and applications; most have found them valuable as a line of defense for their ideas. And, while we have little hard evidence to support it, we are convinced that a teacher with a rationale is less likely to lose that young idealism that most teachers begin with, often reverting to the norm within a few short years. From my perspective, these teachers with rationales are truly rational teachers. Who would want otherwise?

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EMPOWERING FAMILIES IN HANDS-ON SCIENCE PROGRAMS

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Achievement of education reform standards for science literacy will require, as the recently popularized African proverb suggests, the "whole village". In this paper we present results of the Science Parent, Activities, and Literature (Science PALs) project. Science PALs was designed to promote substantive involvement of parents (including relatives and caregivers) in their children's hands-on science education by using take-home, literature-based inquiry, problem-solving, and design activities that connect the school and the home.

Efforts to coordinate players within the "village" remain a major challenge for the science literacy movement. Of these various key players in the community partnership, the family group has been the most under-utilized in the current education reforms (AAAS, 1996). Miller (1989) states "the most effective source of attitudes toward science and mathematics is the family. The family can socialize either a very positive or a very negative attitude toward science. Parents want their children to study science and mathematics and encourage that through the selection of toys, visits to museums, subscriptions to magazines, and talk about topics and problems that involve science and mathematics" (p. 177).

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Nothing illustrates more clearly the family's validation of young children's learning than the refrigerator door. It is the refrigerator door where parents proudly display their children's work and implicitly make statements of validity, priority, and value. A quick survey of the refrigerator "bulletin board" usually finds products of language and art. Occasionally one sees evidence of some mathematics problem solving, but infrequently does one see evidence of science. The refrigerator door testimony of a low priority for science is supported by the dinner table talk about leisure time, daycare, and school. Again, science is rarely discussed.

Why this lack of focus on science at home? For the most part, it reflects the family members' own recollections of preschool, elementary, and high school. Parents, aunts, uncles, and grandparents are products of didactic science programs that stressed drill, skill, and memorization and were geared to preparing scientists and engineers, not a generally literate citizenry. A fair estimate is that few of them (20-30%) actually experienced activity-based science inquiry in their elementary and secondary schooling. Most express a lack of success in, even a fear of, science. Surveys indicate that adult science literacy is disappointingly low for an advanced technological society and for a nation in the midst of an information explosion (Associated Press, May 24, 1996). Only 25% of the adults surveyed by the National Science Foundation had satisfactory knowledge of basic science concepts. Furthermore, family members often have traditional, absolutist views of science that emphasize the quest for the "right" answer and a view of technology that emphasizes big industry, corporate solutions for most of societal problems. Few view science as a human activity of inquiry that uses evidence based on ways of knowing which alternatives must be tested and evaluated. It is, therefore, not surprising that most families do not emphasize the importance of science with their young charges.

Parents, caregivers, village members, and schools have common goals regarding children, but frequently their efforts are uncoordinated and poorly understood by other villagers. Wang, Haertel, and Walberberg's (1994) meta-analysis revealed home environment and parent support were amongst the five most important factors influencing learning. They stated "the benefits of family involvement in improving students' academic performance have been well documented, as have its effects on improved school attendance and on reducing delinquency, pregnancies and dropping out" (Wang, et al., 1994, p. 77). Well-educated, well-served members of the village are aware of how schools work and are organized. They develop effective, efficient advocacy strategies regarding their priorities, goals, and children (Kelleghan, Sloane, Alvarez, & Bloom, 1993). Under-served parents are less fortunate and believe that several barriers reduce their effectiveness and relationships with schools and are generally less active on all fronts of their children's learning (Zill & Nord, 1994). These parents lack time, money, and knowledge to become involved in their children's education (AAAS, 1996).

Academic achievement is influenced by home learning resources, out-of-school learning activities, high family expectations, and parental instruction and involvement. Barriers to effective parental involvement are time, lack of understanding of academic decision making, perceived lack of interest by teachers, feeling of disconnection, lack of training, language and lack of success. Clearly, many parents need education about science education reforms and science-related career awareness. Parents need to increase their confidence, develop techniques to increase their effectiveness and efficiency as advocates for children, increase their understanding of schooling and the new reforms, be aware of effective out-of-school inquiry and design activities and future science-related careers. Likewise, schools and teachers need to redouble their efforts to build trust, lower communication barriers, involve parents, and establish positive rapport and effective working relationships early in the schooling process and ensure these features are maintained and reinforced throughout the school process.

The Science PALs Project

The Science PALs project represents one school district's efforts to systemically reform its elementary science program. The strategies used in Science PALs are based on the earlier successes of a teacher inservice effort in which children's ideas were used as the foil and focus of professional development activities to enhance teachers' content-pedagogical knowledge (Shymansky, Woodworth, Norman, Dunkhase, Matthews, & Liu, 1993). Science PALs also utilizes hands-on activities with a focus on children's ideas but adds parents to the instructional loop and uses children's literature to simultaneously decrease teacher anxiety about science and connect the schools' hands-on activities to both the home and the language arts curriculum.

The Use of Literature in Teaching Science

The literature element of Science PALs is a central feature. Fictional pieces are used with hands-on activities to challenge, scaffold, and enhance science understanding. The literature pieces are not meant to be a substitute for science instruction but as a platform for inquiry. The rationale for using literature in science is multifaceted. In part, it provides a comfortable starting place for teachers and parents to discuss science ideas with students. Using stories with a science theme has added benefits beyond providing a comfort zone for teachers and parents. Trade books offer a wide variety of topics, alternative conceptions and viewpoints that excite and motivate students. Children are more excited about testing ideas in science if the ideas are personally relevant. When the ideas come from a story they have just read, there is an immediate personal connection. This provides a common starting point and a surrogate, prior experience, making learning more meaningful.

The idea of using stories to focus children's thinking to enhance science instruction while making it more relevant, connected, and meaningful to students is not new (Butzow & Butzow, 1989). When teachers are familiar with what their students think, or are likely to think, they are able to plan and present challenging situations that might compel students to restructure their thoughts. When parents are familiar with their children's thinking and prior knowledge, they develop increased appreciation and insights into the teaching-learning process. Furthermore, this alerts teachers and parents to divergent interpretations as they respond, accept, and challenge children's ideas.

Though the use of children's ideas to focus discourse and instruction is not unique to Science PALs, the way that students' ideas are gathered and used in instruction is. In Science PALs, teachers develop a special activity bag for each science unit. The bags serve as the connection between the home and classroom. Each bag contains a piece of science-related children's literature, interview directions, suggested inquiries, and simple equipment to explore ideas related to science topics in the science unit. The activity bags are used by parents to assess their children's prior knowledge and to provide this information to their children's teachers. Parents and children read the story together and explore various science challenges in the story as they occur, using the activity guide and equipment provided in the activity bag.

A typical activity bag for the early years is illustrated by the activity bag designed to assess children's ideas about light and shadows in which The Bear's Shadow (Asch, F., 1985, Scholastic) serves as the problem focus. The activity bag contains a copy of the story; a small flashlight, a gummy bear on a toothpick, an index card; and interview questions and inquiries for the parent co-investigator. Other activity bags have also been developed for each of the district's science units: balls and ramps – The Ball Bounced (Tafuri, N., n.d., Greenwillow); living things – My River (Halpern, S., 1992, Scholastic); pebbles, sand, and silt - Roxaboxen (McLaren, A., 1991, Scholastic); balance and motion – Sheep in a Jeep (Shaw, N., 1986, Houghton Mifflin); growing things – Miss Rumphics (Cooney, B., 1985, Puffin); and life cycles of butterflies – The Lamb and the Butterfly (Sundgaard, A., n.d., Scholastic).

Parents as Partners

A key feature of the Science PALs model is the use of parents as partners in the instructional loop. When parents are meaningfully involved in their children's education, many benefits accrue (AAAS, 1996). Most parents like to have tangible, significant ways to become involved in their child's educational experience (Daisey & Shroyer, 1995; Rutherford & Billig, 1995). Science PALs provides this opportunity. Parents and children collaboratively read the stories and do the inquiries, and the children's responses and experiences are recorded. Interview data collected by parents are then returned to the teacher and are used to confirm and assist the teacher's instructional planning. Preliminary research suggests that activity bags provide reasonably valid and reliable assessment data on children's prior knowledge (Chidsey & Henriques, 1996).

Science PALs teachers provide other meaningful opportunities for parents to be involved throughout the science unit: unit updates and activities are routinely sent home; invitations are extended to visit the classroom, to observe, help, or serve as an expert resource person; and conferences about the children's ongoing performance and formative assessments are regularly conducted. Collectively, these added opportunities allow parents to be true partners in their child's learning experiences, not merely volunteers or observers. More importantly, parents believe their involvement through the activity bags represent quality science learning and provide effective, efficient, and enjoyable time with their children (Shymansky, 1997). Parents state (Shymansky & Dunkhase, 1996):

- Doing the science bags with my child was a great learning experience for both of us.
- My child enjoyed being asked his opinions. He felt that he was in the spotlight.
- We both learned from this experience, and it helped us to interact in a positive way through exchange of information.
- This interaction helps parents extend science topics into everyday at-home situations.
- This was an excellent project, and the time for accomplishing it was just right for one sitting. I wish my parents were involved back when I was a kid. This helps parenting skills.

Response to Science PALs

So, how are students, teachers, and parents responding to Science PALs—particularly the parent empowerment and the use of children's literature in science? Survey data were collected from Grade 1-2 children, parents, and teachers at the end of 1997 school year. The surveys utilized Likert items to assess students' and parents' dispositions toward specific ideas related to children's ideas, use of literature in science instruction, parental involvement, school science, and science careers. Teacher comments were solicited by an open-response format during a workshop.

Students' perceptions of science teaching and learning focused on students' views of : (1) teachers' use of student ideas, (2) parents' interest in science, (3) teacher's use of children's literature in science, (4) attitudes towards school science, and (5) science careers. These factors emerged from a factor analysis of student questionnaire responses. Original items were scored as disagree (1), do not know (2), or agree (3), and were assigned to factors using a varimax approach with minimum loading weights of 0.30. Items not meeting this condition or items not fitting the factor were deleted. This screening process resulted in a final Grade 1-2 survey of 27 items. Table 1 provides the number of items in each factor and the internal consistency based on data collected in the spring of 1997. Generally, the instruments were shown to have acceptable validities and reliabilities.

The students' surveys were scored, summarized, and sorted on the basis of the teachers' Science PALs training in years (0, 1, or 2+ years). Differences in student Likert scores were tested using simple pair-wise comparisons. The results generally indicate that Science PALs students perceived their teachers, parents, instruction, science, and science careers more positively than non-Science PALs students, with the major differences favoring the Science PALs groups occurring between students whose teachers had no Science PALs training and those whose teachers had one year of Science PALs training. Significant differences ($p \leq 0.05$) were found on the "parental interest" dimension and between students whose teachers had no Science PALs training and those whose teachers had one year of Science PALs training and on the "attitude toward science" dimension between teachers with two years of Science PALs training.

Table 1: Descriptive Statistics for Grades 1-2 Student Survey Results from Classrooms with Teachers who have Different Years of Science PALs Experience

Perception/Attitude (number of items, internal consistency)	Years of Science PALs 0 Mean, SD (N = 68)	1 Mean, SD (N = 59)	2+ Mean, SD (N = 172)
View of Teacher (8, 0.69)	2.60, 0.34	2.82, 0.27	2.73, 0.31
Parental Interest (6, 0.69)	2.10, 0.49	2.45, 0.49	2.23, 0.52
Use of Literature in Science (3, 0.45)	2.65, 0.41	2.83, 0.36	2.72, 0.40
Attitude toward Science (6, 0.73)	2.44, 0.43	2.65, 0.37	2.52, 0.51
Careers in Science (4, 0.68)	2.21, 0.54	2.45, 0.47	2.20, 0.57

Analysis of informal parents' comments on the activity bags collected in 1995 and 1996 were used as a foundation for developing the parent survey. An 8-item Likert survey was developed and distributed as part of 400 activity bags in each of 16 elementary schools. The survey of parent participants in Science PALs revealed overwhelming support (> 70% agree to strongly agree) from the 183 respondents (45.8% response rate for 400 surveys distributed). Table 2 summarizes the respondents' beliefs about the Science PALs experience, activity bags, literature as springboards into science inquiry, parent-child involvement, parent orientation meetings, and transferability to other subject areas.

Table 2: Percentage Response for the Science PALs Parent Participation Survey

Question	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1. This experience is valuable for your child.	0	2	8	64	26
2. The science bag activities lead to more discussions of science at home.	0	7	20	59	14
3. Story reading is a good introduction to the activities.	1	2	9	55	33
4. The science activity bag is useful in helping your child learn science at school.	1	1	17	62	19
5. Parent training sessions are useful in helping you work with your child.	1	4	25	49	21
6. No additional information or explanation sessions are required.	2	8	18	57	15
7. The science activity bag helps you have a better awareness of the science your child is studying.	1	3	2	59	35
8. Home connection activities should be used in other subjects like mathematics.	1	1	11	49	38

A survey of the 16 science advocate teachers in Science PALs about the values and benefits of working with parents revealed the following ten comments about parents as resource, parent as partner, parent as teacher, and parent as advocate:

1. *The Science PALs Project has finally given our* ***greatest resource (parents)*** *some power to participate in their child's education.*
    - *Parents are* ***great teachers.***
    - ***Parents' interest motivates*** *students to learn.*
    - ***Parents help me*** *to learn about their children so that I can facilitate student learning in the best possible manner.*
    - *Parents want to* ***help their children*** *but do not always know how.*
    - *Parents* ***can help establish "where a child is at"*** *in their understanding of a topic before unit exploration begins.*
    - *Science PALs provides a great* ***springboard for getting parents involved in their child's learning, rather than merely "helping out" at school.***
2. *Working with* ***parent partners*** *has been rewarding to receive parent input* ***in preparation*** *for the actual classroom instruction.*
3. *Over the five years I have been involved in the project, I have seen a gradual change in parents' attitudes toward science and their critical role in the learning process. Parents seem to be* ***recognizing the value in "doing" science*** *rather than reading about it. They are* ***valuing their role*** *in the activity bag activities. One parent commented, "Each activity bag activity prompts a flurry of experimenting at our house! We love it."*
4. ***Involving parents has proved to be both exciting and beneficial*** *but at the same time a challenge. It is hard to convey the impact Science PALs has had on teachers and students in a short "cover-everything" parent meeting.*
5. *I learned almost all parents do like to be involved and* ***will get involved if given a good reason, specific directions, and valued task.*** *Children also benefit from parent involvement in education.*
6. *Parents have been most supportive. Although some parents feel that they do not know the science for activities,* ***they want to be involved in a substantive way important to their child's education.***

7. *Parents provided with a meaningful role in the interview process and through updates results in a sense of* ***parents as partners that is reinforced at conferences and meetings during the school year.***

8. *The importance of* ***helping parents stay informed*** *about the* ***science program*** *in elementary schools, the* ***"big" science ideas*** *we are addressing with our activities and investigations, and critical* ***role parents play in their children's success*** *is absolutely clear.* ***This needs to take place over a long period of time.***

9. *The Science PALs experience has allowed me to actively and directly work with parents on a unit of study for their child.* ***Parents responded in a <u>very</u> positive*** *manner.* ***Children have responded positively*** *when their parents are part of the education <u>team</u>.*

10. *Getting the parents more involved with our science units has been important. I feel they are* ***more informed about our "hands on" approach and eager to help their children*** *develop a stronger science background.*

<u>Discussion and Implications</u>

The Science PALs reform effort has been successful in many ways: elementary school science teachers are increasingly refocusing their hands-on teaching to incorporate and respond to students' ideas; parents are responding positively to their new roles as partners; and students are expressing positive feelings about their science instruction, their parents' involvement, their attitudes about science, and their performance in science. Science PALs teachers are now using students' ideas to plan instruction; they are more often challenging these ideas with activities and questions; they are attempting to use a greater variety of assessment techniques; they are trying to connect science to other areas of the elementary school curriculum; and they are increasingly involving parents in meaningful ways. Parents believe that Science PALs is making a difference for their children and is allowing them to be meaningfully involved in their children's quest for science literacy.

Orchestrating effective and worthwhile parental involvement in children's science education has become more difficult with both parents working, single parents working two or more jobs, lack of extended families, and school environments with constant tension among schools, governments, and taxpayers. The National Parent and Teacher Association recently released a handbook of standards for parent involvement in children's education (NSTA, 1997). They identified six essential standards for effective parental involvement:

- Regular, two-way, meaningful communications
- Promotion and support of parenting skills
- Active parental participation in students' learning
- Open, welcome acceptance of parent volunteers
- Full parent partnership in school-related discussions about their children and family
- Community outreach for resources.

Coleman (1997) suggests that parents can assume the role of cultural ambassador—sharing cultural insights, customs, and traditions, of teacher—enriching and connecting school learning and family life experiences to ensure relevance, of family service coordinator—to develop an effective interface between social agencies and families and to interface with minority, non-English speaking parents, and of advocate—to ensure schools are concerned about children and the public more clearly understands education. Santa Cruz, California, schools have developed a development matrix for teachers to judge and guide their parental involvement (Chrispeels, 1996). Table 3 illustrates a modified matrix that focuses on parental involvement in science, mathematics, and technology (SMT). Teacher and caregivers can locate their position on these nine dimensions and plan how they might improve their parental involvement, if needed.

Table 3: Analytical Scoring Rubric for Teachers' SMT Literacy Efforts (Adapted from Chrispeels, 1996)

	Category: Level of Development				
Dimension	Beginning (1)	Emerging (2)	Developing (3)	Integrating (4)	Innovating (5)
Children's cultural, physical, and cognitive attributes	May recognize diversity but does not relate to SMT curriculum and instruction	Identifies diverse cultural, physical, and cognitive backgrounds of learners but does not use these for planning and teaching SMT	Identifies diverse backgrounds and sometimes reflects these in planning and teaching SMT	Frequently addresses diversity in planning and teaching SMT	Consistently addresses diversity in planing and teaching SMT
Family and community resources	May recognize the value of family and community resources but does not use them in SMT teaching	Occasionally uses some family and community resources in SMT teaching without incorporating them in planning stages	Involves family and community resources in SMT teaching and may incorporate them in planning	Frequently involves community and family resources in SMT teaching and planning	Consistently involves community and family resources in SMT teaching and planning

Table 3 (continued)

Interdisciplinary integration and relevance	Teaches SMT without connections to other subject areas and learners' interests and experiences	Occasionally connects SMT experiences to other subject areas	Articulates some connections between SMT and other subject areas and learners' interests and experiences	Frequently connects SMT experiences with other subject areas and with learners' interests and experiences	Consistently connects SMT experiences with other subject areas and with learners' interests and experiences
Selection of learning materials	Recognizes need to select SMT materials that align with and support the children's diverse backgrounds	Occasionally selects and uses relevant SMT materials to match and support children's diversity	Selects and uses relevant SMT materials to match and support children's diverse backgrounds	Frequently selects, analyzes, and uses relevant SMT materials to match and support children's diverse backgrounds	Consistently selects, analyzes, and uses relevant SMT materials to match and support children's diverse backgrounds
Home-school communications	May communicate with parents only at regularly scheduled times	Communicates with parents at all regularly scheduled times	Communicates with parents at regularly scheduled times and may initiate additional contacts	Frequently communicates both positive and negative information to parents using a variety of approaches	Consistently communicates both positive and negative information to parents using a variety of approaches
Interpersonal and human relations	Acknowledges need for effective interpersonal and human relations skills, but does not demonstrate them	Develops some interpersonal and human relations skills	Demonstrates some effective interpersonal and human relations skills in working with students	Frequently demonstrates effective interpersonal and human relations skills in working with students, families, and colleagues	Consistently demonstrates interpersonal and human relations skills in working with students, families, and colleagues

Table 3 (continued)

Community as educational resource	Recognizes value of the community as a SMT resource, but is not certain how to use it to support SMT teaching and learning	Develops knowledge of the community to create SMT resources for teaching and learning	Uses knowledge of the community to create some SMT resources for teaching and learning	Frequently uses knowledge of the community to create a network of SMT resources for teaching and learning	Consistently uses knowledge of the community to create a network of SMT resources for teaching and learning
Parental and community involvement in school	Recognizes value of involving parents and community in SMT literacy efforts but is not certain how to do it	May involve some parents in work with SMT classroom activities	Occasionally involves parents in working with SMT classroom activities	Frequently involves parents and community members to work in SMT classroom activities and some other out-of-school SMT activities	Consistently involves parents and community members to work in SMT classroom and many other out-of-school SMT activities
Family-school rapport	Recognizes importance of establishing productive relationships with families, but has not yet done so	Establishes productive relationships with some families	Establishes productive relationships with some families and may use them to develop an understanding of the culture of a family and its expectations	Frequently establishes productive relationships with families and uses them the develop an understanding of the culture of the family and its expectations	Consistently establishes productive relationships with families and uses them to develop an understanding of the culture of the family and its expectations

The Science PALs Project successfully demonstrates that family involvement can be achieved by designing meaningful, time-efficient, and worthwhile take-home science activities. The activity bags provide a natural, safe problem context by using science-related literature to establish a challenge from which the parent can obtain worthwhile preassessment information to help the teacher, gain insights into how their children think, and demonstrate their honest interest in their children's learning. Children do not see these activities with their parents as "work", rather they truly enjoy the opportunity to demonstrate their knowledge and skills. Teachers also view this parent involvement as a chance to establish working relationships and lines of communication with parents. The educational village starts with home and school. These must be well integrated before seeking community-wide involvement.

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INCORPORATING MULTICULTURAL AND SCIENCE-TECHNOLOGY-SCIENCE ISSUES INTO SCIENCE TEACHER EDUCATION COURSES: SUCCESSES, CHALLENGES AND POSSIBILITIES

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Historical Precedents

Beginning in January 1979, colleges and universities applying for accreditation of their professional education programs by the National Council for Accreditation of Teacher Education (NCATE) were required to show evidence of planning for multicultural education in their curricula. While it may be said that multicultural education has been, in various forms, part of the American social fabric from the turn of the century, the concept of *multicultural teacher education* is relatively new (Goodwin, 1997, p. 5). In 1973, the American Association of Colleges of Teacher Education's (AACTE) first Commission on Multicultural Education issued the following policy statement:

> Multicultural education programs for teachers are more than special courses or special learning experiences grafted onto the standard program. The commitment to cultural pluralism must permeate all areas of the educational experience for prospective teachers (p. 264)

This statement sent a clear message to the AACTE membership that teachers needed *specific* preparation to teach a culturally and racially diverse student population; in the United States, this is an educational issue which continues to be hotly debated nearly three decades later (see for example Ladson-Billings, 1994; Pomeroy, 1994). By 1979, the Commission's work became the stimulus for subsequent changes in NCATE standards, presaging an era of greater accountability where rhetorical commitments to the notion of multicultural teacher education required support by substantive actions in order to meet professional requirements of practice (Goodwin, 1997, p. 5).

As the population of ethnically, culturally and/or linguistically diverse students in the United States increases (Hodgkinson, 1992; National Center for Education Statistics, 1997a; 1997b), questions of mainstream classroom teachers' ability to effectively instruct these students remain (see for example Rodriguez, 1998). This is reflected in the inclusion of multicultural education policies in teacher preparation programs (including, but not limited to an understanding of linguistic and cultural diversity) found in accreditation standards of the National Council for Accreditation of Teacher Education (e.g., NCATE, 1998) and guidelines for other professional educational organizations. However, a recent comparative assessment of 59 institutions disclosed that "only 56% were found to adequately address cultural diversity and/or exceptionalities in the professional education curriculum" (Gollnick, 1992, p. 236), while only 68% had teacher certification candidates working with culturally diverse children. As suggested by Goodwin (1997), if such trends continue, then this is indicative of an approaching crisis in K-12 education.

<u>What is Multicultural Education?</u>

A major difficulty facing teacher educators seems to be that of defining just what multicultural education *is*. According to Banks and Banks (1995),

> 'multicultural education is a field of study and an emerging discipline whose major aim is to create equal educational opportunities for students from diverse racial, ethnic, social-class and cultural groups. One of its important goals is to help all students to acquire the knowledge, attitudes and skills needed to function effectively in a pluralistic democratic society and to interact, negotiate and communicate with peoples from diverse groups in order to create a civic and moral community that works for the common good' (p. xi).

Banks and Banks (1995) consequently describe multicultural education as a

> 'field of study designed to increase educational equity for all students that incorporates, for

this purpose, content, concepts, principles, theories and paradigms from history, the social and behavioral sciences, and particularly from ethnic studies and women's studies' (p. xii).

As they suggest, it is because of these characteristics that multicultural education may be termed a "metadiscipline". In a subsequent publication, Banks and Banks (1997) propose that multicultural education is a synthesis of at least three entities, i.e. an idea or a concept; an education reform movement; and a process. Boutte (1999) concurs with the notion of multicultural education and development as a process, and proposes three successive stages of multicultural growth spanning four dimensions (i.e. self-awareness, emotional response to differences, mode of cultural interaction and approach to teaching). These illustrate that when multiculturalism is employed as an educational process, an individual develops from holding unidimensional to adopting multidimensional perspectives (pp. 27-31). Boutte (1999) also addresses a common *misconception* about multicultural education when she states that many educators mistake the term "multicultural" to mean addressing only the needs of minority children (p. 75). This is a *pseudomulticultural* approach since it does not consider the needs of *all* children and assumes that the needs of the mainstream student population are generally taken care of in the classroom (p. 76).

Flaxman, Schwartz, Weiler and Lahey (1998) propose that multicultural education is a theory of the content of education, the teaching and learning process, and the very purpose of education. As a theory of social inclusiveness for example, multiculturalism provides the intellectual and political basis for bilingual education in schooling and for minority language maintenance in the larger mainstream community. What are now considered multicultural education practices in the school and the classroom include, for example, an inclusive curriculum leading to self and societal transformation, cooperative learning, culturally relevant pedagogy, and a greater family and community involvement in education.

However, multicultural education is not without its detractors. As an educational philosophy, it has been criticized for its championing of intellectual relativism and for divisions in the unity of American democratic and cultural ideals that it is thought to engender (see for example Ravitch, 1990; Schlesinger, 1991; Hirsch, 1999).

Multicultural Science Teacher Education and the STS Approach

In terms of the professional preparation of science teachers, Atwater (1996) argues that there must be a union of science teacher education and multicultural education to develop research and teaching agenda for *multicultural science teacher education.* Madrazo (1998) has cautioned that the integration of multiculturalism into any subject or content area can be tricky; in particular, science and mathematics educators (who might regard their disciplines as being purely objective) may find it especially difficult to develop new frameworks which incorporate a multicultural approach. Madrazo (1998, pp. 21-22) provides a description of a "multicultural science teacher continuum", going from *addition* (adding a multicultural component to science curriculum and instruction) to *integration* (relating data and information from various cultures to the concepts and theories of canonical science) to *accumulation* (consideration and appreciation that the manner in which scientific knowledge is constructed is influenced by cultural factors) and finally to *advocacy* (consideration and appreciation that various frames of reference and cultural assumptions influence the accumulation of knowledge).

Norman (1998) succinctly states that an important component of scientific literacy is an understanding of the reciprocal impact of science and the general culture on each other (p. 365; see also Allchin, 1998). This perspective seems to lend substantial support to Madrazo's (1998) conceptions of *accumulation* and *advocacy* as part of a multicultural science teacher continuum of development. However, Norman (1998) advises that the pedagogical strategy he proposes as a means of developing scientific literacy (cf. Madrazo's *transforming knowledge* or *advocacy*) has an apparent limitation in that it might lead to the introduction of too much noncontent material in the science curriculum. This becomes a particularly important issue in the current era of 'educational standards and accountability' when addressing charges (some well founded) that science teachers (and elementary science teachers especially; see for example Tilgner, 1990) are not adequately prepared in the science content areas. To counter this, Norman (1998) suggests that scientific literacy should therefore become the responsibility of the whole school and not just that of the science teacher (p. 372).

Issues of multicultural education, science teacher education and multicultural science teacher education are implicitly foregrounded by Barton and Osborne (1998, p. 340) who urge science educators to address the following questions in their teaching and research agenda:

1. How can historically marginalized students become involved in science?
2. How can we shape practice and curriculum to address the needs of diverse learners?
3. How does reshaping practice and curriculum alter our thinking about the discipline or science itself?

These questions and related issues concerning multicultural science teacher education, scientific literacy and advocacy (as defined in Madrazo, 1998) seem to be addressed very well in the science/technology/society (STS) approach to science teaching.

According to Yager (1990, p. 52), STS may be defined as an integrated approach to science teaching that seeks to:

1. Prepare students to use science for improving their own lives and for coping in an increasingly technological world;
2. Teach students to deal responsibly with technology/society issues;
3. Provide students with a fundamental knowledge of STS issues; and
4. Give students a knowledge of career opportunities in STS-related fields.

Wraga and Hlebowitsh (1991) have defined STS as a topical curriculum that addresses a broad range of environmental, industrial, technological, social and political problems including (but not limited to) the following:

* Acid rain
* Air quality

* Deforestation
* Drug abuse
* Soil and landmass erosion
* Euthanasia
* Food preservatives or additives
* Fossil fuels
* Genetic engineering
* Greenhouse effect/global warming/depletion of the ozone layer
* Hazardous waste
* Hunger
* Land usage
* Mineral resources
* Nuclear power
* Warfare (nuclear, biological)
* Overpopulation
* Pesticide usage
* Rainforest preservation
* Water quality/water usage

More recently, Barba (1998) has specifically addressed the integration of STS issues in the multicultural classroom by advising science educators to seriously consider the following questions: How can students become engaged in taking action on social issues? Why is the integration of science, technology and society important? How does STS education fulfill the need for "real world" applications of science?

Multicultural Science Education -- A Typology

As mentioned above, teacher educators and others associated with the professional preparation of teachers typically find it difficult to propose (and agree upon) a specific definition of multicultural education. This continues to be especially true in the discipline of science education, where the notion of "multicultural science education" currently remains as highly contested epistemological and pedagogical terrain. Since "multicultural education" has come to have many different meanings and conceptualizations during its evolution from the civil rights era of the 1960s to the present time, it is important to provide clarification regarding the different definitions, goals, assumptions and principles of multicultural education and their manifestations in multicultural science education.

Burnett (1994) has proposed a typology of multicultural education, comprised of programs which are broadly divided into three categories according to their primary emphasis. *Content-oriented* programs are the most common and immediately recognizable variety of multicultural education. Their primary goal is to include content about different cultural groups in curriculum and educational materials in order to increase students' knowledge about these groups. In its most fundamental form, this type of program adds a multicultural "piece" to a standard curriculum, perhaps incorporating a number of assignments or a few in-class celebrations of cultural heroes and holidays within the school year. Other versions of content-area programs take a more thorough approach, adding numerous multicultural materials and themes to the curriculum. More sophisticated versions of content-oriented programs actively transform the curriculum by seeking to develop multicultural content throughout the disciplines; incorporate a variety of different viewpoints and perspectives in the curriculum; and transform the canon, ultimately developing a new paradigm for the curriculum (Banks, 1994). In the science curriculum, a content-oriented multicultural science education program might, for example, include a component which acknowledges and studies the contributions to industrial chemistry made by the ancient Egyptians and Mesopotamians over 5,000 years ago (see for example, Williams, 1984; Hernandez, 1989; cf. Madrazo's [1991] stage of *addition* in the multicultural science teacher continuum).

Based on the concept of multicultural education as an effort to reflect the growing diversity of America's classrooms, many programs move beyond curricular revisions typical of content-oriented programs to specifically address the academic needs of carefully defined groups of students, often minority students (Burnett, 1994). Banks (1994; 1998) notes that while curricular programs primarily attempt to increase the body of knowledge about different ethnic, cultural and gender groups, *student-oriented* multicultural education programs are intended to increase the academic achievement of these groups, even when such programs do not involve extensive changes in the content of the curriculum. According to the description provided by Sleeter and Grant (1993), many of these programs are designed not to transform the curriculum or the social context of education in particular, but to assist culturally or linguistically different students make the transition into the educational mainstream. In so doing, these programs often utilize the varied linguistic and cultural backgrounds of their students. What results is that student-oriented programs may adopt many different forms, some of which are not typically thought of as types of multicultural education. Banks (1994) has described four broad program categories which serve as characteristic examples of such student-oriented programs, e.g. programs that use research into culturally-based learning styles in an attempt to determine which teaching styles to use with a particular group of students; bilingual or bicultural programs; language programs built upon the language and culture of African-American students; and special math and science programs for minority or female students. Due to this variety (and because such programs attempt to help students make the transition into the mainstream) many student-oriented multicultural education programs can be viewed as being compensatory in nature. Indeed, such programs might often be practically indistinguishable from other compensatory programs which may or may not be multicultural in their emphasis (Burnett, 1994). In the science curriculum, a student-oriented multicultural science education program might, for example, provide science content classroom instruction in languages other than English for those students who do not speak English as a first language. The epistemological and pedagogical rationales here would be that these students should be given opportunities to utilize the cognitive and linguistic "tools" at their disposal in order to construct viable, contextual and experiential understandings of science. Such a perspective opposes the typical *modus operandi* in many U. S. science classrooms where learning and achievement in science are predicated on the mastery of English-only science vocabulary (see for example, Rosebery, Warren & Conant, 1992; Gallard & Tippins, 1994; Lee, 1997; 1998).

Socially-oriented programs are the third type of multicultural education program described in the typology proposed by Burnett (1994). Generally, these types of program seek to reform both schooling and the existing social, cultural and political contexts of schooling. The aim is not simply to enhance academic achievement nor to increase the body of multicultural content knowledge in the conventional school curriculum, but to have the much broader impact of increasing cultural and racial tolerance and reducing bias. Sleeter (1992) and Sleeter and Grant (1993) extend this type of multicultural education to include a much broader spectrum of programs with socially-oriented and social activist goals. The programs they advocate (i.e. those emphasizing intellectual pluralism and cultural equity in society as a whole and not only within the schools) are much less common and potentially much more controversial. Many emphasize the application of critical thinking skills to critiques of racism, sexism and other repressive aspects of society; some emphasize multilingualism; others attempt to examine issues from a large number of epistemological perspectives, some of which may be radically different from those of the predominant culture; and others utilize cooperative learning approaches and decision-making skills in order to prepare students to become socially-active citizens (cf. Barba, 1998). In the science curriculum, a socially-oriented multicultural science education program might, for example, emphasize the study of history and philosophy of science (HPS), in a manner that integrates science content with relevant STS issues (see, for example, Stinner & Williams, 1998). Such an approach would focus not only on required science content, but also would challenge students to explore and critique how contemporary canonical science as a way of knowing has evolved and developed in the contexts of various sociocultural, epistemological and political paradigms.

As a university level science educator responsible for the professional preparation of K-12 science teachers, I subscribe to a socially oriented perspective of multicultural science teacher education. This perspective places joint emphasis on preparing science teachers who possess a comprehensive understanding of canonical science content together with a highly developed level of scientific literacy and the ability to make reasoned, informed judgments about the influences and impacts of science in everyday life (cf. Carson, 1998; Stinner & Williams, 1998). My conception of multicultural science education also reflects the "multiculturalism as a process" definition (Banks & Banks, 1997; Boutte, 1999). The enterprise of "science", as a way of thinking about and making sense of the world can be traced historically and shown to have multiple and complex cultural, social, economic and political underpinnings which all interrelate (see, for example, Wiener & Noland, 1957; Proctor, 1991; Allchin, 1998); therefore, I take the perspective that a sound, quality program of professional preparation in science education (which includes an understanding of the development of scientific philosophies, theories, laws, principles and applications) *necessarily* must be multicultural.

Addressing Multicultural Issues in Four Science Methods Classes: Data, Findings and Analysis

The University of Central Florida (UCF) is a four-year college, and part of an extensive state system of community colleges and universities. Approximate enrollment figures for the 1997-1998 academic year were 2,500 undergraduates and 1,300 graduates in the university's College of Education. The majority of students in the College of Education major in elementary education (approximately 60%) and many graduates remain in the central Florida area, teaching in local schools.

Over the course of the calendar year Fall 1997 to Fall 1998, I taught four undergraduate level science methods classes. Although an additional two sections of a graduate (Master's) level science education course were taught in the Summer 1998 semester which also explored a number of multicultural issues relating to science teaching and learning, I will focus only on the undergraduate level classes (predominantly preservice teachers) for the purposes of the present analysis.

SCE 3310, *Teaching Science in the Elementary School*, is the elementary science methods course, designed specifically for elementary education majors. It is a required course for the baccalaureate degree in Elementary Education, and accounts for 3 of the 9 credit hours of science coursework contributing to the 120 credit hour requirement for the degree. SCE 4360, *Science Instructional Analysis*, is the secondary science methods course, and is a required course for the baccalaureate degree in Science Education (with specializations in biology, chemistry or physics, respectively). The course accounts for 4 of the 38 credit hours of science specialization coursework contributing to the 120 credit hour requirement for the degree. Typical students in this class are preservice middle/high school science teachers intending to specialize in integrated science, biology, chemistry or physics, or are postbaccalaureate inservice science teachers needing middle/high school science certification or recertification.

Class Demographics

SCE 3310, Fall 1997:

Number of students, 30 (females, 26; males, 4); Minority students, 3 (1 African-American female, 2 Hispanic females).

SCE 4360, Spring 1998:

Number of students, 12 (females, 8; males, 4); Minority students, 5 (1 African-American female, 2 Hispanic females, 1 Hispanic male, 1 Native American female).

SCE 3310, Summer 1998:

Number of students, 35 (females, 30; males, 5): Minority students, 6 (2 African-American females, 3 Hispanic females, 1 Asian-American female).

SCE 3310, Fall 1998:

Number of students, 60 (females, 49; males, 11): Minority students, 5 (3 African-American females, 1 Hispanic female, 1 Lebanese-American female).

Total number of students, N=137

Female students (elementary classes only), 84%

Minority students (all classes), 14%

Class Assignments Dealing with Multicultural Issues

In addition to class discussions/debates which occurred relating to various multicultural issues (e.g. multiple intelligences; learning/cognitive styles; culturally relevant pedagogies; culturally fair testing and assessment; Eurocentric vs. Afrocentric science curricula, etc.), the most frequently employed manner of eliciting deliberately considered student responses to multicultural issues impacting the teaching and learning of science was through the use of reaction paper assignments. A description of the format for reaction paper assignments is reproduced below (Figure 1):

Figure 1

Format for Reaction Paper Assignments in SCE 3310 and SCE 4360

Reaction papers are reviews of journal articles, books, book chapters or other reading assignments which are intended to elicit your reactions and reflections.

This structured response is divided into three categories which closely resemble Bloom's Taxonomy of the domains of learning -- the cognitive, the affective and the psychomotor. The main difference here is that the 3-R format deals with the reaction of the affective domain first, rather than the cognitive as does Bloom. The rationale for the difference in placement is to increase your awareness of affective response, and then to address the cognitive merit of the learning regardless of the positive or negative affect with which it is associated. Please include the following in your papers:

1. *Reaction (affective domain, to feel).* What was your affective response to the material you read (favorable, unfavorable, mixed)? Cite at least one example from the text that illustrates your response.

2. *Relevance (cognitive domain, to think).* How is the article or text related to the issue at hand, and how is it related to other readings and discussions in this course? How is the article meaningful, or how does it contribute to your understanding of the course material and/or issues being discussed? What are some alternative points of view? Cite examples from the text to

support your perspective.

3. *Responsibility (psychomotor domain, to do).* How will the knowledge or perspectives gained from this reading be used in your professional practice? Give at least one example of possible application to your personal or professional life, or explain why you think this information is not useful. What are some questions you still have regarding this topic?

Reaction papers were based either on portions of the representative texts indicated below, or the complete texts where appropriate (see References):

SCE 3310 (Fall, 1997): Reaction papers to selected portions of Ogbu, 1978 and Ogbu, 1995 (voluntary and involuntary minority students and implications for academic performance in school); Banks & Banks, 1995 (definition and implications of multicultural education for science teaching and learning).

SCE 4360 (Spring, 1998): Reaction papers to Rodriguez, 1997 (critique of the National Science Education Standards); Banks & Banks, 1995 (definition and implications of multicultural education for science teaching and learning); Ladson-Billings, 1994 (issues and implications for science teaching and learning of culturally relevant pedagogies).

SCE 3310 (Summer, 1998): Reaction papers to Rodriguez, 1997 (critique of the National Science Education Standards); Banks & Banks, 1995 (definition and implications of multicultural education for science teaching and learning).

SCE 3310 (Fall, 1998): Reaction papers to Madrazo, 1998 (diversity issues in the science classroom); Banks & Banks, 1995 (definition and implications of multicultural education for science teaching and learning).

Findings and Analysis

A cursory examination of the demographic information above provides good support for the findings of the research literature cited in Atwater (1996): most prospective elementary teachers continue to be White, female and middle class, and it is still comparatively unusual for males to enter the field of elementary education. People of color continue to be underrepresented in both prospective and practicing teaching pools, even though there has been a substantial increase in the number of students of color in the nation's schools (pp. 3-4). Allowing for the fact that the information above represents just one calendar year of courses taught by one member of faculty, it is nevertheless interesting to note that no African-American males were enrolled in any of these science methods courses.

Below are seven selected excerpts from reaction papers providing a cross-section of student responses to articles or other texts addressing multicultural issues in science teaching and learning. Selection of the excerpts was based on the range of responses over the course of the Fall 1997-Fall 98 calendar year of which they are representative and also on the stated willingness of the students in question to allow their responses to appear in this paper. The responses are reproduced *verbatim*, and begin to provide some insight into the thinking and attitudes held by these students toward multicultural science teacher education.

> *SCE 3310, Fall 1997 (Student A, White male)*:
>
> Before the debate on multicultural education begins, should it not first be given a clear cut definition of what it entails, along with any and all current subsets of its definition? Is it simply to plan teaching lessons and strategies to transcend any and all learning barriers due to cultural differences, or does it go farther than that? According to his 1994 book "Multiethnic Education", James A. Banks lists 5 different dimensions of multicultural education, ranging from the construction of knowledge process to prejudice reduction. Perhaps it is more than just adapting lesson plans for cultural differences. The successful and effective teacher has been molding and adapting his/her classroom and lessons to meet

the needs of individuals long before the P.C. buzzwords of multicultural education. Have we not had enough of the "victim" in education? And have we not had enough of labeling minorities to receive different- sometimes earlier, sometimes more- instruction than the rest of the field? This went into full swing with the Johnson Administration, and with a few microcosms of success, has not worked. There have been 2 or 3 generations of minorities who have received this additional educational treatment, so why do we still need to do more? [ ] This country was founded, and grew with astounding fervor, by its united spirit, a common united American spirit. Look what the current spirit is doing to the country now. There is no need to surrender your heritage, your history, your culture, but this is America, not someplace else. Not yet, anyway.

SCE 4360, Spring 1998 (Student B, Hispanic female):

My affective response to this article is mixed. I respect Dr. Rodriguez' argument that the NRC uses a discourse of invisibility to lay out its massive reform for science education in the United States. However, I think he is giving too much emphasis to the ethnic part. Like Dr. Rodriguez I am also from Hispanic origin and I see the effort of the education system to try to incorporate the multicultural diversity in our schools. He mentions in page 21 (third paragraph), that words like Latinas and Latinos, African Americans, Asian Americans, and/or First Nations Peoples are not mentioned through the entire document. I don't see the necessity to do that. I think that we don't need to be dividing people by ethnic groups, especially our students, when we talk about them. In my opinion, this will cause more division between people. We don't need more of that. We need to focus in the things that unites us not the ones that divides us. [ ] The knowledge gained in this article will not be used in my future professional practice. I don't agree that the science education standards are framed in a discourse of invisibility. I have noticed a big emphasis in multicultural education in our system. But like I said before, I respect Dr. Rodriguez' point of view. I see more positive aspects to the National Science Education Standards than negative.

SCE 4360, Spring 1998 (Student C, White male):

Learning more about multicultural education and multiculturalism has been an interesting educational experience, especially in a science methods class! It is good that you give us the opportunity to argue and to agree or disagree in class - this is what developing critical thinking skills is all about. However, I must say that I feel uncomfortable with being asked to incorporate all of this "multiculturalism" into my teaching. I am a chemistry teacher, and I get paid to teach chemistry, not social psychology, not sociology, not anthropology, but chemistry. I can see the relevance to chemistry of the STS approach we talked about in class, but I feel that much of the pro-multicultural perspectives we read about are better directed to social workers or guidance counselors or to school psychologists. That's their job, i.e to raise students' self-esteem and to make sure that diversity issues in the school are dealt with appropriately and so forth. I teach kids chemistry.

SCE 3310, Summer 1998 (Student D, White female):

When I began reading this paper, I had an unfavorable reaction. As I continued to read, I began to have mixed feelings. Certain parts I agreed with and others I felt strongly about. I certainly agree that students need to have an integrated and diverse education. I do not think that minority students learn differently than non-minority students and I do not think that a teacher should have to work their classroom around the sensitivities of minority students as mentioned in the article. I do not feel students think they are being excluded because a lesson is revolved around an American society. Each student, minority or not, is a different learner. They all have a culture and to only pay attention to the "sensitive" ones is also neglect. The article also makes reference to learning each child's learning style and I do think this is very important because, as I mentioned, each child is going to have a unique way of learning. People are still going to be able to live and work in a diverse society even if you do not present each subject with a careful cultural thinking.

SCE 3310, Fall 1998 (Student E, African-American female):

After reading the article "Embracing Diversity" I have come to better understand what exactly is necessary to create a multicultural learning environment. I had some mixed feelings about the issue at hand, but more favorable than not. I especially agreed with the line that stated "ethnic identity and cultural, social and economic background of students are as vital as [students] physical, psychological and intellectual capabilities". This is something that I feel is often ignored. We are a country who place a lot of emphasis on our standardized testing scores, but those type of examinations often don't take into account the personal beliefs and experiences of the students taking them.

SCE 3310, Fall 1998 (Student F, White female):

I have mixed feelings about the article, "Discrimination," by Gerry M. Madrazo Jr. My initial thought was that people are emphasizing multicultural education way too much. I definitely believe in an "equal opportunity to learn", but I must be a very ignorant person. I know that discrimination occurs, but I don't think I realize how often it occurs. Before I read the paper, I really didn't see the need or validity for this education. Also, I didn't feel that multiculturalism has any relevance in science. Gravity is just as strong in Canada as it is in Ethiopia. Though I felt that multicultural education was a waste of time, after reading the article and discussing it in class I have come to a new understanding of its importance.

SCE 3310, Fall 1998 (Student G, White male):

The article titled "Diversity" gets under my skin in a big way. I think the term multicultural education was thought up by a group of elites to spark a sense of fear into educators so they don't seem to be racist. I don't think any teacher of mine ever took the time to configure their lesson plans to fit their students, myself included.

Overall, a greater level of resistance to the concepts of multicultural education and multicultural science teacher education was noted especially in the secondary level course. In open class discussions with these students, their rationale for this resistance was that they were more 'content oriented' at their instructional level (see Atwater, 1996, p. 4), and perceived that consideration of multicultural issues had little or no relevance to a middle/high school science curriculum. Student C for example, found it extremely difficult to think about relating chemistry content to multicultural issues in his teaching, and adopted the perspective that there was no place for "...... the highly subjective whimsies of multiculturalism in the objective world of chemistry". When probed a little further about part of his written response, "I can see the relevance to chemistry of the STS approach we talked about in class.... ", he explained that as a chemistry teacher, he could "see" chemistry everywhere in the world around him and wanted his students to gain an appreciation for the vast impact that industrial chemistry, for example, had on their everyday lives. When probed even further about the possibility of industrial chemistry having largely negative impacts on specific sectors of society (the example used being that of the disproportionate level of toxic waste or by-products being disposed of in minority neighborhoods or in so called "Third World" countries), his answer was revealing: "That's politics. I don't want to get into that in my classroom. That's not my job as a chemistry teacher". Student C was obviously scientifically literate in the sense that he could relate science content knowledge to many aspects of everyday life, but was reluctant to use his scientific literacy as a tool to analyze underlying and important social issues.

A distinctly lower level of resistance to the concepts of multicultural education and multicultural science teacher education was noted in the elementary level classes (possibly a function of these students being much less content oriented, and relatively uncomfortable with science content), although the notion of multicultural science education still seemed to be a difficult one to consider. Essentially, criticisms of incorporating multicultural issues into science education were encapsulated by the following question: "Are we teaching *science* or merely another education "feel-good" concept?" Student F, for example, was very conscious of her comparative lack of science content knowledge and was keen to learn more science content and ways in which she could effectively teach science at the elementary level. Like Student C, she also questioned the relevance of incorporating multicultural issues into a science methods course and initially voiced the opinion that this detracted from what she had enrolled in the class to do, i.e. learn how to teach science. Unlike Student C, Student F was willing to use the scientific literacy she possessed to begin thinking more deeply about the ways in which science (and specifically, the ways in which it is taught) may have positive or negative impacts on different types of students. Interestingly, when asked why she had incorrectly referred to the title of Madrazo's (1998) article as "Discrimination" (see above), her response was that the article made her realize that the manner in which teachers decide to design and implement their instruction has an effect on which students are likely to be successful, and which are likely to fail. In her assessment, this was a form of discrimination (unintended or otherwise) and was something she had not thought about until being asked to consider the relevance of multicultural issues in science teaching and learning.

Students in the four classes appeared relieved that they were encouraged to give their *real* opinions in class discussions and in the formal reaction papers without threat of reprisal simply for disagreeing with the philosophical stance of the professor. Unfortunately, it appears from an analysis of these four classes over the past year that many preservice teachers simply "jump through the required hoops", and regurgitate the "multicultural mantra" without really believing in it, but simply as another requirement to be checked off in order to obtain teacher certification. This becomes an issue of some concern when one considers that the central Florida region (in which many of these preservice teachers will teach) has a very high proportion of ethnically, culturally and linguistically diverse K-12 students whose specific educational needs must be addressed by adequately prepared teachers.

One of my explicit goals in exposing my students to issues of multiculturalism in science teaching and learning is to emphasize the concept that teaching is a political act. How and what one teaches is the result of a conscious or unconscious political decision. Pinar, Reynolds, Slattery and Taubman (1996) suggest that no serious curriculum scholar at the present time would advance the argument that schools in general and curriculum in particular are politically neutral (p. 244); however, many preservice and inservice science teachers with whom I interact seem to believe (before it being pointed out to them in my methods classes) that the school curriculum is politically neutral, or even apolitical. Nieto (1992) points out that knowledge (of any kind, including scientific knowledge) is neither neutral or apolitical, yet many schools and educators continue to treat it as if it were. Consequently, educators tend to present knowledge of the lowest common denominator, that which is sure to offend the fewest and is least controversial. However, history is full of debates, controversies and ideological struggles (e.g. the current debate over the canon and cultural literacy versus multicultural literacy) and educators must understand that all decisions that they make, regardless of how neutral they appear, impact in unconscious, but fundamental ways on the lives and experiences of *all* students (Nieto, 1992). Consistent with my socially oriented perspective of multicultural science teacher education and in seeking to emphasize to my students the political nature of teaching, at the conclusion of the respective elementary and secondary level courses, students have engaged not only with science content and science pedagogy, but also have begun to reflect more deeply about some or all of the following epistemological considerations:

* What is human knowledge? How and by whom is it validated and given credence?
* What is distinctive about scientific knowledge?
* Is Western science just one among many equal sciences?
* In what sense is science objective?
* How does science relate to mathematics and other areas of human knowledge?
* How do metaphysics, or worldviews, affect the creation and learning of scientific knowledge?
* Is science value free?
* Is there a feminist way of knowing?
* Do scientific theories make claims about an ontological world or about human perceptions and

experience?

(adapted from Matthews, 1998, p. 983)

Successes, Challenges and Possibilities

As a result of the issues, discussions, debates and formal assignments resulting from the classes, most students, especially younger undergraduates or preservice teachers (usually under 25 years of age) appear demonstrably more receptive to the concepts of multicultural science education and appear to demonstrate a deeper level of theoretical and practical understanding of the act of teaching. I am beginning to observe and hear reports of this being played out in their classroom internships where some students are attempting to explore a wider variety of approaches and techniques to teach science. It has been encouraging to note that more of an effort is being made by these preservice teachers to understand the varied social and cultural backgrounds from which their students come, which in turn positively influences their instructional decisions in the classroom.

Older undergraduates, postbaccalaureate students and inservice teachers (generally, over 25 years of age) tended to question the tenets and rationales of multicultural science teacher education more thoroughly than their younger classmates (which is certainly encouraged), and also tended to take the perspective that multicultural education is *not* a necessary component of the elementary or secondary science curriculum. Typical comments elicited in class debates (all classes) included:

* "It's more watering down of the science content, isn't it?"
* "There's a danger of reverse racism if you take this too far".
* "It's discrimination against the White mainstream". *(Usually prefaced by "No offense Dr. Sweeney, but...")*
* "This undermines the entire American ideal of *E pluribus unum*".
* "This creates more so-called victims of circumstance in the schools,... if they can't learn the same things as everyone else then that's their problem. They'll have to learn to sink or swim".

For these pre- and inservice teachers, it seemed very difficult to conceive of the curriculum as a political entity and of teaching as a political act. Science teaching in particular tended to be perceived as the straightforward and uncomplicated transmission of '.... the scientific knowledge which they'll [i.e. their students] need to survive in modern day society'.

Whether cynical or accepting of multicultural education as a legitimate part of the science curriculum, there are promising possibilities which result from asking these students to engage in a dialogue about this and related issues. From my perspective as a science education professor, encouraging prospective and inservice science teachers to analyze more deeply the hows and whys of their teaching is likely to result in some level of improved professional practice (Nichols, Tippins & Wieseman, 1997) which has obvious implications for K-12 science education and scientific literacy in the general population. Continuing dialogues in science methods classes such as these also might be a means of attracting traditionally underrepresented populations into the fields of science and science teaching, if science is perceived by them to be both relevant and applicable to their lives.

Multicultural and STS issues in Science Methods Courses:

A Representative Activity*

*Source: Adapted from *Teacher Talk*, published by the Center for Adolescent Studies at the School of Education, Indiana University, Bloomington, IN. Accessed on-line at http://education.indiana.edu/cas/tt/v1i3/earth.html .

The following activity is used in my elementary and secondary science methods classes to illustrate how a relatively simple chemical concept (the use of indicators to signal a predominantly acidic or basic solution) may be used as a means of introducing the relevance of multicultural/STS issues to science teaching and learning.

Probability/Dynamics of HIV Transmission

Instructional objective:

Students will demonstrate and understand the dynamics of how *Human Immunodeficiency Virus* (HIV) is transmitted.

Grade level and subject area:

Upper elementary to high school; biology, chemistry, social studies

Resources and materials:

Disposable cups, a base and phenolphthalein.

Activities and strategies:

1. The teacher distributes a cup (half full of water) to each student. At least one student unknowingly receives a cup with the "AIDS virus", which can be any base, e.g. a small amount of baking soda or baking powder dissolved in water or a weak solution of aqueous sodium hydroxide

2. Students are asked to write on a piece of paper their 5 favorite foods; cars; types of music; and hobbies. The students then mill about the room interacting with other students, and exchanging a small volume of their water whenever they meet a person with similar interests to their own. (In a class of about 30 students, each student typically will exchange volumes with at least 10 other people). Finally, the teacher will go around the room and add a drop of the indicator, phenolphthalein, to each cup. Those cups which have been "infected" with the base will change from a clear to a deep pink color.

3. This activity can be followed by a discussion or serve as a bridge to other activities. The teacher can explain that the activity models the mechanism of transmission of the "AIDS virus" and that while it was unclear who was initially infected, many people were subsequently exposed to the disease.

Post-activity Discussion: Teaching Science Content and Multicultural/STS issues

As a method of introducing and teaching science content material (in this case, chemistry) the color change which occurs in this activity indicates the occurrence of an acid-base reaction. Depending on the level of the class, the mechanics of the reaction will be discussed using either the structural formula of phenolphthalein, or by using a schematic to represent the acid (H-X) where H indicates a dissociable proton. The very vivid color change sets the stage for defining the terms *acid* and *base*, which tend to be confusing for many elementary level teachers. The discussion can then be led quite naturally into related concepts such as the *pH scale*, *exponential notation, neutralization, molarity, protons and hydronium ions, reactant-product equilibrium*, etc., and the depth of complexity appropriately modified for the target audience.

As a simulation model for HIV transmission, the activity is extremely effective in allowing students to see just how easily one "infected" person subsequently "infected" everyone else in the class. The activity usually generates a heated debate when I pose the question "Should this activity be used to teach about HIV transmission, or simply of any communicable disease as innocuous as the common cold?" Preservice elementary level teachers especially felt very uncomfortable with the idea of broaching such issues with elementary age students; the secondary level preservice teachers were approximately evenly divided both for and against the idea of using this activity specifically to teach their middle and high school students about HIV transmission. Should a social issue such as this be a legitimate curricular concern for the science teacher, or should this exclusively be the purview of the social studies curriculum, or of school social workers?

To stimulate discussion, students are asked to read and respond to a handout which I have prepared for this part of the activity (reproduced below in Figure 2):

Figure 2

NABT Position Statement: The Role of Biology Education in Preventing the Spread of AIDS (adopted by NABT Board of Directors, 1990)

Since the first reports of its occurrence in 1981, Acquired Immunodeficiency Syndrome (AIDS) has grown to an epidemic of major proportions, both in the United States and abroad. The impact on individuals, families and society is profound. In the absence of effective treatment and cure, *experts in all areas of biomedicine and healthcare agree that education holds the most promise for controlling this deadly disease* (my italics). The National Association of Biology Teachers

(NABT) believes that biology education must play a central role in this important effort. Biology education *at all levels of instruction* (my italics) should help to develop and improve understanding of the many dimensions of the AIDS epidemic by stressing the importance of topics which include the following:

* The role of the immune system in the protection of the individual;
* The natural history of AIDS;
* Patterns of HIV transmission;
* Behaviors associated with transmission; and
* Implications for prevention.

(Adapted from National Association of Biology Teachers, 1990).

In the class discussion which follows, students and I debate the importance and legitimacy of using this activity in upper elementary-high school classes as a means of exploring multicultural and STS issues in science education. The following information serves as an example of additional material which also is provided in order to make the issues at hand "real" and to encourage further conceptual exploration of the relevance (or not) of multicultural and STS issues in the science curriculum:

> Florida has one of the highest rates of HIV infection in the United States. Since July 1997 when name reporting began in Florida through February 1998, 4,123 people have been reported as infected with HIV. This means that approximately one in 172 people in Florida are estimated to be HIV positive. AIDS is the number one killer of nonwhite women aged 15-44 in Florida (North Central Florida AIDS Network, 1998).

In addition to clarifying the difference between HIV and AIDS (a pertinent example of scientific literacy; many students do not distinguish between the two), important questions and concerns arising from the class discussions include:

* Why are nonwhite women in Florida aged 15-44 so particularly at risk from AIDS?
* Are certain sectors of the upper elementary-high school student population more at-risk than are others, and why?
* The incidence of a widespread "drug culture" in some schools and its impact on the spread of HIV infection/development of AIDS (e.g. unhygienic use of needles in intravenous heroin use).
* Adolescent/preteen/teenage pregnancy and sex education.

From a socially oriented multicultural science education perspective, it is apparent that substantively addressing these questions and concerns necessitates an understanding of the various cultural, social, economic and political factors contributing to these issues. Not only should science teachers be able to provide an appropriate level of content instruction in general science (including human biology and biochemistry) which educates these populations in preventive measures, we also should be able to modify and tailor that instruction in ways which are meaningful and applicable to the specific populations being served. From an STS perspective, addressing such social issues becomes, by definition, an exercise in promoting a greater level of scientific literacy since students are being taught how to understand and use science for improving their own lives.

Multicultural Science Teacher Education: Future Challenges for Teaching and Research

Given the demographics concerning the 'changing face' of K-12 students in this country's public education system (Hodgkinson, 1992; National Center for Education Statistics, 1997a; 1997b), it would seem prudent that the knowledge base for teacher preparation be founded firmly on what is known about multicultural education and teaching diverse populations. This is especially pertinent in the fields of science education and science teacher education, where practitioners at all levels typically have found it difficult (both conceptually and procedurally) to incorporate issues of multiculturalism and student diversity into their instruction. If we do indeed subscribe to the professional ideal that "science is for all students" (National Research Council, 1996, p. 20), then the formulation of such a knowledge base for science teacher preparation requires a synthesis of existing knowledge about multicultural science teacher education together with a comprehensive determination of what needs to be known. This study has sought to address some of these concerns by describing the successes, challenges and possibilities which have arisen from an intentional and sustained incorporation of multicultural and STS issues in science teacher education courses. It is hoped that this study might prove to be a stimulus for further, more comprehensive reform-oriented research into understanding and addressing the educational challenges here indicated.

In anticipation of these efforts toward reform, it becomes possible to envision the continued development and sophistication of a knowledge base, elucidation of philosophical positions and subsequent improvement of pedagogical practices which will become the framework for a transformation of science teacher education in America from monocultural to multicultural comprehensiveness. Ultimately, this will lead to the provision of better, more meaningful science education experiences for not just a select few, but for *all* types of learners in our systems of education.

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USING SCORING GUIDES TO TEACH PRESERVICE TEACHERS ABOUT STUDENT-CENTERED LEARNING

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One of the challenges we face in teacher education is how to teach preservice teachers about complex topics, especially those that involve the roles of the teacher and students relative to one another and to what is being studied. Most of our students come to teacher education with expectations based on their own experience as students, and sometimes also with a point of inspiration like a particularly good teacher, or an episode in which they had the "ah-hah" experience of realizing that they had had a positive effect on someone else in a teaching situation. Thus, our challenge is to build on these romanticized images--and to do this we have to encourage our students to look at them critically, and possibly reject all or part of them in order to develop more robust and realistic views of teaching.

Within this scenario, our preservice teachers also usually come to teacher education with deeply-rooted assumptions about who controls what in the classroom. They most often believe that a big part of the teacher's job is to decide what will be taught when, figure out how best to deliver this knowledge to eager young minds, and to then test those young minds to see what they have acquired. Early in teacher education, they often learn about constructivist views of learning, and are confronted with differing "visions" of teaching: student-centered, problem-based, hands-on -- and then are challenged to figure out what these visions mean for the teacher, i.e. how a teacher might make these work in the classroom setting.

As a methods course instructor, I try to structure activities that will stretch preservice teachers by challenging them to define and describe roles that they will take in classroom teaching. In doing so, I purposely include some activities and assignments that assume roles beyond those that they come to the course with. Essentially, I have selected activities that I have found to be incompatible with the narrow, romanticized view that most of them possess. Scoring guides are one such activity, and are presented as an example, nested within the context of the course.

What is the nature of the methods course?

The ten-week secondary science methods class is structured to demonstrate some of the growth and development that many teachers plan for across a school year. The first class meeting has much to do with the physical layout of the classroom, and setting up the first few days of school to lay foundations upon which to build the rest of the year. As the quarter progresses, topics are selected to build on our own foundations of understanding, such as finding out what one's students know via open exploration and other activities, classroom validation processes for student-generated ideas and data, structuring lessons around lab activities, assessing students' progress and understanding, language-rich science instruction, and so on. Guest speakers on fire safety, chemical safety and disposal, and the use of animals in the classroom provide expert views on important topics.

Throughout, one continuous theme in this course is 'developing a classroom culture of increasing expectations.' The essence of this theme is the idea that over a span of time, teacher and students share some evolving history, and that if one views this history as developmental, one can "build students up" to some pretty dramatic accomplishments. In the course, I choose to represent this process by focusing on the role of writing in science teaching and learning, which mirrors my own development as a teacher of Biology and Developmental (Creative) Writing. The scoring guide is an artifact of a particular stage in this process, one that students must "build their students up to". By their nature, the scoring guides themselves can represent positions on at least two continua, one going from simple facts to complex and interrelated understandings, and one from being a scoring guide for simple-known-answers towards being a guide for scoring more open-ended written responses.

We now move from considering the methods course, a "teacher education" context, to considering the details of scoring guides, and how they are used in the high school science classroom. Following this exposition, we will return to consideration of the use of scoring guides in the methods class, including a more complete discussion of the value of this particular tool, and some preservice teachers' responses to it.

What is a Scoring Guide and how is it developed?

A scoring guide is a key for scoring a piece of written work, and it is intended for use by students to evaluate their own or their peers' work. It includes scaffolding statements that assist the evaluator in the process, including point values and how to assign them. It may include content considerations, as well as those related to the form of expression ("genre") and the purpose of the written communication. Scoring guides are different from rubrics, although they may share some features. And, they go beyond the traditional test keys that may be best applied to multiple choice, true/false, and short (known) answer items, by allowing open-ended questions and creative responses. My scoring guides also include feedback of two kinds: noted strengths, and suggestions for improvement.

My experience with scoring guides is that students want immediately to have input into them. The first time I used scoring guides on an essay test, a number of students commented, "I wish I'd seen the scoring guide when I was studying for the test." I took them up on this request, and began posing open-ended test questions the week before the test. During that week, a recurrent task in our classroom was developing scoring guides for each of the questions. This brought an honesty to my teaching that I had not experienced before. No longer was I holding all the marbles, deciding the rules for playing the game. Instead, the students' understanding was "We gotta learn this stuff, because we're going to have to write about it for the test."

Another set of considerations that were important to the students were standards for expression and presentation. This is the "grammar and spelling" part of evaluation that poses challenges for new and veteran teachers alike, but also encompasses issues of understanding and purpose in writing. The students discovered very quickly, during the first round of scoring, that many of their peers had not exercised much care in penmanship, grammar, spelling, and attending to the purpose of their writing. Simply put, many were in the position of trying to decipher illegible marks. So, when the issue of developing scoring guides came up, some suggested that points be given for these kinds of things, and we discussed the relative value of these to the content points. In all 3 classes, the students were satisfied with a relatively small percentage of the total points being allotted for such things, as I indicated that my own standards focused more on relating understanding of the content material. For an example of how this played out in the final product, see Appendix A.

To develop a scoring guide, students need to know what the question will be. For example, a common lesson in high school biology focuses on the molecular structures of proteins, carbohydrates, and lipids. My test question was, "Proteins are important in the human body. Tell what you know about their functions in the body, how they are made, and how their structure is related to their function." To make the scoring guide, the students began by brainstorming lists of

Figure 1: Student-generated list of important information about proteins

Essays:

* understandable words
* good spelling - for understanding
* organization or a plan attempt
* correct grammar + punctuation (sentence form)
* written neatly - legible
* gets point across

Content: Proteins -

* <u>build + repair cells</u>
* <u>C, H, O, N, + others</u>
* <u>amino acids are basic units - strung together like beads (peptide bonds)</u>
* <u>diagram - structure of amino acid or explanation of structure</u>
* <u>groups - amino (NH_2), carboxyl (COOH) (central carbon)</u>
* <u>R group - determines properties</u>
* <u>peptide bonds between amino acids</u>
* definitions of dipeptide and polypeptide
* 3 structural levels
* <u>aid in making enzymes, hormones, antibodies</u>
* built from polypeptides
* assembly line of polypeptides

important information to include in their responses. They did this work individually, some using textbooks and notes, and then I asked a member of the class to lead an idea-gathering session at the chalkboard. During this time, I served as a recorder, making a "hard copy" of the ideas that would be useful later on. As ideas about content came out, students also mentioned other concerns they had about structure and genre (since they had used scoring guides before). Figure 1 shows what the students wrote. An important feature of the development process, when guided by students, is input and approval from the teacher. I used this opportunity to talk to the students about the relative importance of some ideas over others, and to ask them to note which ideas seemed to be critical or more important to answering the question. After some discussion and further teacher direction, these agreed-upon ideas were underlined.

After the class ended, I took the recorded ideas and made the final version of the scoring guide (See Appendix A and B for examples). While students were not privy to the final published form of the scoring guide before they took the test, I had encouraged them to make notes as we wrote, the notes were recorded in a class notebook, and thus were available to any student. I encouraged them to practice-write responses as homework leading up to the test.

One important note: since I was teaching 3 periods of biology, each class developed it's own scoring guide. While they were similar, they were not the same, and my role led me to a conflict: do I impose my own need for parity, or do I allow a reasonable range of responses? I opted for the latter choice, on the basis of wanting as much student investment in the guides as possible and not wanting to do anything to diminish the students' trust. This just meant a bit more development time for me, and also meant that I had to be careful to use the right guide for each class!

How do scoring guides fit into the larger picture of the high school classroom?

The classroom described here and to preservice teachers in the methods course is different in some ways when compared to most of the classrooms in which they work in field experiences and student teaching. Yet, it also reflects some of the many reform-based recommendations for improving science instruction in high schools. For example:

- students worked in various social arrangements (individually, in small groups, and as a whole class) to design and carry out sustained inquiry directed at answering questions they had generated, on topics selected or approved by the teacher.
- the roles of teacher and students were modified to create a learning community in which all members shared responsibility for what was learned, and students had some say in the selection and order of topics.
- assessment and evaluation strategies moved away from strictly known-answer, true/false, and multiple-choice formats to include the use of language for more authentic purposes such as to explain, persuade, elaborate, and evaluate.
- classroom validation processes formed a significant part of instruction, which moved many students to higher-order thinking tasks as they were engaged in inquiry.

Essentially, this classroom most closely reflects Teaching Standard E of the National Science Education Standards (National Research Council, 1996):

> Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers
>
> - Display and demand respect for the diverse ideas, skills, and experiences of all students.
> - Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
> - Nurture collaboration among students

- Structure and facilitate ongoing formal and informal discussion based on a shared understanding of the rules of scientific discourse.
- Model and emphasize the skills, attitudes, and values of scientific inquiry. (45-46)

Having described scoring guides and the classroom much as I would describe them in the methods class, I now return to the "teacher education" issues of preservice teachers' reactions to scoring guides, and some the instructional issues that scoring guides address.

How do preservice teachers react to the idea of scoring guides?

"You should publish this, because it's really good."--*Melanie, preservice intern.*

"Thank you for this. After hearing all of this rhetoric about student centered learning, we finally get to see how it might be done. I still have a lot of questions, but I'm hopeful now that I see how someone has made this work." -*Ernest, preservice intern.*

When preservice teachers first see an example scoring guide, they want to know how it works. I often tease them with a one-liner: "Students use this guide to grade each others' tests and quizzes." Then there's a round of "wait a minute" and looks of disbelief. Instantly, more questions pop up, and I launch into an explanation with the following main points:

1. One must build a classroom culture that supports this kind of activity, and this takes time.
2. One must build the skills necessary for students to begin to do this sort of thing; once students begin with a simple example and the teacher has provided support for them, one can progress to more complex and daunting tasks.
3. The mechanics of using the scoring guide include:
    - each paper is read and evaluated by two peers, so some system for managing the paper flow in the classroom is required. I give each student two scoring guides and one

paper at the outset, and once the first paper is scored, it is placed on a "graded once" pile, and the completed scoring guide is given to the teacher. Another paper is picked up from the "graded once" pile and is scored by the student. As they are completed, these "second readings" are paper-clipped together as they are handed in, and I ask one of the students who finishes first to match these to the first set of score sheets and clip each set together.

- scores are examined by the teacher, who may act as "tie-breaker" in the case of scores that are more than 5-10% different. Teacher records scores in gradebook.
- evaluators initial or sign their evaluations. In some instances, authors do not put their names on their papers, but instead use an alphanumeric code approved by the teacher. This may be necessary to reduce bias, although the teacher will see all papers and scores too, and can catch blatant bias in that process.
- notes, texts, and other materials are allowed during the scoring process, as are discussions with other scorers and the teacher. Much learning occurs as students evaluate peers' work.
- eventually, students will want to develop scoring guides ahead of time, and this is where they take full control of their learning.

Most of the preservice teachers' questions have to do with management: both managing the process and moment, and managing the culture of the classroom to enable this kind of activity. The underlying message that you can't expect this to happen overnight in the classroom is clearly understood by most. My vision of the year as a continuum in which I strive to develop capacities in my students, and my thinking about the continuum of capacities, becomes the focus.

As preservice teachers continue to inquire about scoring guides, I look for an opportunity to remind them that each of them will become "master of the classroom universe"-- ultimately responsible for all that goes on there, but hopefully co-responsible with their students. Within the constraints of district and state curricular mandates (both style and substance), teachers do have quite a bit of latitude in how they achieve their goals....which should be "science for all", and "greater science literacy", but should also involve the teacher being intimately aware of the details of student learning at many points in the learning process.

The general consensus for the last two years in presenting scoring guides in methods classes has two points: it can be viewed as a kind of make-n-take activity, but the work required to develop and maintain the appropriate classroom culture is clear.

Future Plans and Goals

At present, I have not seen teacher education program graduates here using scoring guides in their classrooms. Yet, I am working with a number of graduates from the last few years who are committed to the idea of a progressive classroom culture of inquiry, infused with students writing about their own ideas.

Thus, I must seek examples from classroom teachers, and specifically sites in which to "finish the story" by documenting mini-cases of teacher(s) who decide to implement this kind of assessment practice, and the thinking, challenges, and dilemmas that go with it. This research should be designed for more than my goal to develop a more complete understanding of this tool, but rather to focus on the students' developing capacities over time in such a classroom. Case studies of teachers and students working together in environments such as these will add much to our understanding of what "teaching to the Standards" means.

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Appendix A

SCORING GUIDE - Ch 12 - ***Sarcodines*** AUTHOR ________________

Question: *Imagine that a biologist reported the discovery of a sarcodine that moves by means of pseudopods and has a thick cell wall made of cellulose. Is this report likely to be true? Support your choice.*

First, read the entire essay. Concentrate on understanding what the author has to say. Then, fill in the following:

1. **Overall impression**: CLARITY (3-2-1) (3 is best, 1 is confusing) (3 max) _____
2. **Neatness:** (2-1-0) (2 is best, 0 is undecipherable) (2 max) _____
3. **Organization:** a) clearly states topic at outset (1-0) (1 max) _____

   b) has a plan (4-3-2-1) (4=good plan, 1=rambles) (4 max) _____

SUBTOTAL (10 MAX) __________

Now go back and read for *CONTENT:*

4. Author tells whether report is likely to be true:

   Yes = 1 pt.
   No = 3 pts.
   Doesn't say = 0 pts. (3 max) _____

5. Author says that movement by pseudopods requires a flexible membrane.

   3 pts. = best statement
   2 pts. = partial statement
   1 pt. = implied only
   0 pts. = not stated or implied (3 max) _____

6. Author states that cellulose walls are rigid.

   3 pts. = best statement
   2 pts. = partial statement
   1 pt. = implied only
   0 pts. = not stated or implied (3 max) _____

7. Author refers back to original statement. (1 max) _____

SUBTOTAL (10 MAX) __________

Mechanics Subtotal from above(10 MAX) __________

Content Subtotal from above _______ X 2 = (20 max) __________

TOTAL (30 MAX) __________

One Positive Comment: ____

One Suggestion: ____

Appendix B

SCORING GUIDE: EVOLUTION TEST AUTHOR ________________

1.Name FOUR of the five forces responsible for environmental change over time that we discussed in class:

You may give two points for each of the following responses:

_____*weathering,*

_____*volcanism (or volcanoes),*

_____*plate tectonics (or continental drift),*

_____*climate changes,*

_____*man*

2.Using the data table supplied:*(2 pts. each)*

a.What type of animal first appeared in the Pennsylvanian period?
_____*reptiles*

b.How long did the Permian period last?
_____*55 million yrs.*

c.How many years ago did land plants first appear?

_____*430 million years ago*

d.Which first came out of the water to populate the land, _________plants or animals?
_____*Plants*
Why?
_____*They only require water, sunlight, and oxygen-- and all of these were available on land. Initially the land environment was pretty wet. Animals would have to go through many adaptive changes to meet their many needs on land.*

3.Define and give examples of divergent evolution and convergent evolution.*(2 pts. each for definitions, 2 pts. each for examples.)*

_____*DIVERGENT EVOLUTION is defined as a process of several species resulting from a common ancestor over time. An example might be the birds, which are thought to have evolved from a common ancestor long ago. Today there are thousands of species.*

_____*CONVERGENT EVOLUTION is defined as a process in which members of different species develop similar traits or characteristics due to similar environments. The traits are similar in appearance and function, but not in origin. Examples might be the whales and porpoises that have developed fins similar to those of fish in appearance and function.*

****You may ask me about definitions or examples!*

4.Using an organism of your choice with an obvious adaptation, explain change over time according to LaMarck and Darwin.

*Give 1 point for mentioning the idea or key word listed, and one additional point for telling what it means. Use this guide as a checklist: ***see me if the author does not use a single organism and a single trait to show both theories!****

Lamarck states that

_____*change occurs because the environment creates needs for organisms*

_____*if an organism uses a body part in a particular way, the body part will change to meet the need.*

_____*if an organism does not use a body part, it will grow smaller and eventually become useless or disappear.*

_____*acquired characteristics are passed on to offspring,*

_____*over time, the species changes as these traits accumulate.*

Darwin states that

_____*overproduction occurs in nature. Many offspring are produced.*

_____*there is competition for survival among these offspring. They compete for food, water, shelter.*

_____*variations occur in species. Each member of a species has slight differences from other members, and some of these differences will make a difference in survival.*

_____*survival of the fittest (natural selection). Those individuals which fit the environment best will survive in greater numbers to reproduce.*

_____*over time, the species changes as these traits accumulate.*

5.Define:*(1 pt. for synonym, 2 for def., 3 for def + example)*

_____a.variation=*differences between members of the same species that make each unique. Examples for humans are hair texture, build, shape of nose, skin tone.*

_____b.species=*organisms that interbreed successfully in nature. All birds share certain similarities, yet there are thousands of species, and only those within a species can interbreed successfully.*

_____c.isolation=*in nature, members of a species are separated from other members of the same species by geographic or reproductive barriers. An example is two groups of minnows separated by creation of a waterfall.*

VIRTUAL FIELD TRIPS IN THE EARTH SCIENCE CLASSROOM

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The Field Trip in the Earth Science Classroom

This paper is from the Preconference Workshop entitled "Preparation and Classroom Applications of Virtual Field Trips for Use in Elementary, Middle School, and Secondary Education."

Earth Science is "the field"

Everyone needs to know about the Earth because they live on it, walk on it, and are surrounded by every aspect of it. Earth Science teaching is conducted primarily in three different learning environments: in the classroom; in the laboratory; and in the outdoors (Orion and Hofstein, 1994). Outdoor field trips offer excitement, adventure, and visual, auditory, kinesthetic, olfactory and gustatory experiences for learning about our world and how it works. They are an effective tool to enhance academic learning and are the best technique with which to study real world events and processes (Appendix A).

To geologists, meteorologists, oceanographers, soil scientists, astronomers (and all other Earth scientists), the "field" is where are of the action is! Field studies consist of the methods used to examine and interpret structures, materials, and processes in real time and in the real world. Field studies are the primary means of obtaining scientific knowledge about the great ideas (concepts) of Earth Science. (Compton, 1962).

Why take a field trip?

The literature provides several reasons why a teacher might choose a field trip as a teaching strategy. These include:

1. Promote increased learning (Benz, 1962; Sorrentino and Bell, 1970; Mason, 1980; Watkins and Guccione, 1992).

2. Provide input in all 5 sensory modes (Stonehouse, 1984; Lovedahl and Tesolowski, 1986; Woerner and Stonehouse, 1988)

3. Need for concrete experiences (Novak, 1976; Orion, 1993)

4. Act as subsumers for further learning in the classroom (Novak, 1976)

5. Concentrate on processing, or the generation of meaning (Wittrock, 1974; MacKenzie and White, 1982)

6. Increase motivation and provide a new or different environment for the students which may change their attitude toward the class or the subject (Kern and Carpenter, 1984; McKenzie, Utgard, and Lisowski, 1986; McCombs, 1990).

7. Provide a new environment for the teacher to observe students and their learning strategies.

Prather (1989), in his review of the value of field trips in science instruction, concluded that field trips are effective for both factual and conceptual learning and for achieving affective objectives. In addition, he states, "compared to other traditional teaching techniques, field trips may provide an especially rich stimulus setting for content learning and may excel in generating a natural inclination to learning." Prather reminds us that field trips are not inherently effective instructional tools, and that learning is a result of careful planning and preparation to ensure that the field trip learning is related to the intended instructional objectives. How effective a field trip is depends on how well they are planned and structured so that they do more than provide a novel environment.

Factors which influence learning on a field trip

Orion and Hofstein (1994) studied factors which influence learning during scientific field trips and delineated three categories of factors which could influence learning by students:

1. tea*ching factors*, such as the place of the field trip in the curriculum structure, didactic methods, learning aids, and quality of teachers;

2. *field trip factors*, such as the learning conditions at each learning station, duration and attractiveness of the trail, weather conditions during the field trip;

3. *student factors*, such as previous knowledge to trip topics, previous acquaintance with trip area, previous experience in field trips, previous attitudes toward subject matter, previous attitudes to field trip, and class characteristics (grade, size, area of interest, major)

What are the components of an effective Earth Science Field Trip?

A review of the literature provides the following components which should be included if the Earth Science field trip is to be effective. These are:

1. Must be linked to and integrated with the curriculum (Orion and Hofstein, 1994; Millan, 1995)
2. Careful selection of concepts to be learned (Novak, 1976; Orion, 1993)
3. Focus attention on what is to be learned — specify objectives and focus students on them (Koran and Baker, 1979; Rudmann, 1994; Miller, 1995)
4. Advance organizer and relevant knowledge prior to trip to provide scaffolding (Koran and Baker, 1979; Orion and Hofstein, 1994; Rudmann, 1994)
5. Plan activities and relevant information prior to field trip to reduce "novelty space" [cognitive preparation-geographical preparation-psychological preparation] (Koran and Baker, 1979; Orion, 1993)
6. Focus on concrete activities which cannot be conducted effectively in the classroom; process oriented approach (Orion, 1993)
7. Pace of learning in continuous and flexible (Koran and Baker, 1979)
8. Students move around and participate actively Koran and Baker, 1979) using all five sensory modalities (MacKenzie and White, 1982; Lovedahl and Tesolowski, 1986; Woerner and Stonehouse, 1988)
9. Students generate information, rather than receive it, and construct their own records of the scene (MacKenzie and White, 1982)
10. Assessment or evaluation is congruent with teaching/learning strategies used on the trip

The Virtual Field Trip

What is a Virtual Field Trip?

A Virtual Field Trip is a journey taken without actually making a trip to the site. It should be undertaken as an integral part of the curriculum and address concepts and processes which have been carefully selected by the teacher. In reality, it is any trip taken via an alternative means, and could include slides, a set of rocks appropriately placed around the classroom, a stream table, a movie or video, a CD-ROM, or the use of the Internet and Web Sites about a particular site.

Although all of these would qualify as "virtual" field trips, within the scope of this workshop, a "Virtual Field Trip" is taken with the computer as the vehicle which "moves" students in virtual space and time to a particular real world site.

Why take a Virtual Field Trip?

Virtual Field Trips are a method of providing field experiences that take students to places that, until now, the teacher could only dream about — and these virtual field trips help teach things students might not otherwise learn. Although each teacher does not have a spectacular example on the school grounds to illustrate an Earth Science concept right at the moment it is needed, a trip to such a site is right at the teacher's fingertips. In addition, there are some place you just can't go in the real world!

In addition, various constraints (such a lack of knowledge about the local environment, cost of transportation, time needed for organization, worries about lawsuits etc.) cause teachers to select classroom and laboratory experiences rather than taking students into outdoor environments. During a real world field trip, examples described in the textbook may not be obvious, the site may require great physical exertion or be unsafe, or the weather may be lousy.

The World Wide Web is touted to be able to transform teaching and learning. With the Web's ceaselessly increasing capacity for multimedia, multimodal communication, information presentation, and easy access to an exponentially increasing body of knowledge, the ways in which students learn and interact in classrooms is changing. (Appendix B provides a list of Web sites which have Virtual Field Trips.) Just as is the case with real world field trips however, Virtual Field Trips are not inherently effective instructional tools, and learning is a result of careful planning and preparation (Prather, 1989; Pedretti, 1998; Zhao, 1998). As with its real world counterpart, students need time for exploring, making observations, taking wrong turns, testing ides, doing things over, collaboration, collecting things, and constructing models for testing ideas.

They also need time for learning prerequisite concepts they may need to deal with the questions at hand (Myers and Botti, 1997).

New interactive technologies create new roles for teachers, present opportunities for and barriers to effective instruction, affect student and teacher satisfaction, and demand increased teacher time to learn to use the emerging virtual environments. To be effective, a virtual field trip must be designed using models and theories of human learning (including active learning) and effective instructional design.

What are the components of an effective Virtual Earth Science Field Trip?

Good Virtual Field trips have many features (Table 1) of effective real-world field trips. (The Virtual Geography Department, 1997; Gray, 1997; TLC Systems, 1998).

Table 1
Components of Effective Virtual Field Trips

The Virtual Field Trip should have:

- a specific focus or objective(s) which is clearly stated
- an integral part in the classroom learning
- a pre-trip orientation with concrete activities
- a navigator to guide students easily around the field trip site
- a post-field trip follow-up with activities and debriefing

The students should be able to

- move around at their own speed and select what is meaningful to them to see and experience
- interact with the field trip environment and use multiple sensory modalities
- have access to content experts who understand the events, processes, and concepts illustrated at the site
- make observations, collect and analyze data, and construct their own explanations
- compare their observations and explanations to those made by other students and field "experts"

The online features should:

- be rich in context and aesthetically pleasing
- a navigator to guide students easily around the field trip site
- have online resources which provide easy access to the content
- relate the focus or objectives to the curriculum content of the site
- use the unique features of the Web
- accommodate multiple modalities and learning styles
- facilitate independent investigation and cooperative group work
- contain suggested off-line student activities

• contain appropriate links to related sites

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APPENDIX A

Learning Success

Learning tends to be a rather haphazard activity. The most successful teachers have learned from experience and they do intuitively whatever is necessary to promote learning. What is known about learning strategies is that learners receive information through one of their five senses and store is using the same sensory modality. When people represent what they know in conscious memory (remember). they again use the same sensory modality in which they received the information (Dilts, Grinder, Bandler, Cameron-Bandler, and DeLozier, 1980 and Woerner and Stonehouse, 1988).

Earth Science education is often mistakenly considered to be less important, less rigorous, or a non-college entrance course. Earth Science is, perhaps, less precise than Biology, Chemistry, and Physics, but it is much more complex in terms of systems' interactions. Where else can one deal with Astronomical Units and pico seconds or with the size of the universe and subatomic particles all in the same lesson? What other science involves four dimensions — three spatial and one temporal. What other science ties its abstract thinking so closely to objects we have all experienced as intimately as rocks, water, and air? Earth Science is not simple, but it can provide a motivation for significant learning (Stonehouse, 1984).

All Earth Science teachers are aware of their students' almost universal satisfaction with "hands-on" activities which are an essential part of Earth Science teaching. The reason it is satisfying is that is produces a break in the (perceived) monotony of sitting still and reading, and it also engages two (Visual and Kinesthetic) modalities (representational systems) simultaneously which produces a stronger motivation to learn. Field activities, even though they may only involve sampling the soil in the school yard, have a similar or stronger effect because they tap into remembered pleasant visual, kinesthetic, and other images of "playing in the dirt" or just being outdoors (Stonehouse, 1984).

We have had uncountable informal experiences with the Earth which are there to be tapped as we engage in formal study of the Earth in the field. We can connect our new experiences to the informal ones, and we have more channels of input to help with remembering later on. A primary positive outcome of field trips is that they permit learner to experience sensory impressions that cannot be repeated in the classroom (Lovedahl and Tesolowski, 1986). Field study involves learning and remembering in more than one modality (often all five) which provides for more successful and more pleasant learning.

APPENDIX B

Earth Science Internet Sites

Virtual Field Trips

Virtual Geography Department
http://www.uwsp.edu/acaddept/geog/projects/index.htm

Deep Lock Quarry Physical Geography Virtual Field Trip
http://www.uakron.edu/geography/lrb/trips/dquarry/index.html

CESME Virtual Field Trips
http://cesme.utm.edu/projects/projects.html

Indian Peaks, Colorado, Front Range Virtual Field Trip
http://www.uwsp.edu/acaddept/geog/projects/virtdept/ipvft/start.html

Virtual Tour of the Mendenhall Glacier
http://www.snowcrest.net/geography/field/mendenhall/index/htm;

Virtual Tour of Mt. Hamilton and Lick Observatory
http://www.ucolick.org/pubinfo/tour.html
http://www.irving.org/cgi-bin/xplore.cgi?lick+hwyquim+A

The Virtual Mt. Shasta Climb
http://www.geocities.com/Yosemite/2483/shasmap1.htm

Shasta Virtual Field Trip
http://www.snowcrest.net/freemanl/shasta/index.html

Virtual Hawaii
http://www.satlab.hawaii.edu/space/hawaii/index.html

A Virtual Fieldtrip of the Geology of Kansas City
http://www.umkc.edu/sites/env-sci/virgeol/vftstart/vftstart.htm

Grand Canyon Explorer
http://www.kaibab.org/geology/gc_geol.htm

Virtual Field Trip of the Tomorrow River
http://www.uwsp.edu/acaddept/geog/courses/geog391/toriv/g391main.htm

Monterrey Bay Virtual Canyon Site
http://www.virtual-canyon.org/overview.html

The Virtual Cave
http://www.goodearth.com/virtcave.html

Houghton Mifflin Geology Virtual Field Trip Site
http://www.geologylink.com/fieldtrips/

The Virtual Field Trip Site
http://www.field-guides.com/

A Virtual Field Trip to the Birch Aquarium
http://www.rsf.k12.ca.us/Subjects/Birch/Birch.Aquarium.Fieldtrip.html

BigBend Virtual Field Trip
http://geoweb.tamu.edu/faculty/herbert/bigbend/intro/index.html

The NPS Mammoth Cave
http://www.nps.gov/maca/macahome.htm

Electronic Field Trip to Mammoth Cave
http://www.ket.org/Trips/Cave/Index.html

Geophysics Field Trips
http://gretchen.geo.rpi.edu/field_trips.html

Flynn Bogs
http://csdl.tamu.edu/FLORA/flynnbog/FB1.HTML

Geology of Georgia
http://www2.gasou.edu/geol/1.2TOC.html

Window on Arizona
http://www.geo.arizona.edu/Geo256/azgeology/

Haughton-Mars Expedition 1998
http://www.arctic-mars.org/

Telecom Amazon Adventure Home Page
http://vif27.icair.iac.org.nz/

Welcome Aboard the Earth Quest 2000 Homepage!
http://www.eq2000.com/

GOALS: Global Online Adventure Learning Site
http://www.goals.com/

Arctic Challenge
http://www.adventureonline.com/ige/index.html

The JASON Project
http://www.jasonproject.org/front.html

San Andreas Fault sites

Southern California Earthquake Center
http://www.scec.org/

Southern California Earthquake Center Data Center
http://www.scecdc.scec.org/

U.S,G,S, Pasadena Office
http://www-socal.wr.usgs.gov/

Seismological Laboratory at Cal Tech
http://www.gps.caltech.edu/seismo/seismo.page.html

U.S.G.S.Northern Office
http://quake.wr.usgs.gov/

University of California Berkeley Seismological Laboratory
http://www.seismo.berkeley.edu/seismo/seimso.baseis.html

The San Andreas Fault at the San Francisco Bay
http://sepwww.stanford.edu/oldsep/joe/fault_images/BayAreaSanAndreasFault.html

U.S.G.S. Publications on the San Andreas
http://pubs.usgs.gov/publications/text/San_Andreas.html

Hayward fault tour
http://www.mcs.csuhayward.edu/~shirschf/tour-1.html

The Hayward Fault at UC Berkeley
http://www.seismo.berkeley.edu/seismo/hayward/ucb_campus.html

Hollister Active and Passive Seismic Investigation
http://gretchen.geo.rpi.edu/roecker/hollister/hollister.html

San Fran Museum EQ links
http://www.sfmuseum.org/1906/89.html

Web Design sites

Web Page for Designers (in England)
http://www.wpdfd.com/wpdhome.htm

Web design by Lynda Weinman
http://www.Lynda.com/

HiveFive Info
http://www.HighFive.com/core/cover_left.html

tlc.webdesign
http://www.tlc-systems.com/

Yale Web Design
http://info.med.yale.edu/caim/manual/contents.html

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