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ABSTRACT

The 40 papers from this international conference addressed the major theme of facilitating science literacy for all teachers and students. Papers include the following: (1) "Confronting the Gender Gap in Science and Mathematics: The Sisters in Science Program" (P. Hammrich); (2) Teaching Instructional Materials for Science Educators with a CD-ROM and a World Wide Web Support Network (A. Bodzin, J. Park, L. Grable); (3) Integrated Science and Math for Junior High Teacher Preparation: Staff Development as a Continual Process (B. Baird, S. McClary); (4) Constructivist Assessment Practices (R. Harris Freedman); (5) Influence of Modeling Constructivist Learning Environments on Preservice and Inservice Teachers (L. Richardson, P. Simmons, M. Dantonio, M. Clough); (6) Mentoring Future Mentors: The Preparation of Science Teacher Educators (J. Craven III); (7) What the Science Standards Say: Implications for Teacher Education (P. Hammrich); (8) Student and Teacher Conceptions about Astronomy: Influences on Changes in Their Ideas (V. Dickinson, L. Flick, N. Lederman); (9) Literacy through the Learning Cycle (E. Marek, B. Gerber, A. Cavallo); (10) Laboratory Skills and Competencies for Secondary Science Teachers (G. Saunders, C. Dawson, B. Tripp, T. Pentecost, M. Chaloupka, J. Saunders); (11) Maximizing the Impact of Your Inservice: Designing the Inservice and Selecting Participants (L. Henriques); (12) Science, Parents, Activities, and Literature: Overview, Results, and Reflections (J. Shymansky, L. Yore, J. Dunkhase, B. Hand); (13) Students' Perceptions of Science Teaching and Attitudes toward Science Learning and Teachers' Self-Report of Using Children's Ideas, Applications of Science, and Use of Print Resources as Indicators of Interactive-Constructivist Teaching in Elementary Schools (L. Yore, J. Shymansky, L. Henriques, B. Hand, J. Dunkhase, J. Lewis); (14) Teaching through Inquiry: A Novice Teacher's Authority of Experience (B. Crawford); (15) Less Talk, More Action, for Multicultural Science Education (J. Weld); (16) Integrating Field Experience and Classroom Discussions: Vignettes as Vehicles for Reflection (M. Volkmann); (17) Developing and Acting Upon One's Conception of the Nature of Science: A Follow-Up Study (F. Abd-El-Khalick, N. Lederman, R. Bell); (18) The Impact of Training and

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Induction Activities upon Mentors as Indicated through Measurement of Mentor Self-Efficacy (I. Riggs); (19) Measuring the Self-Efficacy of Upper Elementary and Middle School Teachers: Implications for Outreach (W. Boone, V. Chase); (20) Innovative Science Education Grant: From Recruitment, through Preservice, into Entry-Level Service (M. Neathery, R. Bryant, D. Dill); (21) Good versus Bad Culturally Relevant Science: Avoiding the Pitfalls (C. Loving, B. Ortiz de Montellano); (22) The Classroom as a Stage for Examining Gender Microinequities (C. Wick); (23) Museum & Methods Collaboration: Understanding Science Teaching via Distance Learning Technology (T. Barshinger); (24) Teaching Practices That Provide Cognitive Scaffolding for Classroom Inquiry (L. Flick); (25) The Ideal Advisor: Graduate Science Students' Perspective (M. Ferreira); (26) Modifying Hands-On Science Lessons for Students with Special Needs: A Model of Collaboration (L. Houtz, S. Watson); (27) Pushing the Comfort Zone: Confronting the Perceptions of Teaching and Classroom Culture (M. Fetters); (28) Teaching about Classroom Management in a Constructivist Methods Class Environment (R. Vellom); (29) Mezirow's Theory of Transformative Learning with Implications for Science Teacher Educators (W. DiBiase); (30) Using a Web Site in an Elementary Science Methods Class: Are We Opening a Pandora's Box? (S. Lewis, G. O'Brien); (31) A Project Designed To Engage K-8 Preservice and Inservice Teachers in Classroom Inquiry (C. Barman); (32) Stimulating Professional Growth of Teachers through Action Research (F. Shaka); (33) Using the Science Misconceptions Research To Address Science Teaching Misconceptions (S. Weber); (34) Shifting from Activity Mania To Inquiry Science--What Do We (Science Educators) Need To Do? (H. Moscovici); (35) How Much is Enough? Preparing Elementary Science Teachers through Science Practica (D. Crowther and J. Cannon); (36) Using Negotiated Criteria and Peer-Evaluation in Undergraduate Elementary School Science Education Programs (L. Yore); (37) Extending Our Networking and Professional Development as Science Teacher Educators and Researchers: A Forum by and for Graduate Students (K. Wieseman, B. Rascoe, H. Wang, A. Kemp, L. Bryan, and V. Dickinson); (38) Gender, Ethnicity, and Grade level as Predictors of Middle School Students' Attitudes toward Science (M. Weinburgh); (39) Preparing "Professional" Science Teachers: Critical Goals (P. Dass); (40) Acids & Bases Curriculum Unit: An Inquiry-Based Context for Teaching the Particulate nature of Matter and Changes in Matter (S. Erduran, R. Duschl). (DDR/NB)

ED 421 363

Proceedings of the 1998 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

Preface

These proceedings of the 1998 Annual International Conference of the Association for the Education of Teachers in Science are intended to be a record of the AETS annual meeting held in Minneapolis, Minnesota, January 8-11, 1998. Forty papers presented at and summaries of presentations made at that AETS annual meetings are included here along with a copy of the conference program. The papers and presentations summaries are in order here by the corresponding conference session. The conference program also is included

In editing papers and presentation summaries, suggestions were made on ways to enhance clarity and on formatting. Because the proceedings are to serve as the record of an AETS annual meeting, the papers and presentation summaries were not refereed. Those that were revised and returned by a designated date were included. We thank the members of AETS who presented at the conference and submitted a paper or presentation summary for inclusion in these proceedings.

The proceedings are disseminated via the ERIC Clearinghouse for Science, Mathematics and Environmental Education in microfiche form (with hard copy available through ERIC) and on the AETS World Wide Web Site. Given ERIC documents and web materials are not copyrighted, the papers and presentation summaries published in the proceedings may be submitted by the author(s) to journals, for example the *Journal of Science Teacher Education* and *Science Education* both of which are associated with AETS. Information on how to secure a microfiche or hard copy of the proceedings is available through ERIC -- see you campus or local library, WWW URL http://edrs.com/, or phone 800-433-ERIC. Also, the papers and presentation summaries may be down-loaded directly from the AETS WWW site as RTF (Rich Text Format) files.

We are pleased to have had the opportunity to edit the 1998 AETS Conference Proceedings.

Peter A. Rubba, The Pennsylvania State University
James A. Rye, West Virginia University

Acknowledgments

The editors gratefully acknowledge the assistance of Colleen McMahon and Lieann McDonald in helping to compile these proceedings, and Bobbi Robison and Eileen Pennisi in placing them on the WWW.

Table of Contents

1998 AETS Conference Program

ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE, 1998 ANNUAL INTERNATIONAL CONFERENCE, JANUARY 8-11, 1998: MINNEAPOLIS, MINNESOTA.

1998 AETS Annual International Meeting
January 8-11, 1998
Hilton and Towers Hotel - Minneapolis, Minnesota

Conference Theme: Diversity: Facilitating Science Literacy for All Teachers and Students

Welcome to the 1998 Annual AETS International Meeting in Minneapolis, Minnesota. The luxurious Minneapolis Hilton and Towers Hotel is the conference Headquarters which is centrally located in the downtown walkway system connecting the hotel to numerous dinning and shopping venues. You are just a short bus or Taxi-cab ride from the Science Museum of Minnesota (site of the Thursday evening reception), the Mall of America (Saturdayís evening event) as well as museums, theaters, zoos, and historical sites. The concierge will be happy to assist you in planning any side trips during your trip to the Twin Cities of Minneapolis and St. Paul. If you havenít already noticed, the Hilton is a facility of the highest quality. The meeting facilities are excellent and there is plenty of seating for those impromptu gatherings that are as important as the formal meeting. Our North Central members welcome you and look forward to a highly productive and enjoyable conference.

The corporate sponsors for the event are Compaq Computers, Media Seek Technologies, and Logal Software. Additional support has been provided by local organizations including SciMathMN, Newtonís Apple, the Science Museum of Minnesota and the Minnesota Department of Children, Families and Learning Best Practice Network. Several North Central universities also made cash or in-kind donations to support conference activities. They are Purdue University Calumet, University of Minnesota - Twin Cities, St. Cloud State University, Moorhead State University, University of Wisconsin - Milwaukee, Western Illinois University, University of Wisconsin - La Crosse and Southeast Missouri State University. As a member of AETS and a conference attendee please let these organizations know how much you appreciate their support of AETS.

We would like to thank all of the committee members who worked over the past year to help make this event successful. Their individual names and contributions are listed on the following page. As always, thanks to Joe Peters for the tremendous effort he puts into registration and fiscal arrangements. Thanks also to the local arrangements committee and their representatives who worked hard to make the Thursday evening reception a success despite the ever-changing plans which accompanied the event. Additional thanks are provided to the many AETS members, including our president Bill Baird and corporate sponsor chair Michael Jay, who provided us with insight and guidance on the intricacies of an activity one does only once as a novice. The assistance provided by the committees of the Seattle and Cincinnati meetings were especially helpful. The assistance provided by the hotel staff, Tom Harrington and Ted Trembath are also worth noting.

You will no doubt see several of the committee members scurrying about the hotel attempting to insure that all goes according to plans. If you have any questions, concerns, or comments, please do not hesitate to let us know.

Patty Simpson and George Davis, Conference Co-Chairs

1998 AETS Annual International Meeting
Diversity: Facilitating Science Literacy for all Teachers and Students
Minneapolis Hilton and Towers, Minneapolis, Minnesota, January 8-11, 1998

Conference Committees

Co-Chairpersons	George Davis and Patricia R. Simpson
Program Co-Chairs	Craig Berg, University of Wisconsin-Milwaukee Michael Clough, University of Iowa Lloyd Barrow, University of Missouri
Registration	Lucy Slinger, University of Wisconsin - La Crosse Joe Peters, University of West Florida Judy Beck,University of Wisconsin - La Crosse Sharon Coleman, Southeast Missouri State University
Technology Room/AV	James A Russett, Purdue University Calumet
Local Arrangements	Kathleen Lundgren, Minnesota CFL Marcia Houtz, Science Museum of Minnesota Melva Sayne, Newton's Apple
Speakers	Bob Hollon, University of Wisconsin - Eau Claire
Evaluation	James A Russett, Purdue University Calumet Gary Varella, University of Iowa
Exhibits	Bob Rivers, Purdue University Calumet
Publicity	Kevin Finson, Western Illinois University
Corporate Sponsors	Michael Jay, Larry Flick,Oregon State University Bill Baird, Auburn University

Program Proposal Reviewers

Matt Beisel	University of Iowa
Craig Berg	University of Wisconsin-Milwaukee
Michael Clough	University of Iowa
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Frank Crawley	East Carolina University
Elizabeth Doster	East Carolina University
M. Virginia Epps	University of Wisconsin-Whitewater
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Patricia Simmons	University of Missouri-St Louis
John Stiles	College of the Atlantic-Maine
John Tillotson	Syracuse University
Mark Trax	University of Iowa
Gary Varrella	Ohio University

Peter Veronesi	SUNY College at Brockport
HsingChi A Wang	University of Southern California
Scott Watson	East Carolina University
Jeff Weld	University of Iowa
Randy Yerrick	East Carolina University

Registration Location and Hours The registration desk is located in the cloakroom on the third floor 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. Tickets may also be purchased and/or picked up here for events at the Mall of America on Saturday. Registration will be open during the following hours:

Wednesday evening	8:00 pm - 9:00 pm
Thursday	7:00 am - 5:00 pm: 9:00 pm - 10:00 pm
Friday	7:00 am - 5:00 pm
Saturday	7:00 am - 2:30 pm

Program printing costs were sponsored by MediaSeek Technologies Inc. Cloth bags were provided by SciMathMN.

Amenities

As a part of registration fees, a light continental breakfast will be available on Friday and Saturday from 6:30 am - 9:00 am in Salon A-C. Breaks will be provided on Thursday, Friday, and Saturday in the foyer on the third floor at 10:20 am and 3:20 pm.

Special Events

There are several special events that have been included within your conference registration. These include the Invited Speaker Luncheon, the Annual Awards Ceremony/Business Meeting Luncheon, and the Friday evening reception. Additional social events have been arranged for our members at a minimal charge. They include the Science Museum of Mineesota reception on Thursday evening and the trip to Mall of America on Saturday night. The specific times, dates and locations of these events are as follows:

Thursday Reception 5:00 pm - 9:00 pm

(The meal is sponsored by Compac Computer. The Omni Max presentation is sponsored by University of Minnesota - Twin Cities. Additional sponsors for the eveningís events include the Science Museum of Minnesota, Newton's Apple, Southeast Missouri State University, and MN CFL Best Practice Network)

A cash bar will be available.

Science Museum of Minnesota - St. Paul - Buses provided *Ticket required

Friday Luncheon 12:00 pm - 2:00 pm

Invited Speaker - Eric Jolley, Education Development Center

(Speaker sponsored by LOGAL Software, Inc.)

Salon A-C

Friday Reception 4:50 pm - 6:30 pm

(Event sponsored by Purdue University Calumet)

A cash bar will be available.

Salon A - C

Saturday Luncheon 12:00 pm - 2:00 pm
Annual Awards Ceremony/ Business Meeting

Saturday Evening Event 5:15 pm - 9:00 pm
Mall of America - Bloomington, MN - Buses provided *Ticket required
Camp Snoopy and Underwater World tickets are available at the registration desk.

1998 AETS National Meeting Schedule of Events

Wednesday Jan 7th

Board Meeting:	6 pm - 10 pm	Rochester
Registration:	8:00 - 9:00 pm	Coatroom

Thursday Jan 8th

Registration:	7:00 am - 5:00 pm; 9:00 - 10:00 pm	Coatroom

Workshops:

1) An Exemplary Elementary Science Methods Course: 8 -12 noon	Rochester
2) An Exemplary Secondary Science Methods Course: 8 -12 noon	Duluth
3) Eval.Curr. Materials Against Specific Science Literacy Goals: 8 - 12 noon	Carver
4) Science Teaching for Students With Disabilities: 8 am - 4:30 pm	Hennepin

Lunch:	On your own
Session 1:	1:00 - 2:00
Session 2:	2:20 - 3:20
Session 3:	3:40 - 4:40

Reception at the Science Museum: Buses leave at 5 and 5:30 pm

Friday Jan. 9th

Registration:	7:00 am - 5:00 pm; 9:00 - 10:00 pm	Coatroom
Continental Breakfast:	6:30 - 9:00 am	Salon A-C
Session 1:	8:00 - 9:00	
Session 2:	9:20 - 10:20	
Session 3	10:40 - 11:40	
Lunch:	12:00 - 2:00	Salon A-C
Session 4:	2:20 - 3:20	
Session 5:	3:40 - 4:40	
Session 6:	4:50 - 5:30 (Poster Session & Reception)	Salon A-C
Committee meetings	5:30 - 6:30	Salon A-C
Dinner:	On your own	

Saturday Jan 10th

Registration:	7:00 am - 2:30 pm	Coatroom
Continental Breakfast:	6:30 - 9:00 am	Salon A-C
	6:30 - 7:50 (Committee meetings continued)	Salon A-C
Session 1:	8:00 - 9:00	
Session 2:	9:20 - 10:20	
Session 3	10:40 - 11:40	
Lunch:	12:00 - 2:00	Salon A-C
Session 4:	2:20 - 3:20	
Session 5:	3:40 - 4:40	

Evening Activities at Mall of America: Buses leave at 5:15

Sunday Jan 11th

Board Meeting	8 am - 12 noon		Rochester
Session 1:	8:00 - 9:00	Methods Sharing Session	Board 1
	8:00 - 10:00	CASE Network Meeting	Duluth

Workshops on Thursday

#1
Title: An Exemplary Elementary Science Methods Course.
Presenters:
Cathy Yeotis & Twyla Sherman - Wichita State University
Pat Keig - Cal State Fullerton
Patti Nason - Stephen F. Austin State University
Gail Shroyer & Dee French - Kansas State University
Margaret Bolick - SW Educational Development Lab
Barbara Spector - University of South Florida
Description: In this workshop the presenters are targeting the components of the ideal elementary science methods course.
Time: Thursday from 8-12 noon.
Fee: $25 (covers materials and numerous handouts)

#2
Title: An Exemplary Secondary Science Methods Course.
Presenters: John Penick - University of Iowa
Ron Bonnstetter - University of Nebraska
Description: In this workshop the presenters are targeting the components of the ideal secondary science methods course.
Time: Thursday from 8-12 noon.
Fee: $25 (covers materials and numerous handouts)

#3
Title: Evaluating Curriculum Materials Against Specific Science Literacy Goals
Presenters: Jo Ellen Roseman & 2061 Staff
Description: Participants will use Project 2061's curriculum analysis procedure to evaluate how well a specific curriculum material addresses the science literacy goals outlined in Benchmarks for Science Literacy.
Time: Thursday from 8-12 noon.
Fee: $25

#4
Title: Science Teaching for Students With Disabilities
Presenters: Members of the AETS Committee on Inclusive Science Education
Description: The goals of the program include: 1) sharing information on best practice relating to inclusive instruction in science education, 2) allowing participants to experience model lessons with accommodations for students with disabilities, 3) utilized to more effectively meet the needs of students with disabilities in the science classroom.
Time: Thursday from 8 am to 4:30 PM.
Fee: $40 (materials and covers the cost of lunch).

Thursday 1:00- 2:00

T 1.1 Duluth contributed paper (15 min.) college
Kathryn Powell, University of New York

The Demands of Diversity: Expectations of Teachers From a Multicultural and Diverse Community. What do members of a rural, multicultural community expect from teachers in the classroom? What knowledge, skills, and traits are perceived to be important to community welfare?

T 1.1 Duluth contributed paper (15 min.) elementary
Penny Hammrich, Temple University; Kerri Armstrong, Community college of Philadelphia

Confronting the Gender Group in Science and Mathematics: The Sisters in Science Program: 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. The design, results, and implications will be discussed.

T 1.1 Duluth contributed paper (15 min.) elementary
Carolyn Dickman, Radford University

Reconstructing Science Instruction for Underrepresented Students: Results from a year long institute for teachers of grades k-6 to aid them in teaching science effectively to traditionally underrepresented groups.

T 1.2 Board 1 demonstration (60 min.) general
Alec Bodzin, North Carolina State University; John Park, North Carolina State University; Lisa Grable, North Carolina State University

Teaching Instructional Materials for Science Educators with a CD-ROM and a World Wide Web Support Network: This demonstration will show how we incorporate the instructional materials for science educators (IMSE) CD-ROM and its on-line support network for science teacher education.

T 1.3 Carver contributed paper (30 min.) elementary
Lynn Bryan, University of Georgia

Preservice Elementary Teacher Beliefs about Science Teaching and Learning and the National Science Education Standards: Conflict or Compatibility? This paper will examine five preservice elementary science teacher beliefs in comparison to the National Science Education Standards and explore implications of the compatibility and/or conflict between them.

T 1.3 Carver contributed paper (30 min.) elementary
John Settlage, Cleveland State University

Urban Students' Images of Science and Self: Elementary school children photographed "science" around their homes. Interviews of the children revealed what the images portrayed about their connections to science.

T 1.4 Rochester panel (60 min.)
Jim Ellis, University of Kansas; Lowell Bethel, Janice Earle, Dawn Pickard

NSF Programs: Opportunities For Funding: NSF program officers would explain opportunities for funding teacher education initiatives.

T 1.5 Dir Row 1 contributed paper (15 min.) general
Jimmie Agnew, Elon College

Science Without Borders-Interdisciplinary Science: Collaborative development of an interdisciplinary science course using technology and constructivist techniques for preservice teachers.

T 1.5 Dir Row 1 contributed paper (15 min.) college
Fletcher Brown, University of Montana

Creating Integrated Teaching Experiences in the Science Methods Classroom: This presentation discusses the ongoing reform efforts in the University of Montana secondary science methods classrooms aimed at modeling integrated, inquiry-based, cross-disciplinary teaching.

T 1.5 Dir Row 1 contributed paper (15 min.) middle/secondary
Bill Baird, Auburn University; Susan Gandy, Auburn Junior High School

Integrated Science and Math for Junior High Teacher Preparation: Lessons Learned from the ISTEP Conference. Preservice science and math teachers at Auburn University are learning to work together with colleagues at the local junior high school to design effective theme-based activities that meet state and national standards.

T 1.6 Dir Row 2 panel (60 min.) general
Sandra Abell, Pudue University; Jennifer Karpel, Pudue University; Mark Volkmann, Purdue University; Paul Kuerbis, Colorado College

Standards-Based Reform in Science Teacher Preparation: We will discuss the integration of national standards into science methods and science content courses and national opportunities for engaging in such reform.

T 1.7 Dir Row 3 contributed paper (30 min.) college
Lon Richardson, Southwest State University; Patricia Simmons, University of Missouri; Mike Clough, University of Iowa; Marylou Dantonio, University of New Orleans

Influence of Modeling Constructivist Learning Environments on Preservice Science Teachers: Influence of Modeling Constructivist Learning Environments on Preservice Teachers, integration of theory and practice, and on transfer of learning from university to preservice classroom.

T 1.7 Dir Row 3 contributed paper (30 min.) general
Robin Freedman, Buffalo State College

Assessment Practices: A Merging of Methods: New methods of instruction need new methods of assessment. Reform project participants help define assessments for constructivist teaching strategies.

T 1.8 Dir Row 4 contributed paper (30 min.)
Joseph Riley II, University of Georgia; Michael Padilla, University of Georgia; Katherine Wieseman, University of Georgia; Hideo Ikeda, Hiroshima University

Science Teacher Education in Japan: Student Teaching and the Preparation of Preservice Science Teachers: This paper examines student teaching in the context of a non western Culture.

T 1.8 Dir Row 4 contributed paper (30 min.) general
J. Preston Prather, University of Tennessee; Kueh Chin Yap Nanyang, Technological University

Comparison of Science Teaching and Science Teacher Education in the United States and Singapore-Malaysia: Comparisons of education in the United States and Malaysia will provide insights into the implications of centralized and non-centralized systems for science teacher preparation.

Thursday 2:20 - 3:20

T 2.1 Duluth panel (60 min.) college
Janet Bond Robinson, University of Iowa; Don Duggan-Haas, Bruce Dickau, Claudia Melear, Bill Kubinec, Mike Wavering, John Tillotson, Chin-Tany Liu, Sharon Parsons, Cathy Yeotis, John Craven

Improving Science Teacher Education Based on Research on Thinking and SALISH I Results: Panelists will consist of consortium participants, each a member of one of the university teams who are piloting changes in their teacher education programs. The teams are composed of a science educator, a scientist and a dean. Fourteen universities are involved in the consortium.

T 2.2 Board 1 hands-on workshop (60 min.) general
Alan Colburn, Calif. State Long Beach

Making Web Pages For Use in Your Classes: 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.

T 2.3 Carver contributed paper (30 min.) general
Jodi Haney, Bowling Green State University; Charlene Czerniak, University of Toledo; Andrew Lumpe, Southern Illinois University

Constructivist Beliefs About Science Teaching: Perspectives from Teachers, Administrators, Parents, Community Members, and Students: The constructivist beliefs of teachers and other members of the school community are profiled and compared for similarities and differences.

T 2.3 Carver contributed paper (30 min.) general
Lena Hartzell, Springfield High School; Charlene Czerniak, University of Toledo

Teachers' Beliefs About Accommodating Students' Learning Styles in Science Classes: This paper identifies K-12 teachers' beliefs and subsequent intentions to use a variety of instructional strategies to accommodate students' learning styles in the science classroom.

T 2.4 Rochester demonstration (60 min.)
Michael Clough, University of Iowa

Using the Internet For Extensive Dialogue Regarding Critical Incidents in Science Teaching: This session will address how the Internet may be used to increase instructional time in methods classes while promoting deeper reflection regarding many important issues in science education.

T 2.5 Dir Row 1 panel (60 min.) general
Peter Mecca, Helen Skala, University of Wisconsin- LaCrosse; Peter Csiacsek, Holmen High School; Leah Wisnewski, Onalaska High School

Integration of Mathematics, Science & Technology Education: The Integration of Mathematics, Science, and Technology Education Project at UW-LaCrosse continues an on-going series of programs oriented towards the professional development of teachers in Western Wisconsin.

T 2.6 Dir Row 2 contributed paper (30 min.) general
Steven Gilbert, Indiana University Kokomo; Norman Lederman, Oregon State University

NSTA/AETS standards for science teacher education: An Overview: paper presents the revised NSTA/AETS standards for science teacher education being developed by the CASE Project. Session proceeds a roundtable discussion later in the program.

T 2.6 Dir Row 2 contributed paper (30 min.) college
Penny Hammrich, Temple University; Kerri Armstrong, Community College of Philadelphia

What the Science Standards Say: Implications for Teacher Education: This paper describes changes in teacher candidates' conceptions of science, teaching, and learning as they participate in a K-8 science methods course that utilizes principles derived from national science.

T 2.7 Dir Row 3 contributed paper (15 min.) elementary
Carolyn Keys, University of Georgia; Virginia Kennedy, Tara Elementary School

Implementing Inquiry Science in a Fourth Grade Classroom: A Case Study: This paper describes how one fourth grade teacher interpreted inquiry science teaching in her classroom, including strategies for students pursuing authentic questions.

T 2.7 Dir Row 3 contributed paper (15 min.) general
Meta Van Sickle, University of Charleston

Constructivism: Many Faces: Science educators often speak of Constructivism as though it is one teaching strategy. The presentation will describe personal, radical, sociocultural, and holistic Constructivism as teaching practices.

T 2.7 Dir Row 3 contributed paper (30 min.) elementary
Valarie Dickinson, Washington State University

Student and Teacher Conceptions About Astronomy: Influences on Changes in Their Ideas: This session describes research conducted in two second grade classrooms, tracking the development of the students and teachers' conceptions of astronomy throughout the course of the 8-week units.

T 2.8 Dir Row 4 contributed paper (30 min.) general
Sharon Lynch, George Washington University

An Equity Schema for Science Education Reform: What is Fair in a Climate of Competing Mandates and Limited Resources? : This presentation will lay out a three level definition of equity in the context of science education reform, provide a rationale of this view, and demonstrate how it can be used in making decisions about resources allocation in a climate of competing mandates and myriad reform initiatives.

Thursday 3:40 - 4:40

T 3.1 Duluth contributed paper (30 min.) general
John Wiggins, University of West Georgia; Bethany Nichols, University of Alabama

Components of a Science and Mathematics Teacher Induction Model: Phase II: This study was designed to examine the components that beginning science and mathematics teachers believed to be necessary

T 3.1 Duluth contributed paper (30 min.) general
Barbara Spector, University of South Florida; Thomas LaPorta, Tarpon Springs High School

Science Teachers' Performance During Their First Three Years in a Classroom: Pitfalls and Recommendations for Conducting Research: Recommendations to those planning to assess and, or, evaluate beginning teachers are based on the successes and pitfalls encountered by the Salish Research Project 1.

T 3.2 Board 1 demonstration (30 min.) college
Thomas Thompson, Northern Illinois University; Kenneth King, Northern Illinois University; Stephen Wallace, Northern Illinois University

Telecommunications Applications for Elementary Science Education: Project Storm Front: A model for the infusion of telecommunications into the elementary science classroom is presented. Video documentation of project and student outcomes are also shared.

T 3.2 Board 1 demonstration (30 min.) elementary
Ronald Pauline, Juniata College

Design Your Own WWW Home Page: It's Easy!: A demonstration of Web page construction using PageMill. A sample web site will be constructed and a finished web site will be illustrated.

T 3.3 Carver panel (60 min.) general
Julie Gess-Newsome, University of Utah

Publishing in Science Education Journals: This session is designed for new and experienced researchers alike to give insight into and provide advice on the process of publishing in science education journals. Representatives from a number of the major journals will be present.

T 3.4 Rochester panel (60 min.) general
Patricia Simmons, University of Missouri-St Louis

Outside the Hotel: A Challenging Dialogue and Critical Discourse: Come and participate in this proactive session which will focus on the relationships between "academy theorizing" and "popular theorizing" related to science education reform.

T 3.5 Dir Row 1 contributed paper (30 min.) elementary/middle
Rebecca Monhardt, Utah State University; JoAnne Lewis, University of Iowa; Leigh Monhardt, H.B. Lee Middle School

Ethnoscience and Storytelling: This presentation describes a one week summer workshop for teachers, grades 4-8, in which strategies for integrating storytelling and ethnoscience activities are introduced.

T 3.5 Dir Row 1 contributed paper (30 min.) general
Jeffrey Jay, Northern State University

A Model of Integration for Prospective Teachers: This session presents a model and overview of science, math, social studies, and technology integration within a college-level course for prospective teachers.

T 3.6 Dir Row 2 panel (60 min.) college
Edmund Marek, Oklahoma University; Brian Gerber, Valdosta State University; Ann Cavallo, University of Oklahoma

Literacy Through the Learning Cycle: What are the relationships among the 1. discipline of science, 2.national standards for science education, 3. the nature of the learner and 4. the learning cycle?

T 3.7 Dir Row 3 contributed paper (30 min.) elementary
Joseph Peters, University of West Florida; George O'Brien, Florida International University

Elementary Science Education Issues and Trends: This paper discusses recent concerns regarding elementary science education including the Standards- based movement, business partnerships and publication opportunities.

T 3.7 Dir Row 3 contributed paper (30 min.) secondary
Gerry Saunders, The University of Northern Colorado; Thomas Pentecost, University of Northern Colorado; Carolyn Dawson, University of Northern Colorado

Laboratory Competencies for Pre-service Teachers: This session will present a proposed list of laboratory competencies for pre-service biology, chemistry, earth science and physics teachers.

T 3.8 Dir Row 4 Paper Set (60 min) elementary
James Shymansky, University of Missouri-St Louis; Larry Yore, Laura Henriques, California State - Univ of Long Beach; Jennifer Chidsey, U of Iowa; Eric Olson, U of Iowa; John Dunkhase, U of Iowa

Science, Parents, Activities and Literature: A Collaborative Teacher Enhancement Project. See attached for specific presenters, titles and descriptions.

Friday 8:00 - 9:00

F 1.1 Board 1 contributed paper (30 min.) general
Barbara Crawford, Oregon State University

Teaching Through Inquiry: Two Year Case Study of a Novice Teacher: This two year case study explored a novice teacher's successes and challenges in designing and carrying out inquiry-based instruction.

F 1.1 Board 1 contributed paper (30 min.) college
John Tillotson, Syracuse University; Brenda McKay, Syracuse University

A Cycle of Excellence in Science Teacher Development: Preservice science education students engage in a sequence of events including: writing a research-based rationale; conducting an inquiry project; and developing a teaching portfolio.

F 1.2 Board 2 demonstration (60 min.) college
John Cannon, University of Nevada; David Crowther, University of Nevada

Electronic Publishing in the 21st Century: Its Impact on Scholarly Writing Within the Science Education Community: This sectional will provide an overview of the current state of electronics publication and its impact upon the science education community, specifically promotion and tenure. A demonstration of how to write for electronic publication will follow.

F 1.3 Duluth contributed paper (30 min.) elementary
Larry Enochs, UW-Milwaukee; William Kean, UW-Milwaukee

Field Geology For Elementary Teachers: An Evaluation Study: This presentation will provide evaluation results for a project which prepared 21 elementary teachers in a 3 week field oriented geology program. Earth science teacher beliefs and action planning were used to document the success of the project.

F 1.3 Duluth contributed paper (30 min.)
Margaret Bogan, Jacksonville State U.

The Relationship Between a Manifest and Received Environmental Education Curriculum: Explores the connection between what was taught and what was reported learned. A metacognitive model emerged.

F 1.4 Rochester Roundtable Discussion 60 min. general
Steven Gilbert, Indiana University Kokomo; Norman Lederman, Oregon State University

Roundtable Discussion of the NSTA/AETS Standards for Science Teacher Education: Aets members are invited to meet and discuss the CASE Project's NSTA/AETS Standards for Science Teacher Education. Sessions follows an earlier presentation of the standards.

F 1.5 Dir Row 1 panel (60 min.)
Barbara Spector; Cathy Yoetis; Patricia Simpson; Juanita Jo Matkus; Beth Klein; Caroline Beller; Patricia Simmons

Stages of development of women faculty in science education: The roles of mentoring and networking. Additional speakers: Marianne Barnes, Meta Van Sickle.

F 1.6 Dir Row 2 panel (60 min.) general
Hassan Faraji, The U of Texas at Austin; Kamil Jbeily, The U of Texas at Austin; James Barafaldi, University of Texas; Peggy Carnahan, Space America

The Role of Professional Development Collaboratives for Facilitating Literacy Science. In this interactive panel session, three themes will be explored through a jigsaw discussion and case-study presentation. Themes include science literacy, professional development collaboratives, and systemic reform.

F 1.7 Dir Row 3 contributed paper (30 min.) general
Michael Hughes, Emory University; Mary Garner, Emory University

Using the Rasch Model for Item Selection: Constructing an Instrument to Measure 5th grade Students' understanding of the Nature of Scientific Knowledge. Advocates use of the Rasch model for item selection, and describes an application of the method in instrument development.

F 1.7 Dir Row 3 contributed paper (30 min.) general
Steven Gilbert, Indiana University Kokomo

Application of a Model-Based Paradigm to the Development of Preservice Teachers' Understanding of the Nature of Science and Science Knowledge. Describes an approach to science methods instruction using model-building as a paradigm for understanding active inquiry and the nature of science.

F 1.8 Dir Row 4 demonstration (30 min.) general
Nancy Finkelstein, Harvard U.Smithsonian Ctr for Astrophysics

Private Universe Project: Minds of Our Own: This presentation will focus on a television series that examines current research on how children learn science and implications for the classroom.

F 1.8 Dir Row 4 demonstration (30 min.) general
Nancy Finkelstein, Harvard University; Gordon Lewis, Harvard University Annenberg/CPB Math & Science Project

Using Television and the World Wide Web for Professional Development: This workshop will present a Television/Web service for K-12 math and science education. The service provides extensive math and science programs and workshops at no cost to the viewing audience.

Friday 9:20 - 10:20

F 2.1 Board 1 contributed paper (30 min.) general
Sharon Lynch, George Washington University; Julianna Taymans, George Washington University

Preparing Pre-Service Teachers to Teach Concepts to Diverse Learners Using the Unit Organizer: Four Case Studies: This study describes four pre-service teachers' attempts to implement the Unit Organizer, a concept teaching strategy for diverse secondary school students.

F 2.1 Board 1 contributed paper (30 min.) general
Jeffrey Weld, University of Iowa

How Should Cultural Differences Impact Science Teaching?: From the Rio Grande Valley to urban St. Louis to the farm fields of Iowa, kids are learning science. What are the implications for science teachers who ply the craft in culturally diverse settings?

F 2.2 Board 2 hands-on workshop (60 min.) general
Preston Prather, University of Tennessee; Lisa Bell, University of Virginia; Kueh Yap, Nanyang Technological University

Using Computer Technology and Case Method to Prepare Teachers to Integrate the Teaching of Science, Mathematics, Language Arts, History, and Social Studies, and the Fine Arts: Participants will be engaged in hands-on lesson activities designed for a course to prepare teachers for integrated science instruction in a constructivist learning environment.

F 2.3 Duluth contributed paper (30 min.) college
Julie Thomas, Texas Tech University; Jon Pedersen, East Carolina University

Draw-A-Science Teacher: A Visualization of Beliefs and Self-Efficacy: This research extends the DAST-C research (Finson, Beaver, & Cramond, 1995) to measure the science teacher perceptions of preservice teachers. Field-test results of the DAST-C are compared to STEBI-B (Enochs & Riggs, 1990) results.

F 2.3 Duluth contributed paper (30 min.) college
Mark Volkmann, Pudue University

Vignettes of Early Field Experience in Science Education: Challenges and Dilemmas: In this session, vignettes of secondary science classrooms, written by undergraduates, will be shared. These vignettes contain central dilemmas that uncover practicum student's beliefs and values about teaching.

F 2.4 Rochester panel (60 min.) general
Bill Baird, Auburn University

Standards for the Education of Teachers of Science: Assessment (to follow the session on CASE standards of the whole): This session will examine the current draft of the assessment standards. how can we specify what science teachers should know and be able to do to assess learning outcomes?

F 2.5 Dir Row 1 panel (60 min.) general
William McComas, University of Southern California; Karen Dawkins, Penny Hammrich, Mike Clough, Norm Lederman, Fouad Abd-El-Khalick, Nahum Kipnis, Cathy Loving, Yvonne Meichtry

The Nature of Science: Rationales of Strategies: Join authors of a new book who provide a variety of strategies that science teachers and methods instructors can use to communicate elements of the nature of science with students.

F 2.6 Dir Row 2 contributed paper (30 min.)
Robert Fisher, Illinois State University

Improving Science Education: Complex Strategies to Address Complex Changes: This presentation will describe what we have learned through implementing a complex curriculum in a wide range of middle schools and the implications for staff development.

F 2.6 Dir Row 2 contributed paper (30 min.) elementary
Walter Smith, University of Akron

Incorporating Design Technology in Science: There's more to problem solving than "the scientific method." Surely, practical problem solving so necessary in and out of the workplace, is more like engineering.

F 2.7 Dir Row 3 contributed paper (30 min.) general
Pradeep Dass, Northeastern Illinois University

Preparing"Professional" Science Teachers: Critical Goals : Three Goals- reflective practice, research rationale, and instruction in multiple domains of science- will be discussed as critical during preservice education to prepare "professional" science teachers.

F 2.7 Dir Row 3 contributed paper (30 min.) college
Samuel Spiegel, National High Magnetic Field Laboratory; Angelo Collins, Vanderbilt University/Peabody College

Creating an Effective Teacher Enhancement Program: This paper presents the results of a four year study which has identified the essential and necessary components of a teacher enhancement program.

F 2.8 Dir Row 4 panel (60 min.) general
Nancy Finkelstein, Harvard U.

Using Video Case Studies in Science Teacher Education: This presentation will focus on a series of 25 Video Case studies in science education for preservice and inservice teachers.

Friday 10:40 - 11:40

F 3.1 Board 1 contributed paper (30 min.) middle
Caroline Beller, Texas A&M University; Robert James, Texas A&M University

A Teacher's Perspective of Constructivist Staff Development

F 3.1 Board 1 contributed paper (30 min.) general
Patricia Nason, Stephen F. Austin State University

Experiential Learning & Collaborative Interaction: Change in Teaching Methodologies: Several factors mold eight educators' tropical rain forest experience as participants transfer their experiences as learner-facilitators to their own students' roles.

F 3.2 Board 2 contributed paper (30 min.) general
Fouad Abd-El-Khalick, Oregon State University; Norman Lederman, Oregon State University; Randy Bell, Oregon State University

Developing and Acting Upon One's Conceptions of the NOS: A Follow-up Study: This research presents a detailed analysis of preservice teachers' understandings of the NOS and the factors mediating its translation into classroom practice.

F 3.2 Board 2 contributed paper (30 min.)
Bob Louisell, St. Cloud State University; Geoffrey Tabakin, St. Cloud State University

Using Theme Units on Social Science/Science Topics to Teach Education Majors About the Nature of Science: The presenters will report on their use of thematic units to expose teacher candidates with limited science background to arguments about the nature of science.

F 3.3 Duluth panel (60 min.)
Larry Enochs, UW-Milwaukee; Iris Riggs, California State U.-San Bernadino; Tracy Posnanski, CMSER, UW-Milwaukee

Recent Developments and Research on Self-Efficacy: A report on recent developments and research findings. Included is a discussion of the self-efficacy construct, its measurement, results of recent studies, and a discussion of collective efficacy for school based analysis.

F 3.4 Rochester panel (60 min.)
Patricia Simpson, St. Cloud State University

INTASC Model Standards for Science Teacher Licensure: The Interstate New Teacher and Support Consortium has just completed their draft describing standards for initial teacher certification for science teachers. This subgroup of the CCSSO is being supported by 37 states. Copies of the draft proposal will be available for comment at this session.

F 3.5 Dir Row 1 hands-on workshop (60 min.) college
Dick Rezba, Virginia Commonwealth University

Infusing Graphing Calculators and Scientific Probeware into Middle and High School Science Methods Courses: Through a series of simple experiments, learn to use graphing calculators to teach graphing skills and descriptive and inferential statistics to middle and high school science teachers.

F 3.6 Dir Row 2 demonstration (60 min.) middle/secondary
Patricia Dixon, Florida State University; Samuel Spiegel, Florida State University

STAR TREE (Science Teachers and Researchers Translating Research Experiences into Educational materials): The innovative STARTREE model immersed middle school science teachers in a research environment to create new integrated curriculum products that enhance standards based teaching and learning.

F 3.7 Dir Row 3 contributed paper (30 min.) college
Catherine Cummins, Louisiana State University; Ron Good, Louisiana State University

A Teacher Observation Tool Based on Current Reform Documents: This presentation will describe the development, field testing, and revision of a qualitative tool, The Science Teaching Observation Tool (STOT) for science teacher observation.

F 3.7 Dir Row 3 contributed paper (30 min.) college
William Boone, Indiana University; Valerie Chase

Measuring the Self-Efficacy of Upper Elementary and Middle School Science Teachers: Implications for Outreach.

F 3.8 Dir Row 4 panel (60 min.) general
Faye Neathery, Southwestern OK State University; Richard Bryant, Southwestern OK State University; Dan Dill, Southwestern OK State University; Talbert Brown, Southwestern OK State University

Innovative Science Education Grant: From Recruitment, Through Preservice, Into Entry Level Service Southwestern OK State University will present: (1) the NSF-funded proposal; (2) a 15-minute video of the 1997 Summer Teaching Academy; (3) statistical data; (4) question-and-answer period.

Friday 2:20 - 3:20

F 4.1 Board 1 hands-on workshop (60 min.) general
Kevin Finson, Western Illinois University

Results of Science and Special Education Teachers' Collaborations in Retooling Science Materials: We will retool a science activity following project guidelines so that it is appropriate for special education and general education.

F 4.2 Board 2 panel (30 min.) middle
Beth Klein, St. Norbert College; Mark Bockenhauer, St. Norbert College; Mary Lach, St.Norbert College; Reid Riggle, St.Norbert College

The Ocean Voyagers Program: Partners for Scientific and Technological Literacy: This panel discussion will focus on the issues of a small college implementing a major educational outreach program designed to strengthen the scientific and technological literacy of inservice and preservice teachers and middle school.

F 4.2 Board 2 demonstration (30 min.)
Robert Hartshorn, Univ. of Tenn-Martin

The Virtual Associate Program: A cadres of classroom professionals has produced a hot-linked version of the state science framework and disseminated it electronically to the state's science teachers.

F 4.3 Duluth hands-on workshop (60 min.)
John Penick, University of Iowa; William Leonard, Clemson University

Designing an Instructional Strategy for the Millenium: Description and demonstration of a unique science classroom instructional strategy developed with NSF funding and designed to motivate and teach all students.

F 4.4 Rochester panel (60 min.) elementary
Juliet Baxter, Eugene 4J School District; Norman Lederman, Oregon State University; JoEllen Roseberg; Project 2061; Angie Ruzicka, Eugene 4J School District

Analyzing Elementary Curriculum Materials Relative to Project 2061 and the NSES: A Unique Approach to Reform and Professional Development: Panelists will describe the development and role in teacher education of a curriculum analysis tool based on a draft document prepared by project 2061.

F 4.5 Dir Row 1 contributed paper (15 min.) supervision
Maurice Field, University of Tennessee- Martin

Science Activities Manual: K-8, www edition: The Science Activities Manual: K-8, www edition, includes over 200 classroom connectors with correlations to Tennessee Science Curriculum Framework and National Science Education Standards.

F 4.5 Dir Row 1 contributed paper (15 min.) general
Cathleen Loving, Texas A&M University; Bernard Ortiz-de-Montellano, Wayne State University

Good vs. Bad Culturally Relevant Science: Avoiding the Pitfalls: Criteria are presented that assist science educators in judging multicultural or culturally relevant materials. Examples of "bad" science are given and alternatives suggested."

F 4.5 Dir Row 1 contributed paper (15 min.) college
Penny Hammrich, Temple University; Kerri Armstrong, Community College of Philadelphia

World View: Defining the Cultural Context of the Teacher: This paper examines elementary teacher candidates' world view presuppositions regarding science and nature and how these presuppositions influence teacher candidates' view of science teaching.

F 4.6 Dir Row 2 panel (60 min.) middle/secondary
Patricia Simmons,University of Missouri-St Louis

Science Teacher Education and Precollege Curriculum Models: How Can We Better Prepare Our teachers for Innovation?: Come participate in a session where we discuss how we can help our new and experienced teachers implement innovative curriculum efforts.

F 4.7 Dir Row 3 contributed paper (30 min.) elementary
Jackie Wilcox, University of North Dakota; Mark Guy, University of North Dakota

Science Discovery Centers: Meaningful Learning for Preservice Elementary Teachers: Reports on the implementation of a field-based experience in which prospective elementary teachers present discovery centers to elementary students in local schools.

F 4.7 Dir Row 3 contributed paper (30 min.) college
Steven Rakow, U of Houstn-Clear Lake

Art as a Probe of Scientific Inquiry: Students in elementary science methods were shown a picture of a painting before and after a course in methods to determine their perceptions and development of science inquiry.

F 4.8 Dir Row 4 hands-on workshop (60 min.) general
Nancy Romance, Florida Atlantic University; Michael Vitale, East Carolina University

Mapping Pre-Service Teachers' Knowledge-Base: A Blueprint for Designing Elementary Science Methods Courses: The conceptual knowledge base of pre-service elementary teachers explicated through concept mapping can serve as a framework for the re-design of an elementary science methods class.

Friday 3:40 - 4:40

F 5.1 Board 1 demonstration (60 min.) general
Cathy Wick, St. Cloud State University

The Classroom as a Stage for Examining Gender Microinequities: Performing skits based on life experiences will provide a forum for discussing the inequities that occur in school settings.

F 5.2 Board 2 contributed paper (30 min.) elementary
Timothy Barshinger, Purdue University; Karol Bartlett, Children's Museum of Indianapolis

Museum and Methods Collaboration: Understanding Science Teaching Via Distance Learning: Technology: A children's museum and elementary science methods class team-up via 2-way audio/visual interactive teleconferencing in a project that helps promote understanding of how children learn science.

F 5.2 Board 2 contributed paper (30 min.) middle
Rebecca Monhardt, Utah State University; Leigh Monhardt, H.B. Lee Middle School

Facilitating Science Literacy in a Rural Idaho School: This paper describes how the use of the internet and an STS teaching strategy benefited middle school students in a small Idaho farming community.

F 5.3 Duluth contributed paper (30 min.) college
Carla Zembal-Saul, Penn State University; Melinda Oliver, Louisiana State University

Meeting the Science Content Needs of Prospective Elementary Teachers-An Innovative Biology Laboratory/Recitation Course.

F 5.3 Duluth contributed paper (30 min.)
Linda Ramey-Gassert, Wright State University; James Tomlin, Wright State University

Evolution of An Inclusive Biology Education Program: The biology program, as part of a larger science education program for elementary and middle level educators, is changing and becoming more inclusive for all students.

F 5.4 Rochester contributed paper (30 min.) general
Mary Stein, Wayne State University; John Norman, Wayne State University; Juanita Chambers, Supt. Detroit Public Schools

Scaling up Support in Urban School Districts: Using Summer Institutes to Support Change: The process through which school teams of teachers and administrators have been encouraged to adopt and implement practices aligned with a constructivist perspective as a result of participating at a summer institute will be described.

F 5.4 Rochester contributed paper (30 min.) general
Michael Hughes, Emory University

Towards Science Education Reform at Three Urban Elementary Schools: Voices of Administrators, Teachers, and Students. Contributes to the description of reform in three urban elementary schools participating in a systemic reform of science education.

F 5.5 Dir Row 1 panel (60 min.) college
Jon Pedersen, East Carolina University; Elizabeth Doster, East Carolina University

A Tale of Two Teachers: The Paradox of Methodology & Content: Participants will be engaged in a discussion of two science educators' attempt to clarify epistemologies of teaching science through the teaching of science methods and science content courses.

F 5.6 Dir Row 2 panel (60 min.) general
Jo Ellen Roseman, American Association for the Advancement of Science; Norm Lederman, Oregon State University; Kathleen O'Sullivan, San Francisco State University

Issues in Curriculum Analysis: This panel discussion will focus on issues related to evaluating curriculum materials for their match to specific science literacy goals.

F 5.7 Dir Row 3 contributed paper (30 min.) general
Lloyd Barrow, University of Missouri

Success in Becoming a Professor: This session will summarize a course to assist graduate students in securing a higher education position and how to progress through the system.

F 5.7 Dir Row 3 contributed paper (30 min.) college
Quincy Spurlin, University of New Mexico

Professional Development Re-Formed to Improve Elementary School Science Teaching: A Look at One Effort: Description and analysis of a re-formed professional development effort to expand elementary teachers' science content knowledge and promote autonomy in teachers' own professional growth

F 5.8 Dir Row 4 contributed paper (30 min.) middle/secondary
Larry Flick, Oregon State University

Teaching Practices that Provide Cognitive Scaffolding for Classroom Inquiry: Two experienced middle level teachers collaborate with a university science educator in developing a detailed description of teaching practices that scaffold inquiry-oriented instruction.

F 5.8 Dir Row 4 contributed paper (30 min.) general
Julie Gess-Newsome, University of Utah

A Review of the Research on Teachers' Knowledge and Beliefs of Subject Matter and Its Impact on Teaching: This literature base will be explored in a developmental and cross-disciplinary fashion through the sub-topics of teachers' knowledge and beliefs about conceptual knowledge, subject matter structure, nature of the discipline, subject-specific teaching.

Friday 4:50 - 5:50

F 6.1 Salons A-C poster presentation college
Lehman Barnes,University of North Florida; Marianne Barnes, University of North Florida; Edwin McClintock, Florida International University

Promoting Inquiry in Multiple Contexts: An Initiative of the Florida Higher Education Consortium: The presenters will describe a model and strategies for enhancing inquiry teaching and learning in post secondary science and mathematics settings, particularly in cross-college contexts.

F 6.1 Salons A-C poster presentation college
Joanne Olson, University of Southern California; Anne Cox, University of Southern California

Improving University Teaching Effectiveness Through the Use of Peer Coaching: We will examine a successful peer coaching model used by two university instructors to improve practice. These strategies can result in significant improvements in teaching effectiveness.

F 6.1 Salons A-C poster presentation elementary
Karen Ostlund, Southwest Texas State University

The National Science Education Standards: Inquiring Minds Want To Know: Participants in this hands-on workshop will engage in activities which model how to implement the processes of inquiry to learn science content at the elementary level.

F 6.1 Salons A-C poster presentation college
Maria Ferriera, Wayne State University

The Ideal Advisor: Graduate Science Students' Perspective: This paper presents the perspective of graduate science students in two science departments at a large research university about the character of the ideal advisor.

F 6.1 Salons A-C poster presentation general
George Nelson, American Assoc. for the Adv. of Science; Mary Brearton, American Association for the Advancement of Science

Resources to Help Teachers Promote Science Literacy: This presentation will introduce Resources for Science Literacy: Professional Development, Project 2061's print/electronic tool designed to help teachers understand and teach toward science literacy goals.

F 6.1 Salons A-C poster presentation college
Paul Adams, Fort Hays State University; Germaine Taggart, Fort Hayes State University; Linda Kallam, Fort Hays State University

Sequenced Undergraduate Mathematics and Science Instruction for Preservice Teachers: We will present our efforts to develop a sequence of instruction (physical science, statistics, and teaching methods) designed to empower preservice teachers for inquiry teaching.

F 6.1 Salons A-C poster presentation general
Robert James, Texas A&M University; Craig Wilson, Texas A&M University

Is There a Role for Research Scientists in the Classroom?: There is! We have piloted a program which links USDA/ARS scientists with teachers. It works and this poster session will explain our model to you.

F 6.1 Salons A-C poster presentation general
David Nickles, Penn State University

Examing Evidence: Concept Maps, Metaphors, and Personal Philosophies: Describe the influence of a conceptual change curriculum on preservice teachers' beliefs about teaching and learning science.

F 6.1 Salons A-C poster presentation general
Bruce Johnson, Institute for Earth Education

Earth Education: An Alternative to the Infusion Model of Environmental Teaching: An Overview of Earth Education, a Sample Program (Earthkeepers), and ideas on How to Include it in Science Methods Courses.

F 6.1 Salons A-C poster presentation
Mary Koppal

Resources to Help Teachers Promote Science Literacy Poster Session.

F 6.1 Salons A-C poster presentation
Michael Clough, University of Iowa

Student teacher's perceptions regarding preservice NOS instruction and its implementation in secondary science teaching: This study investigated preservice teachers' perceptions of their university NOS experiences, and their self-efficacy, lesson planning, and reflections regarding implementing nature of science instruction during student teaching.

F 6.1 Salons A-C poster presentation
Craig Berg, UW-Milwaukee

An Analysis of Field Work Students Time Utilization During Practicum: What we learned about time utilization of our students during field work and student teaching provided information useful for program modification.

Friday 5:30 - 6:30

Committee Meetings: The following committees are scheduled to meet in Salon A on Friday from 5:30 - 6:30 p.m. as well as tentatively on Saturday from 6:30 - 7:50 a.m. in Salon A-C (take in the continental breakfast).

Elections Committee
Program Committee
Publications Committee
Awards Committee
International Science Education
Financial Advisory Committee
Ad Hoc Committee on Science Teacher Educator Standards
Ad Hoc Committee on Professional Development for Science Teacher Educators
Ad Hoc Committee on Electronic Communications
Ad Hoc Committee on Corporate Sponsorship for AETS Activities
Ad Hoc Committee on Mentoring New Members
Ad Hoc Committee on Structure and Finances of the AETS Annual Meetings
Committee for Inclusive Science Education
Membership Committee
Long Range Planning Committee
Committee for Inclusive Science Education
Committee on Liaisons with Professional Organizations of Science Educators
Science Teacher Education Section Editorial Board for Science Education
Journal of Science Teacher Education Editorial Board
Ad Hoc Committee on Dissemination and Implementation of the National Science Education Standards, Benchmarks, and (AAAS) Blueprint on Science Teacher Education
Ad Hoc Committee on Liaison with Scientific Societies
Ad Hoc Committee on Science Faculty Development
Ad Hoc Committee on Liaison with INTASC
Ad Hoc Committee on Regional AETS Units
NCATE Subcommittee of NSTA Science Teacher Education Committee
Committee for Inclusive Science Education

Saturday 8:00 - 9:00

S 1.1 Board 1 panel (60 min.) general
Nancy Lowry, Hampshire College; Jacqueline Chase, Hampshire College; Deirdre Scott, Fairview Veterans Middle School; Eric Heller, University of Massachusetts

School/college Partnerships to Encourage Middle School Girls' and Ethnically Diverse Students' Interest in Science and Technology: The key elements of pedagogy, program structure, and curriculum responsible for the success of programs for students and teachers intended to increase students' enthusiasm and skills in using science and technology will be described.

S 1.2 Board 2 hands-on workshop (30 min.) supervision
William Slattery, Wright State University

Using Internet Data and Learning Resource Sites in a Methods Class for Pre-Service Elementary and Middle School Teachers

S 1.2 Board 2 contributed paper (30 min.)
Craig Berg, UW-Milwaukee; Lisa Dieker, UW-Milwaukee

A Collaborative Science Teacher Preparation Program: Focuses on a collaborative of profs. planning and delivering a reformed science teacher education program.

S 1.3 Duluth hands-on workshop (30 min.) general
Michael Cohen, Indiana University-Purdue University

To Boldly Go Where Everyone Has Gone Before: A Brief Interactive History of Curriculum and Instruction in Science: A historical look at several "standard" science topics included at all education levels. It asks participants to review when and how they should be taught.

S 1.3 Duluth hands-on workshop (30 min.)
Paul Jablon, Brooklyn College

Eleven Things Not to Do for Systemic Change in Elementary Science Education: What 6 years of research about effective collaboration with large school districts to move their elementary school teachers towards active, inquiry based instruction.

S 1.4 Rochester hands-on workshop (60 min.) elementary
Lynne Houtz, Creighton University; Silvana Watson, Nebraska Wesleyan University

Modifying Hands-on Science Lessons for Students with Special Needs: Participants solve Dracula's Dilemma" and "Mystery of the Giant Hand" as science methods and special ed collaborated to demonstrate modifications for hands-on lessons.

S 1.5 Dir Row 1 demonstration (60 min.)
Maria Ferreira, Wayne State University

Teaching the Science Process Skills to Preservice Teachers: Using examples of science activities and students projects, this session will describe an approach used in a teacher education program to teaching science process skills to preservice teachers.

S 1.6 Dir Row 2 panel (60 min.) college
Paul Vellom, The Ohio State University; Marcia Fetters, The University of Toledo

Modeling Dimensions of Constructivist Teaching in Preservice Methods Courses: Interactive panel examining tensions and challenges of constructivist-designed methods courses. Attendees are encouraged to bring ideas and favored practices to share and question.

S 1.7 Dir Row 3 contributed paper (30 min.) elementary
Patricia Simmons, University of Missouri-St Louis

Building Professional Bridges: Come hear about a new model for teacher socialization for elementary and secondary preservice teacher education programs.

S 1.7 Dir Row 3 contributed paper (30 min.)
Peter Veronesi, State U of New York, College at Brockport

A Research-based Elementary Science Teaching Rationale as an Alternative Summative Assessment: A First Year Report: This paper discusses student growth after writing and defending a research-based elementary science teaching rationale as a final assessment in a science methods course.

S 1.8 Dir Row 4 hands-on workshop (60 min.) general
Robert James, Texas A&M University; Craig Wilson, Texas A&M University

When We Say Hands-on, We Mean It!: Making and using simple apparatus to bring science alive for teachers and students alike, while actively engaging them in the scientific process.

Saturday 9:20 - 10:20

S 2.1 Board 1 contributed paper (30 min.) general
Warren Di Biase, University of North Carolina

Tranformative Learning and Teacher Change: Overview of Meziros's (1991) transformative theory, a constructivist theory of adult learning, and its implications for science educators.

S 2.1 Dir Row 1 contributed paper (15 min.) general
Mark Latz, University of North Carolina; Frank Crawlev, East Carolina University

The Man in the Boat: New Lenses on an Old Problem: The purpose of this hands-on workshop is to provide participants with an opportunity to critically analyze the variables associated with floating objects.

S 2.2 Board 2 contributed paper (30 min.) college
Janice Koch, Hofstra University

Technology and the Elementary Methods Course: Re-thinking Science and Technology and Ourselves as Science Learners: This session will explore the integration of several technology experiences in the elementary science methods course, leading to regular communication with elementary science methods course students in Australia.

S 2.2 Board 2 contributed paper (30 min.) college
Scott Lewis, Florida International University; George O'Brien, Florida International University

Using a Web Site in an Elementary Science Methods Class: Are We Opening a Pandora's Box?: The use of a World Wide Web site in an elementary science methods class will be described in terms of its benefits and problems.

S 2.3 Duluth contributed paper (30 min.)
Marvin Druger, Syracuse University

Perspectives on Science Teacher Preparation: This presentation will reflect on current teacher preparation practices and will suggest new ways for improving the preparation of science teachers at all levels.

S 2.3 Duluth contributed paper (15 min.)
Craig Berg, UW-Milwaukee

Preparing Science, Math and Social Studies Teachers For Collaborative Online Internet Projects: This three year inservice effort has focused on using the Internet as an instructional tool with the session focusing on how to facilitate this type of effort.

S 2.4 Rochester contributed paper (30 min.) college
Elizabeth Day, University of South Carolina; Christine Ebert, University of South Carolina

Comparison of Teaching Model Effects on Graduate Instructional Assistant Attitudes Toward nd Confidence in Teaching Introductory Marine Science Laboratory Courses: A comparison of the effects of a constructivist teaching model (Conceptual Change Model) and a traditional teaching model on graduate student instructors' attitudes toward and confidence in teaching marine science laboratory courses will be presented.

S 2.4 Rochester contributed paper (30 min.) college
Elizabeth Doster, East Carolina University; Denise Crockett, University of Georgia; Allen Emory, University of Georgia

A Holistic Description of the Development Levels of Scientific Literacy: A Case Study of Three University Students.: This research study represents an in-depth exploration of the perceptions, values and beliefs of individuals whose personal worldviews represent those characterized by cultural, practical, and true scientific literacy.

S 2.5 Dir Row 1 contributed paper (30 min.) general
Thomas Koballa Jr., University of Georgia; Dava Coleman, Clark County Schools; Wolfgang Graber, University of Kiel

Preservice Teachers' Perceptions of Chemistry Teacher Education in Germany: Prospective chemistry gymnasium teachers' perceptions of their university based pedagogical experience were investigated as part of a larger study of science teacher education in one state of Germany.

S 2.5 Dir Row 1 contributed paper (30 min.) general
Paul Otto, University of South Dakota

What, No Test? Project-Based Physical Science for Preservice Elementary School Teachers: Project-Based physical science teaching will be modeled. Rubrics will be shared. Become involved in constructivist physical science teaching which is based upon the everyday experiences and previous knowledge of the students.

S 2.6 Dir Row 2 contributed paper (30 min.)
Farella Shaka, Southwest Missouri State University

Stimulating Professional Growth of Teachers Through Action Research: This paper describes an Eisenhower project in which action research played a vital role in the professional development of teachers.

S 2.6 Dir Row 2 contributed paper (30 min.) elementary
Middle/Jr.High/College/Univ./Supervisior Charles Barman IUPUI

Teachers as Researchers: Data From K-8 teachers Regarding Their Students' Perceptions of Scientists and Studying Science: This presentation will focus on the procedure and results of a national study conducted by 154 preservice and inservice teachers from 23 different states and D.C.

S 2.7 Dir Row 3 contributed paper (30 min.) college
Suzanne Weber, SUNY College- Oswego

Using the Science Misconceptions Research to Address Science Teaching Misconceptions: Preteachers often believe that direct instruction in the only effective science teaching strategy. Pedagogical misconceptions can be clarified using strategies designed to deal with science content misconceptions.

S 2.7 Dir Row 3 contributed paper (30 min.) general
Sherry Nichols, University of Texas at Austin; Sandra Johnson, Educational Service Center XII; Deborah Tippins, University of Georgia

Contemplating Literacy as "textual Politics" in Science Education Reform: Terms of Change in an Elementary School Community: A case study of science education reform in an elementary school community. The theoretical notion of textual politics is used to frame the discussion.

S 2.8 Dir Row 4 contributed paper (30 min.) college
Virginia Anderson, Towson University

Urban Visions, Campus Strategies: In-progess report on innovative NSF-sponsored faculty teaming model to help science and science educators engage their universities in urban science issues.

S 2.8 Dir Row 4 contributed paper (30 min.) middle/secondary
Lee Meadows, University of Alabama

Effective Teaching in an Urban Middle School: Urban middle schools challenge science educators & science teachers trained traditionally. I'll present strategies that worked when crossing over to a new teaching culture.

Saturday 10:40 - 11:40

S 3.1 Board 1 contributed paper (30 min.) general
Hedy Moscovici, Western Washington University

Shifting from Activitymania to Inquiry Science- What Do We Need to Do?: This study explores factors which contributed to activity mania and ways in which science educators can and should influence the shift toward inquiry science teaching and learning.

S 3.1 Board 1 contributed paper (30 min.) college
Julie Luft, University of Arizona

Rubrics: Design and Use in Science Teacher Education: In this presentation I will discuss the term rubric, provide a rationale for using rubrics, share how I have incorporated rubrics into my methods course, and conclude with an overview of the benefits and detriments of rubrics.

3.2 Board 2 contributed paper (30 min.) college
David Crowther, University of Nevada; John Cannon, University of Nevada

How Much is Enough? Preparing Elementary Science Teachers Through Science Practicums: This session will explore the "ideal" length for a science practicum with the development of self-efficacy through a time series analysis utilizing both quantitative and qualitative measures.

S 3.2 Board 2 demonstration (30 min.)
John Craven III, Queens College; John Penick, University of Iowa

Improving the Education of Field Supervisors: A Mentor's Model: The use of two-way, wireless communication systems and videocameras in the K-12 classroom provide exemplary means for assessment, instruction, and evaluation between a mentor and pre-professional field supervisors.

S 3.3 Duluth contributed paper (30 min.) college
Jason Painter, East Carolina University; Helen Parke, East Carolina University; Jon Pederson, East Carolina University

Field Experiences for Elementary Science Methods Students: Reflections on Course Organization: Designing a model to challenge beliefs about teaching and learning of university students enrolled in a field-based elementary science methods courses.

S 3.3 Duluth contributed paper (30 min.) general
Linda Ross, University of Texas; Lynn Jones, University of Texas

Perspectives of Prospective Science Teachers During Their Student Teaching Semester: For this session, we will present a study which examine and analyze the changing perspectives of prospective teachers during their student teaching semester.

S 3.4 Rochester contributed paper (30 min.) general
Bambi Bailey, Texas A&M International University; Ellen Johnson, University of Delaware; Kate Scantlebury; University of Delaware

Teacher Metaphors and their Impact on the Decision to Engage in Educational Research: Teachers' metaphors for educational research and impact of those metaphors on their participation in action research about gender equity are explored in this paper.

S 3.4 Rochester contributed paper (30 min.) general
Andy Hurford, University of Utah

A Dynamical Systems Based Model of Conceptual Change: Conceptual change models have been expanded to include an increasing variety of changes. A systems approach to conceptual change will be presented which has the potential of embracing the widest range of knowledge reorganizations.

S 3.5 Dir Row 1 panel (60 min.) general
Judy Reinhartz, University of Texas at Arlington; Jim Barufaldi, University of Texas at Austin

Collaborative Driven Professional Development: Models in Science Education: The examination of both past lessons and future challenges for professional development for science teachers will be the theme of our session. Regional collaborative for Excellence in science Teaching model will be highlighted.

S 3.6 Dir Row 2 panel (60 min.)
Deborah Tippins, University of Georgia; Steve Oliver, University of Georgia; Sharon Nicols-Thompson, University of Texas; Andy Kemp, University of Georgia; Hua Li, University of Georgia

Scientific Literacy: Exploring the Metaphor: The metaphor of scientific literacy will be examined from a historical perspective, in the context of current research, and in light of its use in current science education reform documents. We will use an innovative format, the roving interview, to facilitate the session.

S 3.7 Dir Row 3 panel (60 min.) supervision
Penny Gilmer, Florida State University; Chris Muire, Florida State University

Non-Traditional Forms of Assessment in University Science Courses: This interactive session will provide visions of how, with the guidance of science education graduate students, university science instructors are bringing alternative assessment to science classrooms.

S 3.8 Dir Row 4 panel (60 min.) elementary
Julie Thomas, Texas Tech University; Caol Stuessy, Texas A&M University; Mary Jane Schott, Dana Center

On the Road to Reform: Strengthening the Science Preparation of Elementary Teachers through Collaboration: This panel will address three issues: the Texas SSI model of change, Guidelines for the science preparation of elementary teachers, and models of institutional change.

Saturday 2:20 - 3:20

S 4.1 Board 1 panel (60 min.) college
Elizabeth Doster, East Carolina University; Jon Pedersen, East Carolina University; Jo Wallace Alise Wicker, University of North Carolina at Charlotte; Lundie Spence, Harriet Stubbs, North Carolina State University; Joel Mintzes, University of North Carolina at Wilmington

Planning and Implementing a State-Wide Environmental Education Course via the Telecommunications Network: Strategies, Solutions, and Outcomes: This critical discussion addresses strategies, obstacles and solutions encountered during the planning and teaching of a state-wide environmental education course. An evaluation of course effectiveness and overall value is provided by students and instructors.

S 4.2 Board 2 panel (60 min.) secondary/college
Libby Cohen, University of Southern Maine; Ah-Kau NG, University of Southern Maine; Dale Blanchard, University of Southern Maine; Elizabeth Fales, University of Southern Maine

Biotechnology Works!: This project demonstrates that high school students with disabilities can be successfully accommodated in biotechnology coursework and that high school teachers, who work alongside their students, are able to modify their instruction and laboratories.

S 4.3 Duluth hands-on workshop (30 min.) middle/secondary
Betsy Price, University of Utah

Hands On Workshop to Teach Genetics: Hands-on workshop for teaching genetics to all students. How to teach material that isn't in the textbook, incorporate technology, and provide affordable and "real" activities.

S 4.3 Dir Row 4 contributed paper (30 min.) general
Katherine Norman, California State University- San Marcos; Virginia Marion, Ursuline College

Recommendations for AETS on Inclusive Science Education: Representatives of the AETS Committee on Inclusive Science Education will present recommendations to the AETS community on serving the science learning needs of all students.

S 4.4 Rochester contributed paper (30 min.) elementary
Larry Yore, University of Victoria

Using Negotiated Criteria and Peer-Evaluation in Elementary Science Education: This presentation will describe the procedures and results of using negotiated criteria and peer-evaluation of a student-led workshop in an advanced instructional strategies course.

S 4.4 Rochester contributed paper (30 min.) general
Gary Varrella, Ohio U.

Caring Relationships in the Science Classroom: The role of caring in science teaching receives relatively little attention in the literature; however, in their study of constructivist beliefs and practices, caring emerged as a critical factor.

S 4.5 Dir Row 1 contributed paper (30 min.) middle
Joseph Engemann, Brock University

Internet Inservice for Middle/Junior High School Teachers: Does It Create Science Cybernauts?: An inservice workshop program focusing on use of the internet is examined for its impact on science instruction and attitude towards the use of this medium.

S 4.5 Dir Row 1 contributed paper (30 min.) college
Frank Crawley, East Carolina University; Randy Yerrick, East Carolina University

Learning Science and Mathematics with Technology Tools: Helping Teachers Transform Their Practice: This paper reports on the results of the project titled "Learning Science and Mathematics with Technology-Tools," a professional development project funded by the University of North Carolina's Mathematics and Science Education Network through the Center's Dwight D. Eisenhower Professional Development Program.

S 4.6 Dir Row 2 panel (60 min.)
Kathy Wieseman, University of Georgia; Hsing Chi Wang, University of Southern California; Lynn Bryan, Valarie Dickinson, Andy Kemp, University of Georgia; Barbara Roscoe, U of Georgia

Extending Our Networking and Professional Development as Science Teacher Educators and Researchers: A Forum By and For Graduate Students: A forum for graduate students of science education to share their experiences and stimulate professional development regarding the many dimensions of the work of a science teacher educator and researcher.

S 4.7 Dir Row 3 contributed paper (30 min.) middle
Michael Padilla, University of Georgia; David Jackson, University of Georgia

Bringing the Classroom Teacher into Middle School Science Methods Instruction- Tryday: This session describes how classroom teachers contribute to methods instruction through a novel structure called Tryday.

S 4.7 Dir Row 3 contributed paper (30 min.) college
Norene Lowery, Texas A&M University; Carol Stuessy, Texas A&M University

Construction of Teacher Knowledge by Preservice Elementary Teachers in a Professional Development School for Mathematics and Science: Describe findings of a study conducted to investigate how preservice elementary teachers construct teacher knowledge and pedagogical content knowledge in math and science in a school-based setting.

S 4.8 Dir Row 4 contributed paper (30 min.) college
Kathryn Powell, University of New Mexico

Vertical Teaming: A Model for Curricular Alignment and Enhancement: A model to support curricular alignment and enhancement utilizing vertical teams is explored. Data on teacher responses to the utilization of the model and its implications for school practice are presented.

S 4.8 Dir Row 4 contributed paper (30 min.) college
Carole Kubota, University of Washington

The Wetlands Immersion: A Science Methods Class Teaching Strategy Involving Scientists, K-8 Preservice Teachers, and Science Educator: "The Wetlands Immersion" is an experimental teaching strategy used in a science methods class composed of thirty K-8 preservice teachers. Used as a focus experience, "The Wetlands Immersion" provides an opportunity for the preservice teachers to do real science with real scientists.

Saturday 3:40 - 4:40

S 5.1 Board 1 contributed paper (30 min.) middle
Molly Weinburgh, Georgia State University

Gender, Ethnicity, and Grade Level as Predictors of Middle School Students' Attitudes Towards Science: The Attitude Toward Science Innovatory is used to examine the attitudes of 1381 middle grade students. Data are sorted by gender, ethnicity, and grade level. Results and recommendations are given.

S 5.1 Board 1 contributed paper (30 min.) general
Pamela Fraser-Abder, New York University; Alice Mastrongello-Gittler, International Women's Tribune Ctr

Science Education: Perception, Practice and Policy: This project investigated existing state and district policies regarding science education and scientific literacy and what practices have emanated from these policies.

S 5.2 Board 2 panel (60 min.) college
Donald Maxwell, BSCS; James Ellis, University of Kansas; Christine Jones, Colorado State University; Paul Kuerbis, The Colorado College; Keith Kester, The Colorado College

CO-STEP: Colorado's Elementary Science Teacher Staff Development Project: The results. The panel will share the results of this six year elementary science staff development project's effects to improve elementary science instruction through a staff development program designed to meet the needs of teachers and their colleagues at the local level. We will look at the effect of the CO-STEP model upon the six participating centers, the lead teachers involved in the project, the lead teachers' colleagues, student learning, and the local districts' elementary science instructional programs.

S 5.3 Duluth contributed paper (30 min.) general
Sandra Henderson, Oregon State University; Norman Lederman, Oregon State University

Partnership Between Secondary/Elementary Science Teachers and Laboratory-Based Scientists: Delineating Best Practices: The teacher enhancement programs of two national research laboratories were the focus of this research that undertook a grounded study to delineate best practices of science education partnerships between science teachers and national laboratory scientists.

S 5.3 Duluth contributed paper (30 min.) college
Phillip Wade, Oregon State University; Barry Goldman, Lawrence Livermore National Laboratory

Student Conception of the Research Process: How Non-Academic Research Internships Provide a Unique Educational Opportunity. A survey to assess students' conception of the research process was completed during an eighteen week internship program at a National Laboratory.

S 5.4 Rochester panel (60 min.) college
Elizabeth Doster, East Carolina University; Floyd Mattheis, East Carolina University; Mike Padilla, University of Georgia; Andrew Kemp, University of Georgia; Joe Riley, University of Georgia; Yasushi Ogura, National Institute for Educational Research; Atsushi Yoshida, Aichi University of Education

Culturally Centered Perceptions of Science: A Collaborative International Research Study of Students in the United States and Japan. Participants will be engaged in a discussion of student perceptions of science within the context of their social and cultural background.

S 5.5 Dir Row 1 panel (60 min.) general
Julie Stafford, Wisconsin Academy Staff Development ; Robert Hollen, University of Wisconsin; Billie Sparks, University of Wisconsin; Le Roy Lee, University of Wisconsin

Wisconsin Academy Staff Development Initiative: Improving mathematics science and technology education through a Lead Teacher Institute and a statewide network of teaching centers or Academies funded by the NSF, DDEA and Corporate sponsors.

S 5.6 Dir Row 2 hands-on workshop (60 min.) middle
Sibel Erduran, Vanderbilt University; Richard Duschl, Vanderbilt University

Acid and Bases Curriculum Unit: An Inquiry-Based Context for Teaching the Particulate Nature of Matter and Changes in Matter. The session will introduce an inquiry-based middle school science curriculum. Several activities from the Acids and Bases Curriculum will be demonstrated.

S 5.7 Dir Row 3 contributed paper (30 min.) secondary
Starlin Weaver, Salisbury State University

Using Portfolios to Asses Learning in Chemistry: One School's Story of Evolving Assessment Practice. This qualitative study was conducted to explore how teachers and students in a small math, science, and technology magnet school define and implement a program of portfolio assessment in their chemistry classrooms.

S 5.7 Dir Row 3 hands-on workshop (30 min.) college
Jackie Palmer, Southwest Educational Development Laboratory (SEDL)

Developing Student Assessment Systems That Nurture Instruction: Using the Alternative Assessment Toolkit for Professional Developers in Pre-Service Settings. Ideas for teacher preparation courses in classroom assessment practices; useful advice on improving classroom assessment practices; modeling of hands-on instructional activities for pre-service teachers.

S 5.8 Dir Row 4 contributed paper (30 min.) general
Erica Brownstein, Ohio Dominican College

Zoning in Chemistry: One Classroom Example: Utilizing videotape, this session will track the Zone of Proximal Development in a high school chemistry classroom.

S 5.8 Dir Row 4 contributed paper (30 min.) general
Paul Otto, University of South Dakota

Conceptual Physical Science Knowledge of Taiwanses and USA K-6 Preservice and Inservice Teachers: Four physical science concepts were demonstrated to groups of preservice and inservice in Taiwan and the USA. Written explanations of observations were analyzed as to understanding.

Sunday 8:00 - 9:00

Su 1.1 Board 1 college
Larry Wakeford, Brown University; John Penick, Ron Bonnstetter

Secondary Science Methods Course: The panelists will describe the methods courses they teach. Participants are encouraged to bring copies of their syllabi to share.

Sunday 8:00 - 10:00

Su 1.2 Marquette Network Discussion 120 min. general
Robert Fisher, Illinois State University

Participate in the Certification and Accreditation in Science Education (CASE) Network: Case is a cooperative effort between NSTA and AETS to develop and disseminate performance-based standards for science teacher education. The CASE network is intended to facilitate a high level of interaction among those who have a strong interest in the development and implementation of science teacher education standards in their states.

1998 AETS Conference Papers and Presentation Summaries

CONFRONTING THE GENDER GAP IN SCIENCE AND MATHEMATICS: THE SISTERS IN SCIENCE PROGRAM

Penny L. Hammrich, Temple University

Introduction

The *Sisters in Science Program (SISP)* [1] was conceived within the context of rising public opinion that there exists a gender gap in science and mathematics achievement (Kahle and Meece, 1994). Inherent in the program's focus in the recognition that female-specific intervention programs have a lasting impact on school success (Kaplan & Aronson, 1994). The program's efforts are also consistent with the call for systemic educational reform that recognizes gender related learning style difference in science and mathematics (Tamir, 1988 & Versey, 1990).

As the *SISP* addresses the call for national reform, it is also in line with local science and mathematics education reform. When the *SISP* was developed it was found to supplement recently begun initiatives in the Philadelphia School District's Children Achieving Agenda. In addition, the program was also seen as a complement to currently functioning National Science Foundation initiatives in Philadelphia (e.g. Urban Systemic Initiative). Thus, it can be stated that the *SISP* is a vehicle for both local and national reform in science and mathematics education.

As was mentioned, female students are lagging behind their male counterparts, as early as 9 years old, in science/mathematics achievement for a variety of reasons (Mullis & Jenkins, 1988). Research from the National Science Foundation (1990) and the Task Force on Women, Minorities and Handicapped in Science and Technology (1989) has also noted that while efforts have been made to narrow this gap in achievement, little change has been realized.

[1] [1] A paper based upon work supported in part by a grant from the National Science Foundation (Grant No. 9553426). Any opinions, findings, conclusions, and/or recommendations expressed in this paper are those of the author and do not necessarily reflect those of NSF

One focus of the research on gender inequity in science and mathematics has been the classroom environment. Researchers suggest that teachers beliefs about student ability effects the manner in which female students operate in the classroom (Shepardson & Pizzini, 1992). Such research identifies teachers as the agents of gender bias. Also, [2]female students tend to differ from their male cohorts in their receptivity to and participation in science and mathematics education. It has also been noted that female students contribute less often to classroom discussion than their male classmates. In fact, the very conversations girls have and the matters they concern themselves with (i.e. interactional issues) is different from boys (Theberg, 1993). Finally, currently implemented science and mathematics education, which is often competitive and individualistic runs counter to female learning styles which are more cooperative and interdependent in nature. Shakeshaft (1995) says that science and mathematics classes have expectations that simply exclude girls leading to lower participation and achievement.

A female's perception of science and mathematics also contribute to inequity in achievement. It has been found that female students harbor stereotypical ideas about science/mathematics and scientist in general. They often feel that it is a male dominated field (Kelly, 1985). Weinberg (1995) did a meta-analysis of the literature on gender difference and student attitudes, concluding that there is a correlation between students' attitudes about science/mathematics and their achievements in science and mathematics.

Reformists believe there are some essentials to encouraging female student success in the classroom. They include fostering a safe and nurturing environment, promoting problem solving skills, creating collaborative experiences, using hands-on learning and allowing for open discussion about gender stereotypes (Allen, 1995 & Mann, 1994).

Constructivism, an epistemological perspective of knowledge acquisition, serves as the foundation for many of the aforementioned suggestions regarding science and mathematics education reform. In the constructivist framework, learning is both social and dialogical in nature. Meaning, as human beings interact with objects in their environment they construct mental models of their environment. The constant interaction of human and environment creates learning about the world (Driver, 1995). Kenneth Gergen, a social constructivist, proposes that individual knowing is not determined by a single person but by a collection of persons in a position to render judgment..."What I say remains nonsense until you assent to its meaningfulness and vise versa." (p. 24, Gergen, 1995). In short, people learn in partnership with other individuals and that knowledge is socially agreed upon knowledge.

What then do science and mathematics educators need to do in order to foster science learning? Driver (1995) offers science and mathematics education some suggestions. She suggests that learners need to be given access to physical experiences as well as concepts and models of conventional science and mathematics. Science and mathematics learning should account for what the learner brings to the learning situation, their purposes and ideas, which can differ for each socially constructed group, particularly, females. Finally, teachers need to be the presenter of experiences that enable students to make mental connections to pre-existing events.

The *SISP* offers a multilevel intervention centered around the constructivist learning model. To this end, cooperative exploratory hands-on science and mathematics education tasks along with self reflection are being employed to facilitate learning. Within this framework of constructivist learning, the *SISP* was designed to provide instructional methods that; demasculize and demystify science and mathematics, promote women role models and career information, and allow for active involvement. While girls are "doing" science and mathematics their self-confidence and self-perceptions of their ability to do science and mathematics is enhanced (citation omitted for anonymity).

<u>Program Description</u>

The *SISP* intervention allows for cooperative interdependent exploration of science and mathematics concepts within a single sex learning environment. The rationale being that when girls are allowed to work in a manner that is intrinsic to their collective learning style with the manipulation of materials, learning will occur. Additionally, the program's designers are interested in the reformation of girls' perceptions of science and mathematics education and science and mathematics as a career option via reflective discussion as well as hands on experience with science and mathematics.

The program model as mentioned briefly in the aims and background sections is as follows. Females have been found to lag behind their male counterparts in science and mathematics achievement. The reason being, current science and mathematics education practices run counter to the intuitive learning style of female students. In addition, females tend to view the field of science and mathematics as a male domain, often leading to the reluctance of girls to go into science and/or mathematics as a field of study or career. The proposed *SISP* has been designed to provide female students a "girls only" environment that employs hands-on cooperative activities and discussions around science and mathematics careers. The constructivist centered, single sex paradigm allows girls to be girls in the presence of other girls so as to facilitate increased science and mathematics interest, achievement, positive attitude, and awareness.

The proposed objectives of the *SISP*: (1) increased interest in science and mathematics, (2) increased positive attitude toward science and mathematics, (3) enhanced awareness of academic and career opportunities in science and mathematics, and (4) increased achievement in science and mathematics were met via the implementation of a series of twenty 90 minute after-school science and mathematics programs of which preservice teacher enhancement was a part.

These after-school activities for females included environmental service learning projects and reflection sessions. The activities included such things as developing community environmental awareness campaigns, conducting surveys of the schools' and neighborhoods' recycling plans, testing for levels of pollution in their schools and in their homes, identifying pollutants found in garbage, air, water, etc., and creating an environmental newsletter that will be distributed throughout their respective schools.

The students also engage in reflection activities designed to help them better understand their personal learning, challenge stereotypical notions about science/mathematics and to develop critical thinking skills. These reflection activities included writing, interactive discussions, and creative expression through the arts.

As part of the program's preservice enhancement component, students in a science and mathematics education methods course at Temple University facilitated the program session along with their instructor. The preservice teachers' coursework explored gender-equity issues in the classroom. These students were introduced to the constructivist approach to learning in order to facilitate science knowing. They also learned about the community service learning concepts presented in the programs.

The after-school science programs were scheduled to meet once each week at each school from October through May of the academic year. For 20 weeks, fourth grade girls at both schools performed science and mathematics activities utilizing various science process skills and problem solving tasks. Approximately sixteen of those weeks were devoted to actual experimentation. The other four weeks, two in the beginning and two at the end were devoted to data collection.

Methodology

Principals from two Philadelphia public elementary schools accepted the program designer's offer to run an after-school science and mathematics program for fourth grade females. The fourth grade females at each school were invited to participate in the after-school program. There were no stipulation for females' participation in the program other than being able to attend the sessions between 3:00 p.m. and 4:30 p.m. one day a week.

The maximum number of females that could participate in each schools' program is equal to the number of female students in each of the schools' fourth grade classes. Thus, thirty to forty females could potentially participate at each schools' program. Additionally, content validity. In addition reliability figures were calculated on a test-retest correlation model, and confirmed using the Kuder-Richardson (formula 22) procedure.

Analysis

There were fifty-three (53) complete sets of data for the science skills test and sixty-eight (68) complete sets of data for the mathematics skills test. Analysis of co-variance was used as the statistical test for the purpose of revealing the extent of change from pre- to post-test for the science and mathematics instruments. The analysis of co-variance for post-test scores, using the corresponding pre-test scores as the co-variant yielded the following results: (See Table 1).

Table 1
Analysis of Co-Variance

Science Skills (pre to post changes)			
N = 53	F = 1.2796	$p>0.20$	Non-significant
Mathematics Skills (pre to post changes)			
N = 68	F = 0.8282	$p> 0.20$	Non-significant

Student questionnaires regarding their interests, attitudes, and awareness were completed by 65 students and were analyzed using a pre and post design. Changes were analyzed utilizing the chi-square statistical procedure. The data were analyzed in four sections (school science, school mathematics, science/mathematics, other). The first three sections were analyzed using the chi-square statistics (See Table 2). Items in the "other" category were presented in tabular form only (See Table 3).

Table 2
Analysis of Attitudinal Instrument Data: Pre to Post Changes

School Science		
X2 = 3.0010	p>0.08	Non significant
School Mathematics		
X2 = 20.5453	p<0.01	Highly significant
Science/Mathematics		
X2 = 10.7633	p<0.05	Significant

Table 3
Analysis of Attitudinal Instrument Data: Tabular Form of "Other" Category

Item 1	Yes 84%	No 2%	Don't Know 14%
Item 4	Yes 96%	No 0%	Don't Know 4%
Item 15	Yes 89%	No 8%	Don't Know 3%

Discussion

With respect to the result from the science process skills instrument there was no statistical significant changes for the girls participating in the program This is a combination of small losses and small gains for the two schools involved. Clearly, to the extent that the instrument is appropriate to the problem, the outcome did not meet the expectation of an increase in the science process skills. Skills tested for were: observation, recognition of variables in an experimental procedure, graphing (using bar graphs), and interpretation of graph results, classification, measuring using non-standard units, description of a measuring procedure (finding an average), and estimating lengths. All of these appear in the Philadelphia Schools by the end of the fourth grade. Of the skills tested for, the student responses were most nearly correct for observing and measuring on both the pre- and post-tests, and for classifying on the post-test. For the identification of variables, a very limited response was given, students confused the controlled and responding variables. No one gave a correct answer for the responding variable. Similarly, the obtaining of an average was nearly never answered correctly on the pre- and post-tests. The test itself may been the problem, in that it did not reflect directly the experiences utilized in the program, but rather was based on skills employed in the aspects of the program. This lack of a direct connection may have possibly limited the responses for these students. Relatively few of them mentioned "sisters" in the context of their school science experience in responding to the questions at the end of the test. A second possibility stems from the clear displeasure expressed by students with their previous science experience, including references to reading and talking being the primary characteristics of these experiences. Reading ability could also have been a factor in their performance on a paper and pencil test requiring reading of the questions.

With respect to the results of the mathematics skills instruments, while the changes in results from pre- to post-test administration were not statistically significant, clear areas of gain were seen. The skills tested for included: basic number manipulation (addition, subtraction, multiplication, and division), use of decimals, multiplication and division by zero, various formats for expression, word problems of the one step variety, number sentences, coin money equivalence, pie graphs of fractions, reading of a bar graph, appropriateness of distance measuring units, and simple figure perimeter and area. Again, these are elements of the fourth grade curriculum, but as with science, they do depend on prior experiences, including their reading ability. From the outset, the students best skill performances were in the areas of addition, subtraction, and multiplication of small numbers. Multiplication involving 3-digit numbers, division and anything involving decimals produced problems. Word problems simply eluded them on the pre-test. On the post-test, however, a modest number of them were willing to try the word problems and a few reached correct numerical solutions. The pie graphs showing fractional equivalence were a strong point. A majority of them were able to identify correctly the fractional equivalence by the post-test. Likewise, progress appeared in interpreting the bar graph. While the lack of a statistically significant result was disappointing, the amount of change that was observed was within the range of expectation for the program. Considering that the gain in math skills was an adjunct rather than a primary result, and assuming that the effort in mathematics by the regular classroom teachers was on the same level as the effort in science, then the math results can be interpreted as favorable. A part of the difference in results for math and science may lie in the lower demand for reading skill on the math test than was the case on the science test.

With respect to the results of the interest, attitude, and awareness index the results were quite positive; i.e., the students showed very positive changes in attitude toward school science and mathematics and toward the possibility of pursuing a career involving some aspect of science and/or mathematics. The three items presented singly as response percents, the high percentages of positive responses suggest a recognition that there is a level of community responsibility on the part of all of us, with specific emphasis on girls. The generalized response that they "like school" was something of a surprise, but placed in the context of the program can be taken as an indication of increased attitude. The pre to post results can reasonably be taken as an indication of the success of the program in increasing the students interest, attitude, and awareness in science and mathematics. A further question remains, however, will this be sustained when the program ends its support of t he school's effort in promoting science and mathematics performance and interest.

Conclusion

The program met its stated goal with respect to enhancing fourth grade females attitude, interest, and awareness toward school science and mathematics and toward scienceand mathematics both as part of a larger enterprise and as potential career pursuits.

The project also met its stated goal with respect to increasing the students' mathematical skills. However, the project did not meet its stated goal with respect to increasing the students science skills. Although, there is a possibility that this was at least in part a function of the instrument chosen to gather data in that poor language skills of the students and a lack of direct reference to the activities of the project may have reduced its effectiveness. Program modifications are being taken into account to further refine the assessment instruments and closer align the after-school activities with the classroom science and mathematics activities.

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Teaching Instructional Materials for Science Educators with a CD-ROM and a World Wide Web Support Network

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New science reform platforms, such as the National Science Education Standards, recommend including educational technology, especially telecommunications, in our K-12 classrooms. Using a telecommunications network in science education can serve to provide a support system for inservice and preservice teachers, and provide a collaborative network of teachers who share resources, ideas, support, and interactions.

Many studies have identified problems with science teachers incorporating a telecommunications network and using telecommunications technology in secondary educational settings. These include lack of access to telecommunications in their school, including hardware and software; problems with connecting into an online network; lack of training to learn how to use the Internet with their classroom curricula as well as the time to use it; and lack of support within a teacher's school.

To meet the problems that science teachers have with incorporating a telecommunications network and using telecommunications technology in secondary educational settings, we have compiled an Instructional Materials for Science Educators (IMSE) CD-ROM and have created a support network for science teachers on the World Wide Web. The IMSE CD-ROM is used in conjunction with the on-line support network to train preservice and inservice science teachers at North Carolina State University to incorporate a variety of existing instructional technologies into their curricula. The IMSE CD-ROM is used as a primary resource in our preservice science teacher materials course offered by the Department of Mathematics, Science and Technology Education in Fall, 1997; a series of workshops offered at the Science House in Summer, 1997; and at training sessions for MEGA (Middle School Educators Global Activities) participants.

The IMSE CD-ROM contains a variety of instructional science resources including science content web sites, Internet tutorials, science software, video clips, and CBL and MBL laboratories. The IMSE CD-ROM serves to facilitate our preservice and inservice science teachers at all levels to develop basic technological competency skills. The CD-ROM incorporates new and existing technology into teaching by providing templates that show teachers how to use instructional technology resources into their classroom curricula. Preservice and inservice teachers learn to enhance their present science curriculum by using the IMSE CD-ROM to connect them to information that is only accessible on the World Wide Web. These include current data on geophysical events, current weather conditions, and interactive computer simulations using the scientific method to explore science on a global scale. As an overview of science on the WWW, the resource CD-ROM contains lesson templates and lists of science web resources that will enable an easier integration of on-line materials into science teaching.

Preservice and inservice teachers are instructed to use the IMSE CD-ROM as a tool to use a variety of freeware and shareware applications for the following:

1. to incorporate science activities into the classroom;
2. configure a common World Wide Web browser, such as Netscape, to add helper applications needed for viewing movies, spreadsheets, pict or jpg files, audio files, pdf files, and other useful files;
3. explore Web sites rich in data in the science content areas of interest to them;
4. use a WWW browser to search for, locate, download, and use desired information;
5. use and critique instructional materials on science content web sites for teaching middle and high school students; and
6. communicate electronically using a web-forum.

The web-forum is a place where science teachers can share ideas, reflections and conversations on teaching and implementation of technology in the classroom, while also providing support for each other as members of an electronic professional community.

The focus of our demonstration session provided many examples of how we incorporate the IMSE CD-ROM and its on-line support network for science teacher education.

Integrated Science and Math for Junior High Teacher Preparation: Staff Development as a Continual Process

Bill Baird, Auburn University (Alabama)

Susan McClary, Auburn Junior High School

Background

During June of 1997 teams of three representatives from middle school environments were invited to Colorado Springs, where they participated in one week of observation and planning of an integrated approach to science teaching and professional development (ISTEP) with funding from the National Science Foundation under the leadership of Dr. Paul Kuerbis of Colorado College. Our team from Auburn Junior High School consisted of an eighth grade teacher, the school principal, and a university science teacher educator. Susan McClary is the mathematics teacher and leader of a faculty team of four consisting of science, mathematics, social studies and English disciplines. Charles Tarver, the principal, is a former science teacher who believes in the integrated approach to junior high and middle school teaching and supports faculty efforts in this direction. Bill Baird is a professor of science education at Auburn University, and has been bringing his preservice teachers to AJHS for three years to offer them classroom teaching opportunities in a constructivist environment that uses a theme approach to integrating science with other subjects. The junior high school is located three blocks from the university campus, and serves about 800 students in grades seven and eight with about 50 faculty. Auburn University is a land-grant institution serving about 22,000 students, of whom around 40 per year receive preparation for the Alabama secondary science teaching credential. Similar numbers of students are prepared each year for an Alabama teaching license in secondary English, mathematics, and social studies.

In addition to the week at Colorado College, each of the ten teams that came to Colorado Springs received a $6,000 grant to carry on its work at the local level. In this paper we will describe our progress toward professional development of the teaching faculty at AJHS, our efforts to expand this program laterally to other preservice programs at the university, our efforts to expand vertically into sixth and seventh grades in the Auburn City Schools, and our plans to use funds provided by both Auburn City Schools and the NSF grant to achieve our future goals.

Our Goals

The targets of the project are two-fold. The first target combines Auburn Junior High School eighth grade students and Auburn University preservice students. The second group consists of AJHS faculty and Auburn University faculty.

For AJHS students, our goals are:

1. improve student content knowledge;
2. experience the interdependency of four different discipline areas;
3. become more inquisitive, active learners;
4. achieve better self-esteem and positive attitudes towards learning.

For the AU preservice students, our goals are:

1. to understand how middle school students interact in the classroom;
2. to understand how middle school students respond to different teaching techniques;
3. to gain experience in classroom teaching under the guidance of experienced teachers;
4. to practice teaching in their own discipline and other subject areas;
5. to gain experience in planning thematic units and understanding how a teaching team functions.

For the AJHS faculty, our goals are:

1. to achieve better team relationships and planning skills;
2. to experience different teaching techniques from the AU faculty and students;

3. to expand the available resource pool of manpower, ideas, and equipment for classroom teaching.

For the <u>AU faculty</u>, our goals are:

1. to obtain better field experiences for AU preservice teachers in local schools under model teachers;
2. to access demonstration classrooms for constructivist, integrated teaching;
3. to develop a better working relationship with Auburn City Schools;
4. to share responsibility for the preparation of future teachers with area teachers;
5. to explore problems and solutions for the above goals.

Timelines

We have two interdependent timelines. One is for the AU faculty and preservice students, who are on a quarter system and taking a single, three-hour methods course. The other is for AJHS faculty and students, who begin school in late August and end in early June. These two timelines are interleaved, so that critical tasks can be scheduled by both groups for the same day on the calendar. The timelines below (see Figure 1) show duration and spacing of critical events by both groups.

Figure 1

AJHS faculty and students: {five class days per week with five teaching periods per day of 55 minutes each; N~120-150 eighth grade students per team of four faculty members plus one resource teacher per team; single, common, two-hour planning period for each team}

week of July 1st – McClary and Baird meet with Auburn City Schools Curriculum Director and AJHS Principal (1) to plan faculty retreat for the AJHS teams, (2) to inform them of what occurred at the ISTEP Institute in Colorado Springs, (3) to explain changes in the original proposal, and (4) to request matching funds for faculty release time and expenses for the faculty retreat.

week of July 9th – plan faculty retreat with Baird, McClary, AJHS Principal, and Auburn City Schools Curriculum Director. Invitations sent to 15 eighth grade AJHS teachers, ACS Superintendent, Auburn City Schools Curriculum Director, and AJHS administrators, and methods faculty of Auburn University from each of the four discipline areas.

Aug. 7th & 8th – faculty retreat for team building, goal setting, planning for school goals in our proposal.

Aug. 18-23 – Team 5 curriculum planning and unit planning

Aug. 24th – beginning of school year

The three eighth grade faculty teams at AJHS (15 teachers) participated in a retreat at a state park in early August, about two weeks prior to the opening of school. They were joined by seventh grade faculty who are not yet involved in multidisciplinary teaching, and observers from the sixth grade middle school faculty. The principals of both schools, the city superintendent, assistant superintendent, and former state superintendent attended. The success of the first retreat resulted in a second one two months later designed to bring sixth and seventh grade teachers to a common perception of teaming, and middle school philosophy. Additionally, the superintendent purchased copies of The Exemplary Middle School by William M. Alexander and Paul S. George (1981, Holt, Rinehart and Winston) and two other middle school resource books for all city 6th, 7th, and 8th grade teachers. For the 1998-99 school year the city will reorganize into two middle schools housing 6th, 7th and 8th grades, with faculty split equally between the schools. All faculty are being prepared for a new approach to teaching.

AU faculty and students will meet for two class meetings per week over ten weeks. Figure 2 below shows our plan for the nineteen meetings with approximately twenty-four preservice teachers.

Figure 2

Class Meeting #2 – Introduce the AJHS connection as part of field experience requirements of the class. Especially tutoring of 8th graders after school as start-up for later classroom encounters. Set dates for classroom teaching episodes.

Class Meeting #4 – First 1-hour observation of AJHS Team 5 teachers. This is done in six groups of 4 AU students, who may observe different subjects being taught. Followed by 1-hour debriefing with entire Team 5 faculty at AJHS.

Class Meeting #5 – Second 1-hour observation of AJHS Team 5 teachers done in groups of 4 AU students, who observe different teachers this time. Followed by debriefing.

Class Meeting #6 – Making meaning from our observations. What was happening with students? With teachers? What outcomes? What did you understand? AJHS science teacher visits AU class to help us understand the environment we observed.

Class Meeting #10 – First planning session with AJHS teachers in Team 5. How topics will be presented and taught. Dates and schedules AU students to visit and team teach.

Class Meeting #13 – Begin teaching by AU students in AJHS classrooms. Each two-member team will be responsible for at least one class, which will be video taped with feedback provided to the novice teachers by AJHS staff and AU supervisor.

Class Meeting #18 – Complete last teaching by AU students. Discuss outcomes and set goals.

Later we expand this model by following additional team leaders on AJHS staff and AU College of Education faculty so they will be ready to replicate the above stages with their own students.

Budget

The grant funds from Colorado ISTEP have been placed in an account at AJHS under the control of the principal and teachers there. To date all funds have been matched dollar for dollar by moneys from Auburn City Schools. Thus, the first faculty retreat in August actually cost about $3,000, but consumed only $1,500 from the ISTEP budget. Funds are allocated for faculty release time, three academic year faculty workshops on interdisciplinary teaching, supplies, and reference books. Much of the release time funds will be used to provide faculty time to "shadow" other teachers who serve as models for interdisciplinary teaming. Plans are for continued cost sharing between the city schools and the ISTEP grant.

Links with Preservice Teachers

AU preservice students plan and rehearse these lessons and present them under the watchful eyes of experienced teachers. This serves to promote reflective practice among the "teachers-to-be" while bringing special equipment and ideas for AJHS faculty. Providing future teachers with this experience before their internship helps them (a) prepare for teaming with other teachers, (b) practice teaching in a constructivist environment, and (c) obtain valuable feedback from experienced teachers who critique their teaching skills.

Summary

We believe that professional development should begin before teachers are certified. By starting our efforts at the preservice level, we hope to convince future teachers of the value of collaborative relationships with other teachers and the university community. We will foster better working relationships between university faculty and local schools by providing a needed service and professional development for inservice teachers as part of this joint effort. All participants gain from the planned collaborative.

The faculties of both institutions benefit from sharing resources and personnel. The eighth grade students gain by having a lower student-teacher ratio and through improved teaching techniques in the classroom. The preservice teachers gain by having mentors who are experienced classroom teachers. Discipline faculty at the university will be invited to join this project early. Figure 3 shows the initial phase of our project, involving 8th grade only and science teachers only.

Figure 3

Phase I (First Year)

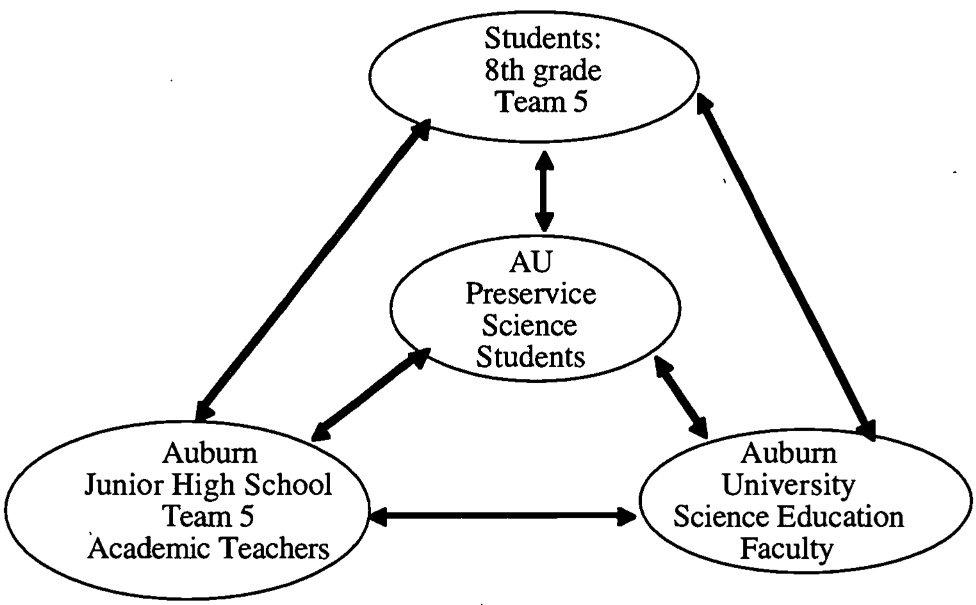
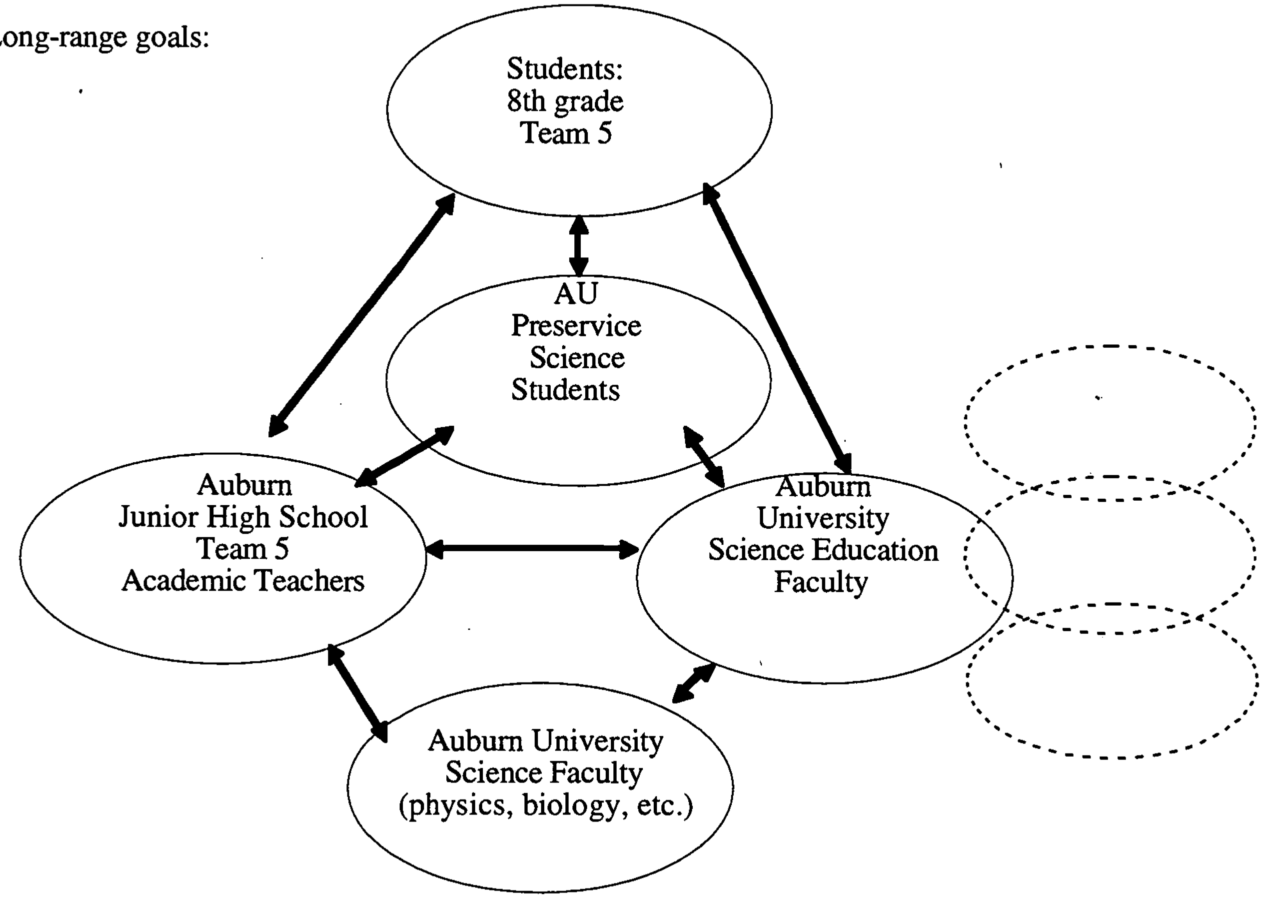


Figure 4

Phase II (Second Half of First Year)

Phase II (Figure 4)will be identical to Phase I except that we will add additional discipline areas to science education on the right side of the diagram, e.g. math, English, and social studies AU faculty and preservice students. Also additional faculty teams at AJHS will join the project. Preservice teachers will learn to negotiate subjects and time allocation with other team members at each level to insure goal achievement and smooth transition to visiting teaching teams.

Long-range goals:



This second phase of our model will be used by other schools in the local area within three years.

CONSTRUCTIVIST ASSESSMENT PRACTICES

Robin Lee Harris Freedman, Buffalo State College

Introduction

What kinds of assessments do teachers use in traditional and reform classrooms to determine a student's grade? If assessments evolve out of instruction, as is expected in inquiry and constructivist-based classrooms, then assessments should reflect what students learn and can do. There is a problem with investigating classroom assessment strategies because teachers' beliefs, practices, and other factors cause teachers to use many different formal and informal assessments (Airasian, 1994; Angelo & Cross, 1993; Penick & Bonnstetter, 1993; Smith, 1979; Smith, 1993). There is abundant research on the variety and diversity of assessments used by teachers (Airasian, 1994; Angelo & Cross, 1993; Brownstein, 1996; Champagne, 1992; Council, 1996; Doran, 1990; Harrison, 1996; Hart, 1994; O'Sullivan & Chalnick, 1991; Wiggins, 1989). There is little research on what actually happens between teacher and student in terms of assessments undertaken in classrooms (Shepard, 1989; Stiggins, 1991a; Stiggins, 1985; Stiggins, Conklin & Bridgeford, 1986; Watson, 1995; Briscoe, 1994; Tobias, 1992; Stiggins & Conklin, 1992).

The purpose of this study was to describe, not prescribe, the assessment environment as it pertains to constructivist assessment practices presented in Iowa Scope, Sequence, & Coordination (Iowa SS&C) and other Iowa science classrooms (IST).

Theoretical Framework

This study used constructivist theory and the goals and tenets of the Iowa SS&C project as its framework. Three constructs emerge from the literature regarding constructivism and have implications for the learning environment. They are (1) learning is an active process, (2) the learner has prior knowledge, and (3) the learner takes responsibility for their own learning (Yager, 1991; Cobb et al 1992, Magoon, 1977; Hewson & Hewson, 1988). These three ideas are central to this study. These ideas can be operationalized by the following statements.

1. Assessments are in a meaningful context that is relevant or has emerging relevance to students (Brooks & Brooks, 1993).

2. The process of learning does not shut down during assessment (Brooks & Brooks, 1993).

3. Formal assessments are tailored to specific modules and teaching situations (Zahorik, 1995).

4. Assessments include higher order thinking skills, i.e., application, evaluation, analysis, synthesis (Burry-Stock, 1995; Yager, 1991).

5. Assessments include application of knowledge and comprehension (Zahorik, 1995).

6. A range of techniques is used in assessments (Burry-Stock, 1995; Zahorik, 1995).

7. Assessments focus on the big pictures on concepts and on issues and their accompanying facts and evidence (Zahorik, 1995).

8. Assessment includes inquiry (Brooks & Brooks, 1993; Yager, 1991).

9. Students go beyond initial information levels (knowledge and comprehension) through elaboration doing in-depth analysis of big ideas, issues and concepts (Brooks & Brooks, 1993).

10. Students solve problems in which they extend and re-conceptualize (accommodation) knowledge in new contexts (Brooks & Brooks, 1993; Osborne & Wittrock, 1983; Zahorik, 1995).

11. Students generalize (synthesis) experiences from earlier concrete experiences a to understand abstract theories and applications (Brooks & Brooks, 1993; Osborne & Wittrock, 1983; Zahorik, 1995).

12. Students exhibit knowledge through application (Yager, 1991).

Students interact with each other in all circumstances including during assessments (Zahorik, 1995).

Methods

Participants

The participants that contributed information for this portion of the study were a sub-sample of a larger study group (Freedman, 1997; Marshall & Rossman, 1995). Potential candidates were defined by the parameters of the larger study. Nine teachers from the Iowa

SS&C sample and eight teachers from the IST sample agreed to participate in this section of the study. The sample, n=17, included 9 females (5 in Iowa SS&C, 4 in IST) and 8 males (4 in Iowa SS&C and 4 in IST). There were 7 middle school teachers (4 in Iowa SS&C, 3 in IST) and 10 high school teachers (5 in each). Teaching experience ranged from 4 to 36 years with 19.3 years being the average.

Data Collection

The interview format was chosen for its adaptability (Cates, 1985; Gall, Borg & Gall, 1996) . The interviews used in this study were semi-structured and contained four main questions (Gall et al., 1996) . Interview questions included:

1. Please explain or describe how your assessment/grading items were used to grade your students.
2. Which assessments/grading items intrinsically motivated your students?
3. What is the relationship between your assessment/grading practices and beliefs about good assessment/grading?
4. What people, courses, programs, etc., have influenced the way you assess/grade your students?

Data Analysis

A pilot interview with one Iowa SS&C middle school teacher was used to define the initial interview questions derived from Iowa SS&C tenets and specific constructivist assessment behaviors (Yager & Tamir, 1993; Yager, 1991; Zahorik, 1995) . Questions were asked of the interviewees in a semi-structured manner. An interview protocol was used. Two interviewees, one middle school and one high school, were chosen to act as key informants. The two were picked on the basis of their known expertise as expert constructivist/STS approach teachers (Yukatom, 1997; Varrella, 1997).

The constant comparative method following a grounded theory model was followed for analysis of the interviews (Marshall & Rossman, 1995; Miles & Huberman, 1994) . The information gleaned from this phase was used to answer the implied 'Why' in the research question, "How is participation in a reform project a predictor for constructivist assessment practices?" In this study the multi-case sub-sample of teachers added to the generalizability of the study (Gall et al., 1996) .

Interviews were recorded and transcribed. HyperResearch® (Version 1.65) was used to facilitate the unitizing of data from each interview (Marshall & Rossman, 1995) . After coding was completed, refinement of categories occurred (Marshall & Rossman, 1995) . Finally the rules of inclusion and accompanying text were examined for connections and emerging themes. Data synthesis was checked with an independent researcher to add to the trustworthiness of the analysis. Three themes emerged: a description of the assessment environment, a variety of assessments are used to make up students' grades, and the usage of higher order thinking processes during assessment.

Findings and Discussion

The Assessment Environment

In the assessment environment teachers take on the role of facilitator (Harms & Yager, 1981) . The assessment environment has two major sub-divisions, what defines the environment, and what influences the environment. The defining elements of the assessment environment are (a) teacher beliefs, (b) teacher practices, and (c) how teachers engage students in the social context in which assessment and instruction takes place. Influences on the environment are both internal and external.

Defining the Environment Through Teacher's Beliefs

Teachers are guided in their assessment practices by their beliefs. Three beliefs were identified by teachers that guide their practices in a constructivist classroom. They were: (a) teachers need to change, (b) doing and thinking about science is more important than being able to recite facts, (c) students can be responsible for their own assessment and learning. The first belief is that teachers believe they need to change in order to create assessments that meet the changing needs of all students. They do this by changing their perspective.

> And then I started changing and once you start changing, the more you change the more you want to change. And so it becomes almost a passion to take it to another level every year and hopefully meet the needs of every kid that you teach.

They do this by exploring new avenues.

> The most difficult task I have as a teacher is to be sure that at times I teach out of my comfort zone, that I try to learn the needs of all learners and that's also the reason that I think a wide variety of assessment strategies need to be incorporated.

They do this by infusing new information into their classes.

> Infusing technology is another one that you have to constantly have to keep up with that. They're always coming out with something new. So I've got to keep going.

In order for change to occur teachers need to accept it (Fullan, 1996; Fullan & Hargreaves, 1991). Teacher beliefs affect their practices (Varrella, 1997). Iowa science teachers accept change. The second belief is that <u>doing</u> science is more important than being able to recite facts.

> Number one if we're doing things that they're interested in and I'm still getting the kinds of things covered that I feel are necessary or at least the practices that are being covered, <u>if they know how to manipulate things, if they know how to ask good questions, if they know how to find information, if they know how to write a good paper</u>. That's more important than whether or not they know what constellation is going to be in the night sky tomorrow night.

Teachers believe that skills and attitude are important (Harms & Yager, 1981). They believe in doing science through inquiry (Yager, 1991). They believe that <u>less is more</u> (NSES, 1996). In the previous quote, the underlined sections contain the heart of the NSES definition of what it means to be scientifically literate (NSES, 1996; Rutherford & Ahlgren, 1990). The third belief, is that students can be responsible for their own assessment and learning. They have to be offered an opportunity and an environment where they feel safe to take on responsibilities. Iowa SS&C Goal 3 states that student growth should be improved in terms of attitudes about science, science classes, science teachers and careers. Tenet 7 states that students should work toward quality of thought and understanding (Yager, 1993). These beliefs are supporting an environment where students feel comfortable in taking an active role.

<u>Defining the Environment Through Teacher's Practices</u>

In addition to beliefs, teachers follow a number of practices that add breath to the assessment environment. They include (a) teachers do not feel restricted to text-embedded assessments, (b) teachers ask for student input, (c) teachers use questioning strategies to assess students' prior knowledge, (d) teachers incorporate knowledge of a larger picture into assessment and instruction, and (e) teachers use a variety of inquiries.

Teachers do not feel restricted to text-embedded assessments that come with texts. They change and modify existing assessments based on perceived student needs and abilities, personal goals, and district policy.

> I try to understand what it is that they're trying to get at and then adjust the assessment so that it really reflects what they've done and that there isn't some kind of an artificial thing there that has a built in thing that they're always going to be successful or it's so structured that they can't possible do well. So as long as we have some kind of agreement before we start, that these are the things that are reasonable expectations, then there isn't any problem.

Teachers also use student input to design and modify assessments. When an environment has been created where students are given the opportunity to accept responsibility, they do. Sometimes student input goes so far that students accept the responsibility of presenting their opinions, designing their own assessments, and selecting the criteria for grading.

> Yes, it was part of the points. And all of the points, the whole thing, what we were going to grade on, was discussed with the kids before it ever started. They decided on the criteria. This is what they wanted to find out.

Teachers listen to the student voice in this assessment environment (Brooks & Brooks, 1993; Stiggins, 1985; Tittle, Hecht & Moore, 1993) . They engage and present highly valued, student directed formative and summative assessments (Angelo & Cross, 1993; Geocaris, 1997) .

Teachers use questioning strategies to assess student prior knowledge (Penick, Crow & Bonnstetter, 1996) . Response to questions can reveal what students already know and what their beliefs are (Brooks & Brooks, 1993; Driver & Oldham, 1984; Jeffryes, 1994; Magoon, 1977) .

> It was just like four essay questions, this one was, or short answer but it was based more on their belief system and really a search of what they knew coming in.

Teachers incorporate knowledge of a larger picture, of big ideas, into assessment and instruction (NSES, 1996). SS&C Tenet #5 is the commitment to begin with larger ideas and themes (Yager, 1993) .

> Kids are used to be doing like, this animal is a mammal, this ones a reptile or something like that but it [the assessment] asks them to look at larger systems and cycles and how animals and habitat are interdependent on each other and also how man affects that.

Teachers use a variety of inquiries. Inquiry is the heart of the content standards in the NSES (1996). Using inquiry helps increase scientific understanding and reasoning (NSES, 1996). Inquiry is central to an understanding of the nature of science (Bentley & Garrison, 1991). SS&C Tenet 6 states the commitment to encouraging new student experiences based on inquiry (Yager, 1993). Inquiries include those that are examples of: the strength of observations, how to accommodate new knowledge into a larger picture, and how results are validated.

> And they would test and modify, test and modify, test and modify. Steal from each other, learn to watch what other people do, build upon that. So the idea, again, was to learn more about how science operates, for them to be able to do a different type of an inquiry. With each inquiry due, there's a different set of expectations which means they have to be more consistent with what the nature of science would be like.

Defining the Environment Through Student Engagement

Students have an active role in STS/Constructivist classrooms because their minds are engaged. They are not empty vessels sitting politely in rows in silence. Students question themselves, their peers, and their teachers on the new knowledge they are trying to incorporate into their mental structures (Osborne & Wittrock, 1983).

Iowa SS&C teachers encourage student involvement in the assessment environment in a variety of ways. Four are described here: (a) teachers involve students in decision making, (b) teachers enroll students in directing their own assessments and learning, (c) teachers engage students by using relevant issues, and (d) teachers motivate students by using a variety of assessments. Student involvement is essential in STS/Constructivist classrooms. The more they are involved the stronger voice they have (Angelo & Cross, 1993; Brooks & Brooks, 1993).

Students are involved in the decision making process of what makes up the assessments used to give them a grade. Sometimes their involvement is direct, and sometimes it is indirect.

> Every time that I come up with something, I'll always ask kids and say does this make sense and does this. And I think they're some of the best judges because they're involved in the process. I'll say, is this a good question and I usually test it out on, I'll

> pick some students out in the study hall setting and I say, read this and tell me what you think.

Students are enrolled in directing their own assessments and consequently the learning that goes along.

> I'm getting more comfortable with them being able to show me in different ways that they've gotten it. That's still hard, is letting them be able to pick the vehicle and then all I have to do is respond to the criteria. They struggle with it too, they're not used to it.

Student engagement is another important area where students' interaction with content can be gauged (Geocaris, 1997). Students are actively engaged in learning in constructivist assessment environments because learning has personal relevance for them (Yager & Tamir, 1993). This happens because the teacher knows what is relevant and/or uses local issues to draw students into the learning process (Yager, 1993). Issues emerge from student brainstorming that is guided by teacher "savvy."

Finally, teachers report that students are intrinsically motivated by different kinds of assessments, ones that are or are a combination of: (a) goal or product oriented, (b) student self-directed, or (c) entertaining.

> The one that motivates them the most I think, without any doubt, is the visual one where they can perform. That there's a performance component. Where they know that what the expectations are, first of all to start with. And the second piece is that they have ownership of it.... It's more open-ended, they're motivated by their own questions much more so than they're motivated by my questions.

> I would probably have to say that the trials at the beginning were probably the most. I don't know if it's because the kids are still fresh and they haven't realized that they're learning anything yet. They still think it's fun. But I also liked it because it gave those kids that were good at writing a chance. It gave those kids that were good at speaking a chance and it gave those kids that really weren't sure what they were good at yet, a chance to just kind of get started.

Something else that emerges in motivating practices is that all of the assessments mentioned involve group work. Students enjoy the social aspects of collaboration. Teacher practices support assessments that are highly valued and that are directed by teachers and students (NSES, 1996). The assessment environment is one where there is active learning in a social context (Cobb, 1994; Magoon, 1977). Assessment is not an after thought but a respected component of the classroom environment (Tamir, 1993).

Influences on the Assessment Environment

The assessment environment is influenced internally and externally. Internal influences include the daily interactions of the students and teachers within the context of classroom instruction. External influences came from district, state, or other educational sources.

The constant internal influence on the assessment environment is the teacher's curiosity and the need to find a solution to the statement, "there's got to be a better way." Teachers report that networking with other teachers and professionals is a source of new ideas (Fullan, 1996) . Teachers enjoy "kicking around ideas" with others and working as a team which is one consistent element of the Iowa SS&C project (Yager, Liu & Varrella, 1993) . Networking is a major source of ongoing change (Fullan & Hargreaves, 1991; Trax, 1997) . Interactions with others and intrinsic motivation leads teachers on a journey of change. Motivating factors for change focus on never being satisfied with the status quo. Iowa SS&C teachers seek new methods that will help them improve their teaching and assessment practices; the search for new ideas from educational research because they are life-long learners. They seek information from a variety of places. Here is a list gleaned from the teacher interviews: workshops, courses, magazines, conferences, study groups, mentors, professors, discussions, their own children, feedback from students, the cooperating teacher/student teacher relationship, Chautauqua, SS&C, colleagues, NSTA, IST, university funded programs, studying constructivism and the nature of science.

External influences on the classroom assessment environment can come from two sources. First is externally designed assessments that come from test-banks or as resource material that accompanies textbooks. Some teachers are required to use the text and the tests that come with them. Externally constructed national standardized tests are not usually relevant to students everyday learning (NSES, 1996). Consequently their use is often forced (NSES, 1996).

A second form of external influence is the *coverage* issue. Pressure is applied from a variety of sources, e.g., state mandates, district tests, parents, or the school board. The teacher is compelled to cover the material. Coverage acts in a similar manner as standardized tests. It reduces the scope of the curriculum and can focus on LOTS instead of HOTS (Darling-Hammond, 1993; Latchaw, 1995).

A Variety of Assessments

A second theme that emerged from the interview data is that teachers use a variety of assessments to make up a student's grade. Variety in this case does not mean sheer numbers. Variety means that different kinds of items make up assessments (Brooks & Brooks, 1993; Shepard, 1989; Stiggins, Frisbie & Griswold, 1989; Wiggins, 1997). This assumes that the teacher is aware of how students learn best and that the teacher wants students to grow in competence in a variety of learning situations (Brownstein, 1996; Caine & Caine, 1991; Gardner & Boix-Mansilla, 1994). Students are given multiple opportunities to show their competence and have opportunities to gain experience in styles where they are not so competent. Variety means visual, performing, writing, talking, designing, and presenting knowledge as individuals and in groups (Champagne & Newell, 1992). Variety also means that grades are a profile of many areas of competence that may include: concepts, inquiry, application, creativity, attitude, and a world view (Yager & McCormack, 1989). Effort that reflects engagement, motivation, and ultimately attitude expands variety beyond achievement. Assessments are characterized by being different. Variety according to interviewees includes: demonstrations, explanations, write a script, cartoons, draw a food web, inquiry, observations, use a rubric, make a checklist, drawings, immune skits, concept maps, role play a situation, projects, collage, logbook, review sheet, explorations, experiments, summaries, uses for new technology after viewing a video, presentations, outlines, and scale drawings.

Variety includes application, a specific type of assessment of knowledge, that is an essential element of STS approach and the Constructivist Learning Model (Harms & Yager, 1981; Yager, 1991). Students must make extra effort in order to complete the conceptual change process. Application assessments have four elements: (a) HOTS levels are used (Yager & McCormack, 1989), (b) content is well structured (NSES, 1996), (c) uses exhibitions of student knowledge (Brooks & Brooks, 1993), and (d) involves problem solving (Yager, 1993).

Variety includes different social configurations for assessments. Students like to work in groups. They enjoy the interaction. Additional avenues of assessment become available when students work in groups. During group work students usually accept responsibility and are engaged (Geocaris, 1997). Group work is an essential principle of social constructivist theory (Cobb, 1994; Cobb, Yackel & Wood, 1992). Some of the options include peer evaluation and making use of the cooperative or collaborative intellect.

> Well, it looked like chaos. There was a lot of discussion going on. There were groups on the floor, there were groups at desks, they were just all over the room but there was excitement. You could feel the excitement.
>
> But what they did was devise ways to be able to classify the soil. They had to work in groups and come to a consensus of how they could interpret or look or observe soil and make varying things.

Higher Order Thinking Skills (HOTS) in Assessment

The third theme that is relevant to this study is the use of higher order thinking skills in all aspects of assessment and learning. Going beyond recall and on to application, comparison, analysis, and evaluation (Burry-Stock & Cochran, 1996), is essential if students are going to accommodate information into new mental structures (Hewson & Hewson, 1988; Osborne & Wittrock, 1983). HOTS is incorporated into three of the eight SS&C Tenets, i.e., "focus on comprehension of science concepts, explain and apply science in personally meaningful ways, and work toward quality of thought," (Yager, 1993).

When HOTS are an integral part of instruction/assessment, two additional assessment formats become available, relating assessment to real-world phenomenon, and the ability to use a broader variety of assessments (Brooks & Brooks, 1993).

> This is a Copernican model that they drew... we used it a lot, for a lot of different labs and then to explain a lot of different things. We used it to explain not only Copernicus's theories about heliocentric universe, or heliocentric solar system but we also used it to explain the retro grade motion of Mars, and we used it to explain the seasons of the year. ...we looked at the constellations that were visible on the plain of the elliptic so we took a look at those and why they were there and then we were able to use those constellations to help us with the seasons of the year, that helped a lot because we could talk about, ...[what] constellations would be visible, you know, if this were summer this is where the constellations were. On the other side of the sun during summer you would be able to see...why.

When HOTS are evident, content becomes a vehicle for students to show understanding of HOTS (NSES, 1996).

> [Students role play a team of doctors whose task it is to identify a muscular disorder and present it to the family of the patient.] They have to diagnose it, there is no diagnosis there, they have to figure out what it is. And again, you have to get problems that are figure-outable by a high school kid at this point. That's the tough part. You want at least 12 or 13 of them so that if they work in pairs, everybody has a different one. To find 12 that aren't rare muscular diseases in some obscure medical text that these kids can find is not easy. They keep a work log, they have to come up with a visual.

When HOTS are evident, it opens the door to exciting inquiries. Inquiries where there are: solution, information acquisitions, and more questions (Yager, 1991).

> I do have one student-designed experiment in there whether doing it - you can call it product testing if you want - where they're trying to determine the effectiveness of various mouth washes.

Inquiry with HOTS also leads to the processing of information. Once again a vital component of the conceptual change process (Osborne & Wittrock, 1983).

> And then from there we brainstorm and we come up with a list of characteristics as to what does make up a good source and what are you looking for when you go research things for science. And this is the very first thing we do, this is day one. Because when they go and do their projects and things, they always ask themselves those questions.

Students working in groups learn and apply HOTS process knowledge to create team assessments. These assessments include projects, presentations, and performances. Group work allows students to exercise their strengths and receive support for their weaknesses. Often the knowledge gained is more than expected of an individual.

> On geological history....everybody researched Iowa's geological history and created their own mural. And they could do it anyway they wanted....Some did it really long, some did it in circle graphs, they were able to do it circle graphs, you know, where it's a pie chart. And they had to learn angles. These kids had never studied angles so they learned the circumferences of a circle and they learned how many degrees were in a circle. So they got a lot more out of that than just the geological that went ------ a lot of math went into that one.

HOTS are an integral element of each of the NSES changing views of assessment (NSES, 1996, p.100). They are discussed as a missing component of assessment in the issues of <u>teaching to the test</u> and <u>grading practices</u> (Latchaw, 1995; Stiggins & Bridgeford, 1985). HOTS are needed for conceptual change (Osborne & Wittrock, 1983). HOTS are integrated into frameworks, modules, and everyday lessons by the participants in the Iowa SS&C project (Yager, 1993; Yager et al., 1993) .

Implications

Philosophy, pedagogy, and teacher practices combined to affect the nature of assessment used in classrooms of participants in this study. The main results were:

1. The assessment environment can be described by teachers.
2. A variety of assessments are used to determine a student's grade.
3. Higher order thinking skills are an integral part of Iowa SS&C teacher assessment items.

The assessment environment is a complicated dynamic place. Iowa SS&C teachers who were a part of this study described an assessment environment that is viable and conforms to the NSES, constructivist theory, and STS pedagogy. Iowa SS&C teachers receiving reform information and integrating it into their classroom assessment environment are different from those who are not involved in the reform movement. The existence of this kind of environment should be shared. Implications for pre-service teaching and professional development include:

1. Iowa SS&C teachers should discuss their assessment practices with other teachers as a means of informing others as well as a means of gaining new ideas themselves.
2. Other teachers should observe Iowa SS&C teachers classrooms.
3. Assessments used in Iowa SS&C classrooms should be shared, along with the instruction that surrounds assessment items.

Variety in assessment is more than a list of items as designated by the ACLSI. It is defined in depth by teacher practices noted from the interviews, including: addressing multiple learning styles, variety in semester and week projects, variety in thinking skills, and variety in inquiries. Implications for pre-service teaching and professional development include:

1. Multiple learning styles need to be explored in pre-service teaching courses.
2. A deeper exploration of different items needs to be developed (more than just listing possibilities).
3. Explanations of purpose need to be addressed.

Assessments that include higher order thinking skills represent one type of this variety. Implications for pre-service teaching and professional development include:

1. Course material should include suggestions for teacher development and specific identification of HOTS for assessment purposes.

2. Students should be given more time to think about the science they are doing.

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INFLUENCE OF MODELING CONSTRUCTIVIST LEARNING ENVIRONMENTS ON PRESERVICE AND INSERVICE TEACHERS

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The Study

Researchers from four universities asked their students to contrast their learning experiences in the constructivist courses they created against other courses they had taken or were currently enrolled in or, if they were graduate students, against their previous coursework. The data collected by Simmons and Clough contrasted undergraduate students' perceptions, while the data collected by Dantonio and Richardson contrasted graduate students' perceptions in two masters programs. One masters program was a very traditional on-campus transmission format, the other an on off-campus constructivist program. The instrument used to collect the data was an modified version (Appendix One) of the Constructivist Learning Environment Survey (CLES: P.Taylor, B. Fraser, & L. White, 1994). The modified CLES was administered twice to the students in the study. During the first administration students responded regarding the current constructivist course they were enrolled in. During the second administration students responded regarding their other coursework.

The CLES instrument contained eight scales (Personal Relevance Scale - questions 1, 14, 16, 26, 36, 42, 49; Critical Voice Scale - questions 3, 9, 20, 29, 34, 43, 50; Shared Control Scale - questions 4, 10, 21, 27, 37, 44, 51; Student Negotiation Scale - questions 5, 12, 23, 31, 39, 48, 55; Educational Uncertainty Scale - questions 2, 8, 18, 22, 32, 56; Classroom Consistency Scale - questions 13, 41, 45, 54, 57, 58; Educational Leadership Scale - questions 7, 11, 15, 19, 24, 28, 38, 46, 53; and Attitude Scale - questions 6, 17, 25, 30, 33, 35, 40, 47, 52). Figures 1-8 summarize the data collected by the researchers, sorted by the eight scales. The vertical lines on the charts in the figures represent the average difference the students perceived between their current constructivist classroom and their other coursework. The top point of the vertical line represents the average Likert response regarding their current constructivist course, while the bottom point of the vertical line represents the average Likert response regarding their other coursework. The number of students in each cohort was: Clough-34, Simmons-23, Dantonio-30, Richardson-34

General Findings

1. Of significance was the fact that for each of the fifty-eight questions in the modified CLES, all four university cohorts perceived the constructivist approach as more positive (Figures 1-8).

2. Responses in Dantonio's traditional graduate program (a one-year Master of Arts in Teaching in which students with a college/university degree became licensed teachers) were generally closer to the undergraduate range, although for most items in the CLES the MAT students' perceptions were below those of both undergraduate programs, and far below those of the constructivist masters program (Figures 1-8). This finding makes sense because none of the students in either of the undergraduate or the MAT cohorts had any actual teaching experience to ground their current learning.

3. A corollary to number two above is that a constructivist teacher in a predominantly traditional program can make a difference, but that difference is minimal (Figures 1-8).

4. Teachers in Richardson's cohort who had classroom experience and who were now experiencing a constructivist delivery of their entire masters program, consistently perceived a much larger difference between their current coursework and their past (other) coursework than did either the undergraduate cohorts or the traditional MAT cohort. This was true in 56 of the 58 responses (Figures 1-8). This can be interpreted (and has since been substantiated by member feedback) as meaning that until the learner experiences a system-wide constructivist program, comparisons to past coursework do not have the depth of contextual understanding needed to make a true contrast. Further, once the depth of understanding of the constructivist framework has been incorporated into the learners cognitive framework, the perceived value of past coursework is diminished. This can be seen by the fact that in 51 of the 58 questions (Figures 1-8), the students in the constructivist masters program perceived their past (other) coursework as less valuable than all three of the other cohorts. Clearly, you cannot perceive a difference until you have truly experienced a difference.

5. The Educational Leadership Scale (Figure 7) is of significance in that both of the masters programs in this study purported to have a leadership strand as the major unifying component. Note that only in question number 11 did the students in the MAT program exceed the perceptions of the undergraduate programs. In all the rest of the questions, the students' perceptions of the MAT program were below that of either undergraduate program and further below the constructivist masters program.

6. In the undergraduate constructivist courses leadership was not a specific unifying component. However, in the context of a constructivist approach the attributes of leadership, surveyed by the CLES, were perceived by undergraduates to be integral to their coursework (Figure 7).

7. Without the contextual experience in the classroom as an inservice teacher and being a member of an ongoing program in which teachers are incorporating constructivist methods, community building and leadership into their day-to-day activities in the educational community (as are the teachers in the constructivist masters program), perceptions of the development of leadership skills may be somewhat inflated, as indicated by the responses of both undergraduate and graduate MAT programs (Figure 7).

8. Attitude (beliefs, values, emotions) plays a fundmental role in learning (Caine & Caine, 1994). It is of significance that attitude was lower across all nine questions for the traditional MAT graduate program than for either the undergraduate courses or the constructivist masters program (Figure 8).

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Appendix 1

TEACHER DEVELOPMENT CLASS SURVEY

Directions: For each statement, fill in the circle that best describes your feelings about experience in this instructor's course (s).

In this course(s).....	(5) Almost Always	(4) Often	(3) Some-Times	(2) Seldom	(1) Almost Never
1) I learn about the classroom (s) in which I am teaching (observing).	0	0	0	0	0
2) I learn that educational theories and practices are human inventions.	0	0	0	0	0
3) It's OK to ask my professors "why do we have to learn this?"	0	0	0	0	0
4) I help the professors plan what I'm going to learn.	0	0	0	0	0
5) I have opportunities to dialogue with other students.	0	0	0	0	0
6) I look forward to my on-campus coursework.	0	0	0	0	0
7) I learn how to incorporate the community into my classroom to help children meet challenging standards.	0	0	0	0	0
8) I learn that educational theories and practices are influenced by people's values and opinions.	0	0	0	0	0
9) I feel free to critically question the way I'm being taught.	0	0	0	0	0
10) I help my professors decide how well my learning is going.	0	0	0	0	0
11) I learn how I (and my students) can take social action to solve or resolve school and/or community problems.	0	0	0	0	0
12) I talk with other students about how to solve classroom problems.	0	0	0	0	0
13) My supervising teacher helps me to put the educational theories I learn into classroom practice.	0	0	0	0	0
14) New learning starts with the experiences I have had in the classroom in which I am teaching (observing).	0	0	0	0	0
15) I develop a relevant education information base.	0	0	0	0	0
16) I understand how to transfer what I am learning on-campus to the classroom in which I am teaching (observing).	0	0	0	0	0
17) I feel emotionally and intellectually safe in my on-campus classrooms.	0	0	0	0	0

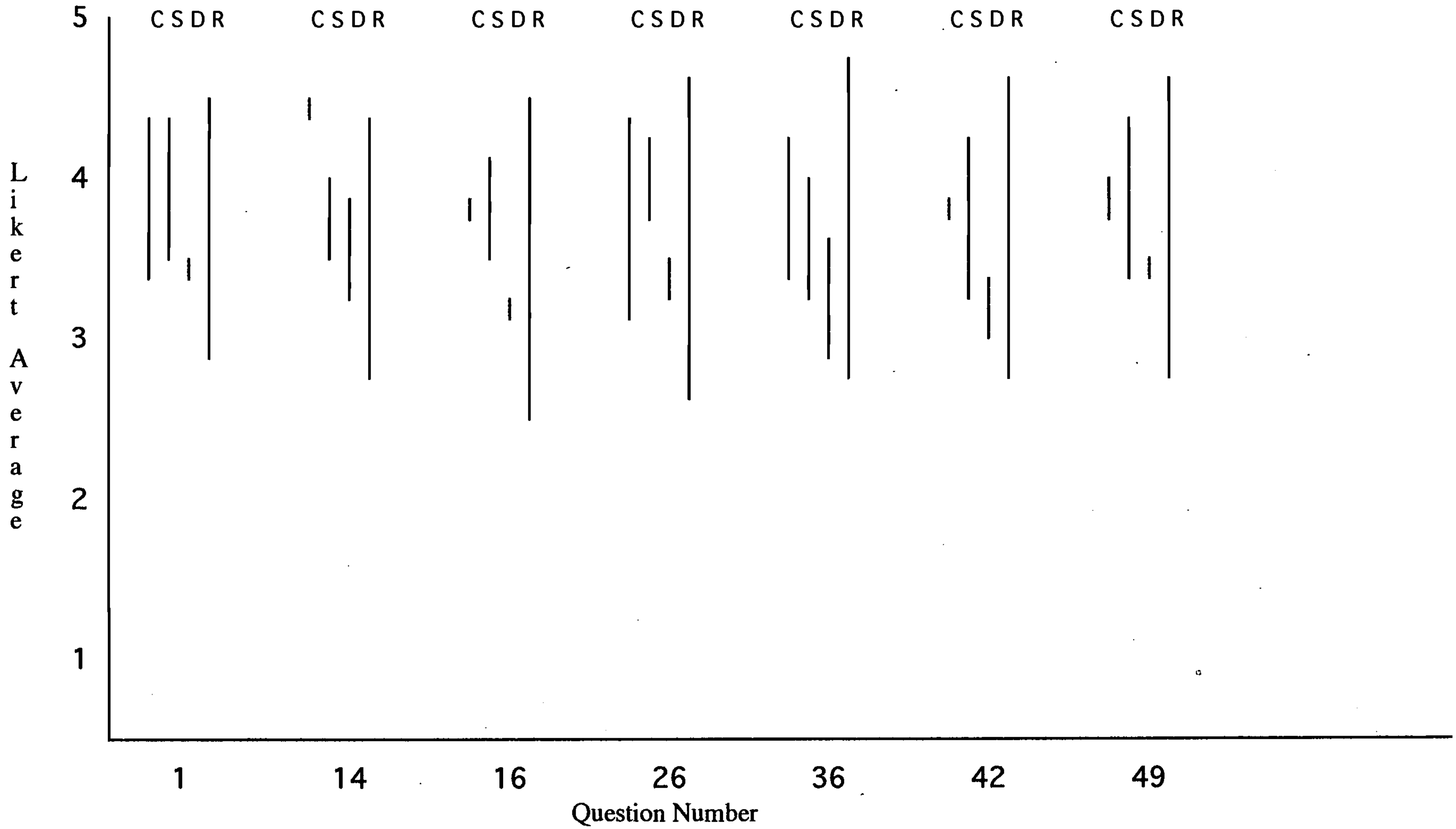
In this course(s).....	Almost Always	Often	Some-Times	Seldom	Almost Never
18) I learn that educational theories can be questioned.	0	0	0	0	0
19) I learn the value of joining and becoming active in professional organizations (attending & presenting at conferences)	0	0	0	0	0
20) It is OK to critically challenge coursework that is confusing.	0	0	0	0	0
21) I have a say in deciding the procedures for classroom discussion.	0	0	0	0	0
22) I learn that educational theories have changed over time.	0	0	0	0	0
23) I have opportunities to make sense of other students ideas.	0	0	0	0	0
24) I learn to coach my peers in a manner that does not create collegial resistance.	0	0	0	0	0
25) I feel confused.	0	0	0	0	0
26) I get a better understanding of the classroom in which I am teaching (observing).	0	0	0	0	0
27) I have a say in deciding how much time I spend on an activity.	0	0	0	0	0
28) I learn how the "system" works at my school and how to interact with central office, parents, & local community.	0	0	0	0	0
29) It is OK to critically challenge anything that prevents me from learning.	0	0	0	0	0
30) My on-campus coursework makes me interested in becoming an educator.	0	0	0	0	0
31) I have opportunities for other students to explain their ideas to me.	0	0	0	0	0
32) I learn that different approaches to education are used by educators in other cultures.	0	0	0	0	0
33) I feel tense.	0	0	0	0	0
34) I have the freedom to express my opinions.	0	0	0	0	0
35) I feel emotionally and intellectually safe in my supervising teacher's classroom.	0	0	0	0	0

In this course(s).....	Almost Always	Often	Some-Times	Seldom	Almost Never
36) I learn interesting things in my on-campus classes about the classrooms in which I am teaching (observing).	0	0	0	0	0
37) I have a say in deciding how I will be assessed and evaluated.	0	0	0	0	0
38) I learn how to develop educational goals & strategies that reflect legitimate interests of parents, community & state.	0	0	0	0	0
39) I have opportunities to ask other students to explain their ideas to me.	0	0	0	0	0
40) I enjoy the on-campus learning activities.	0	0	0	0	0
41) The classroom learning environment created by my professors is similar to the one they ask me to create for my students.	0	0	0	0	0
42) What I learn in my on-campus coursework has nothing to do with my personal needs as a developing classroom teacher.	0	0	0	0	0
43) It is OK for me to speak up for my rights.	0	0	0	0	0
44) I have a say in deciding on what on-campus classroom activities we do.	0	0	0	0	0
45) My methods courses help me put the educational theories I learn into classroom practice.	0	0	0	0	0
46) I learn how to cultivate support networks to minimize any failure I may experience during risk-taking.	0	0	0	0	0
47) The activities in my on-campus coursework are among the most interesting I've experienced in my post-secondary education.	0	0	0	0	0
48) Other students ask me to explain my ideas.	0	0	0	0	0
49) What I learn has nothing to do with my classroom experiences as a teacher (observer).	0	0	0	0	0
50) I feel unable to critically challenge any part of my teacher development experience.	0	0	0	0	0
51) I have a say in how my learning is assessed.	0	0	0	0	0
52) The learning activities in my on-campus courses are a waste of time.	0	0	0	0	0
53) I learn to responsibly challenge existing procedures and policies.	0	0	0	0	0

In this course(s).....	Almost Always	Often	Some-Times	Seldom	Almost Never
54) In my classrooms professors practice the same teaching strategies they advocate.	0	0	0	0	0
55) Other students pay attention to my ideas.	0	0	0	0	0
56) I learn that educational knowledge is beyond doubt.	0	0	0	0	0
57) My college coursework helps me to put the educational theories I learn into classroom practice.	0	0	0	0	0
58) I feel alone when it comes to translating the educational theories I learn into classroom practice.	0	0	0	0	0

Figure 1

Personal Relevance Scale



C=Clough Undergraduate

S=Simmons Undergraduate

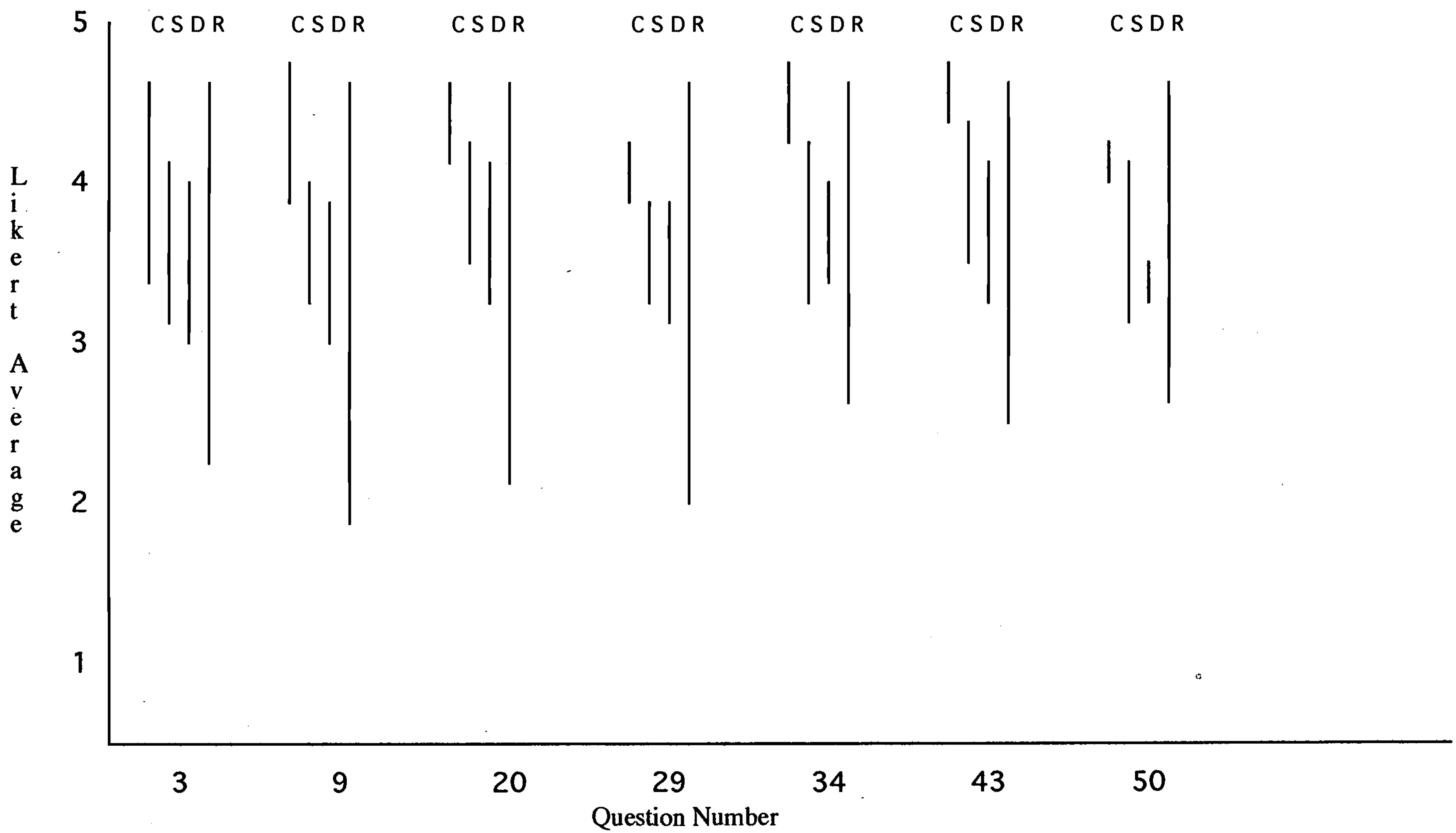
D=Dantonio Traditional Graduate

R=Richardson Constructivist Graduate

91

92

Figure 2
Critical Voice Scale



C=Clough
Undergraduate

S=Simmons
Undergraduate

D=Dantonio
Traditional
Graduate

R=Richardson
Constructivist
Graduate

Figure 3
Shared Control Scale

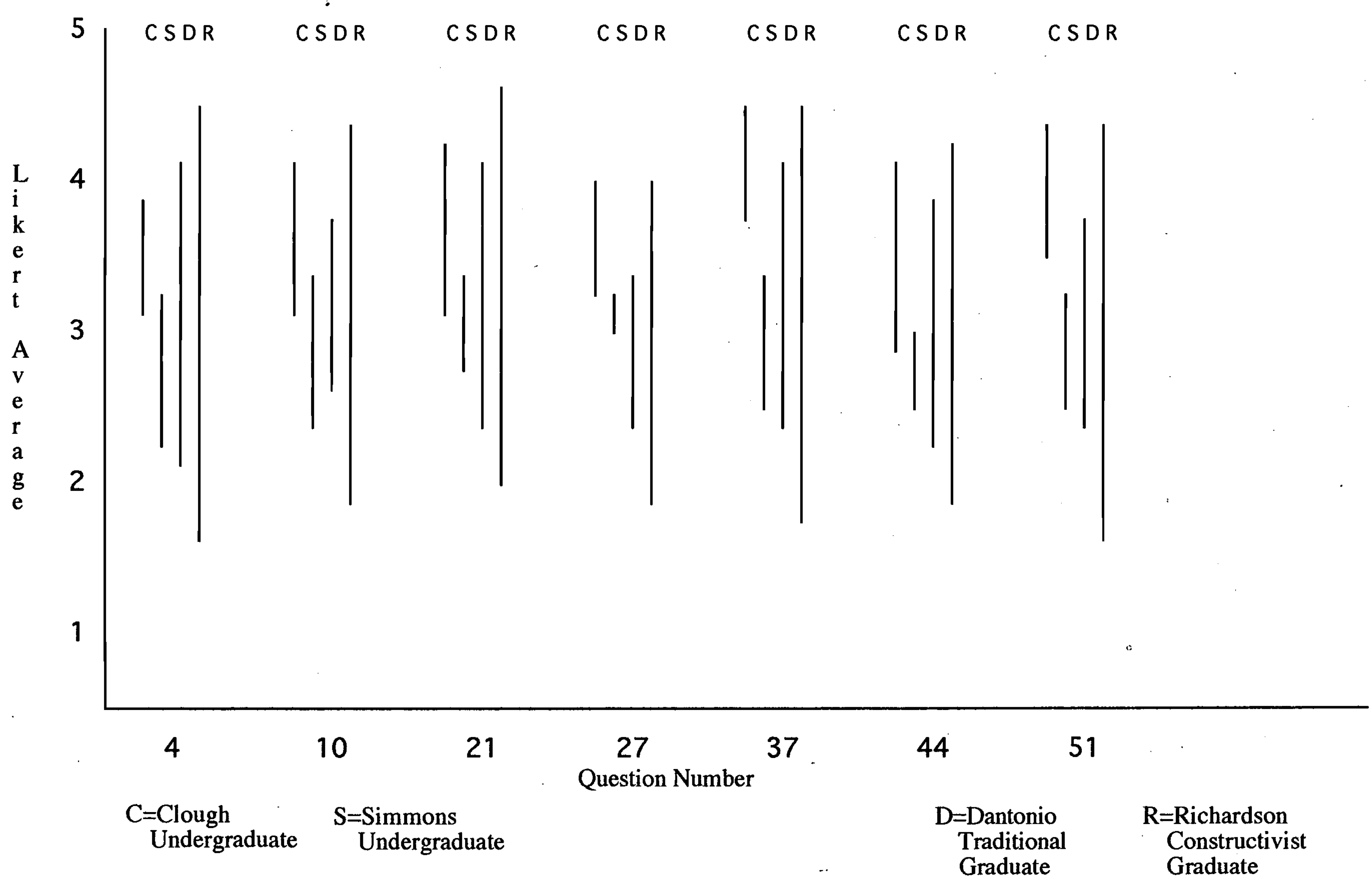
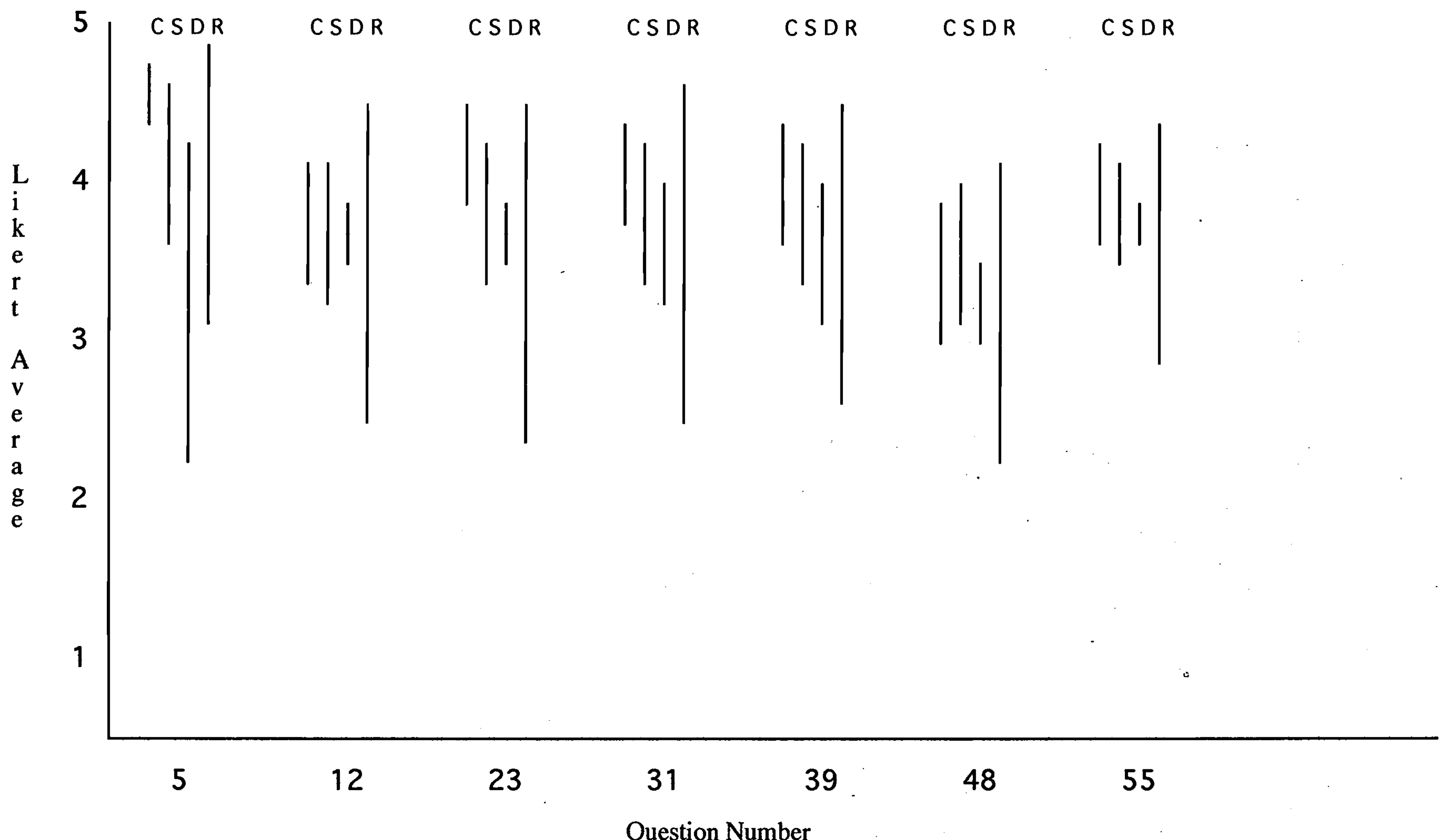


Figure 4

Student Negotiation Scale



C=Clough Undergraduate

S=Simmons Undergraduate

D=Dantonio Traditional Graduate

R=Richardson Constructivist Graduate

Figure 5

Educational Uncertainty Scale

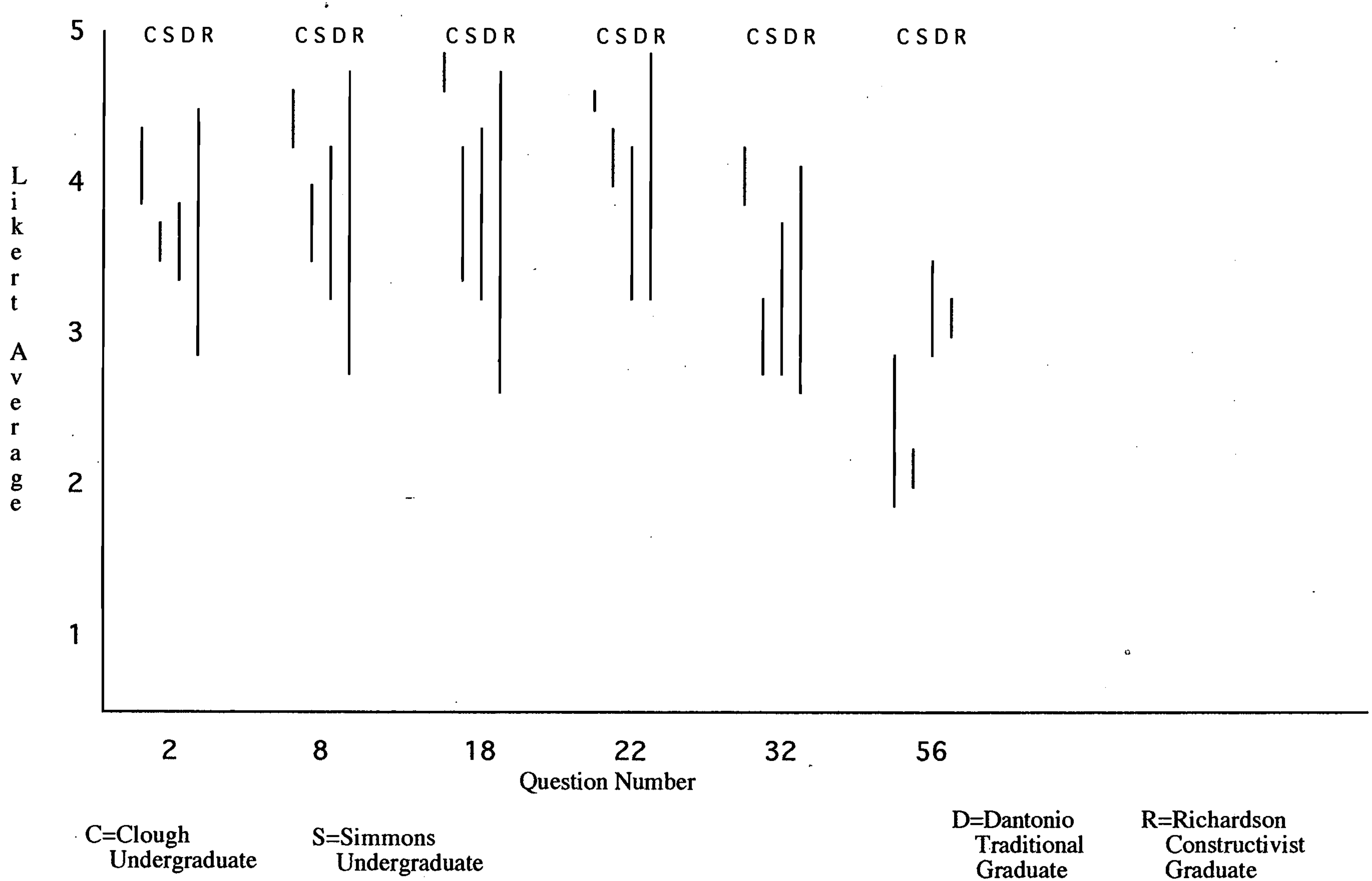
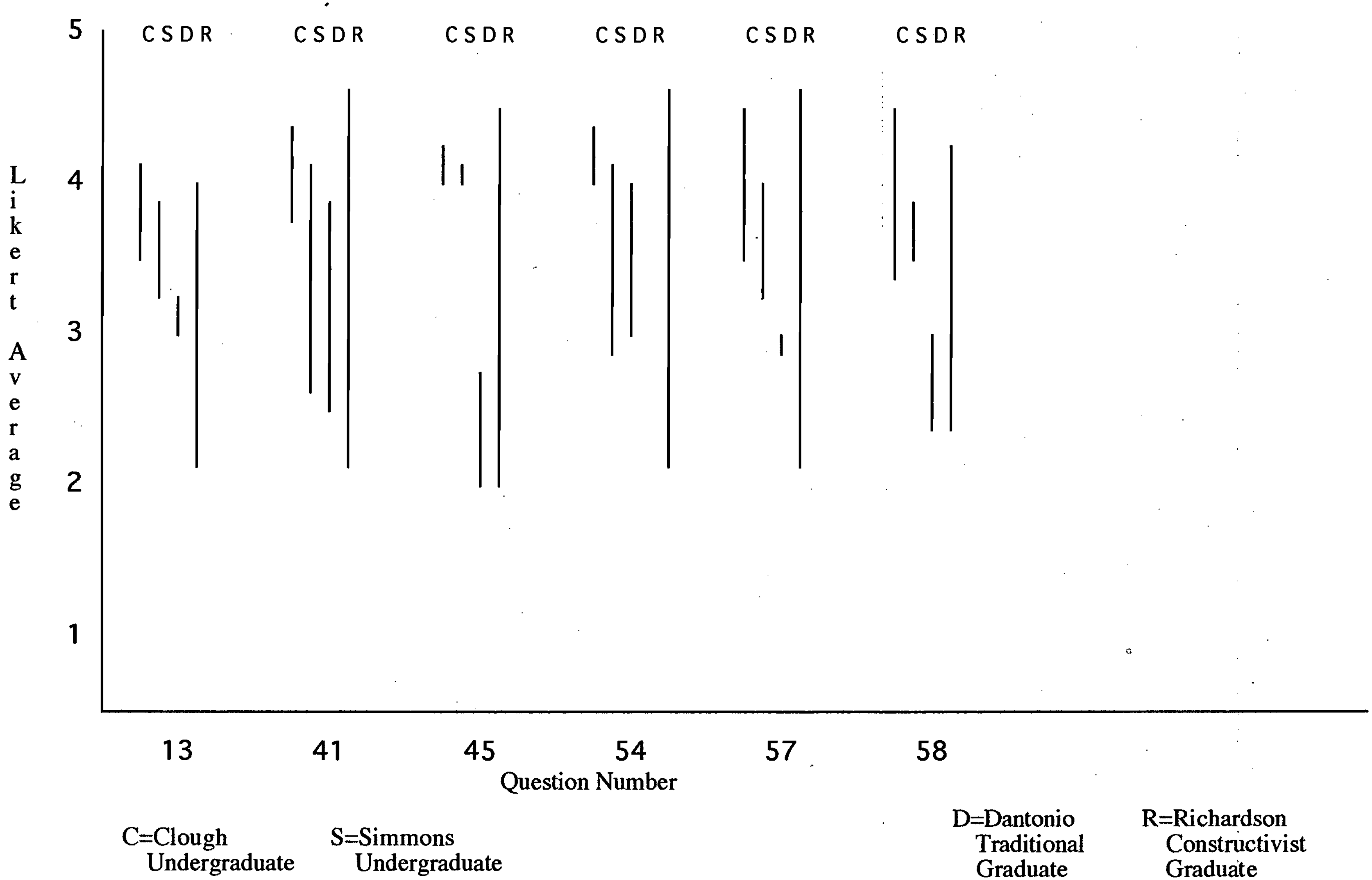


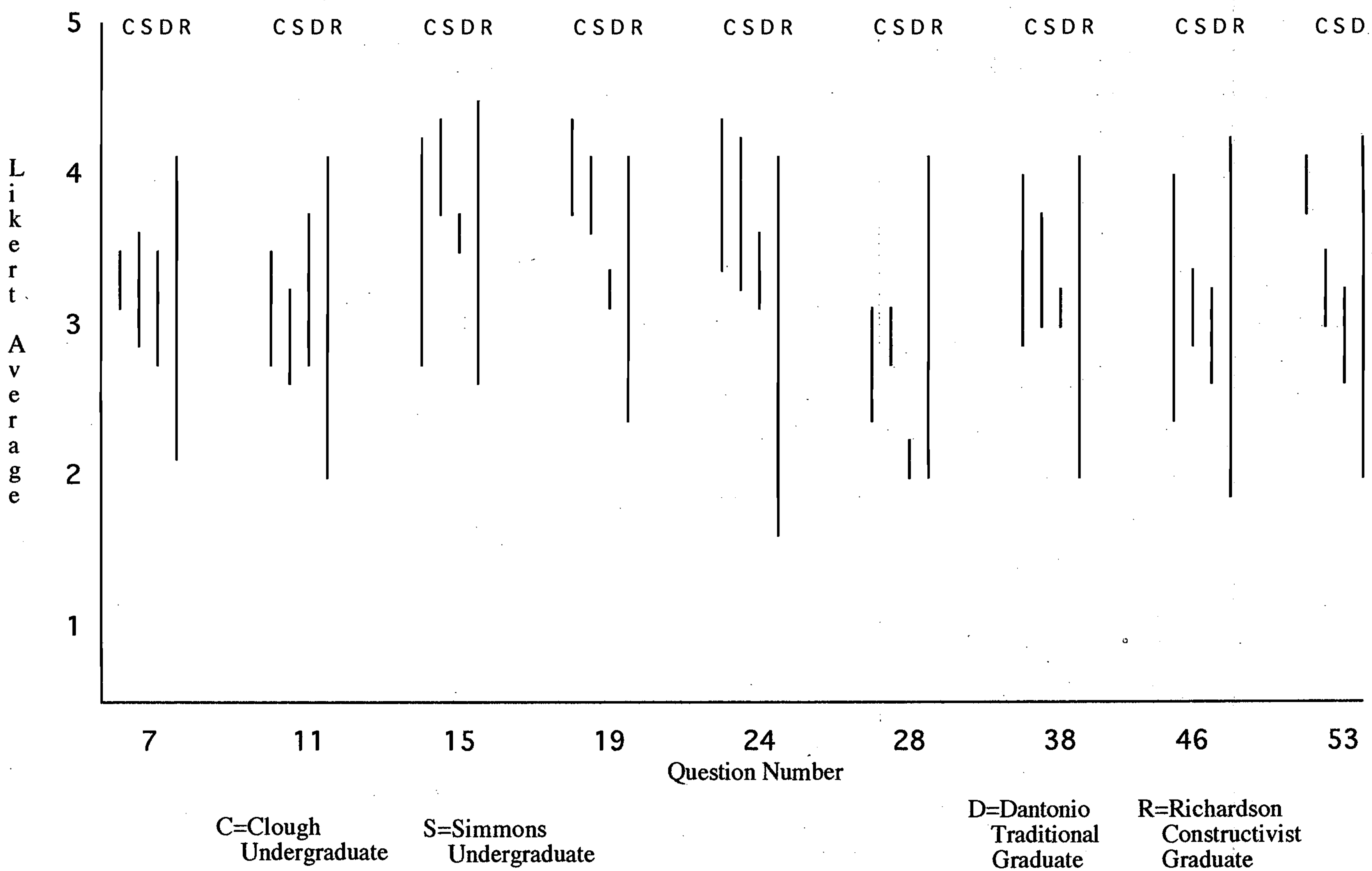
Figure 6
Classroom Consistency Scale



101

102

Figure 7
Educational Leadership Scale



103

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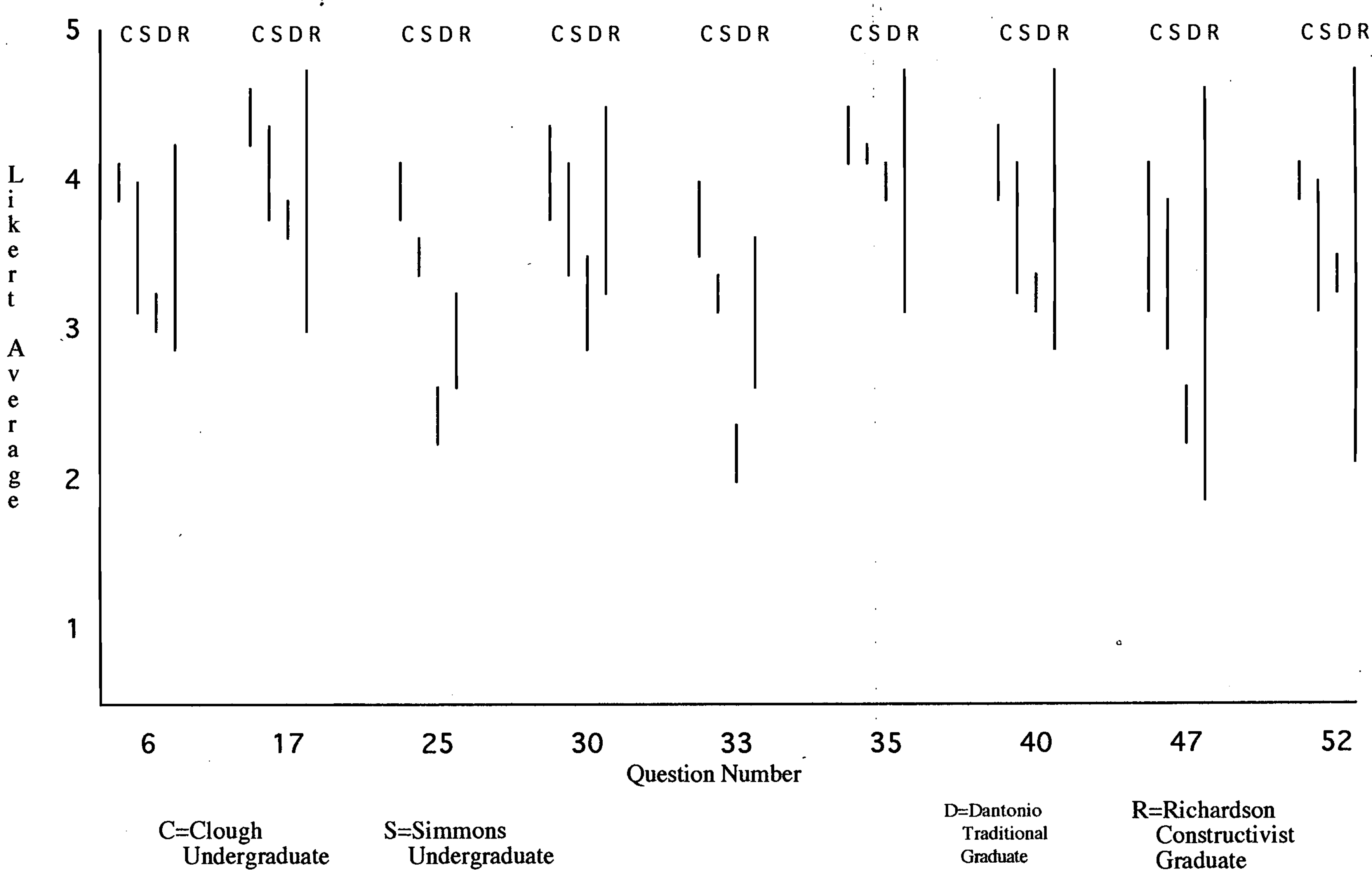
Figure 8
Attitude Scale



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MENTORING FUTURE MENTORS: THE PREPARATION OF SCIENCE TEACHER EDUCATORS

John A Craven III, Queens College/City University of New York

Introduction

Issues regarding the structure of science teacher preparation programs have been in existence for several decades (e.g., Yager et al., 1997; Yager & Bybee, 1991; Yager & Penick, 1990; Bethel, 1984; Mechling et al., 1982;). Yet in existing studies of science teacher education programs, no distinction is acknowledged between the preparation of the science teacher and that of the science teacher educator. For as little that is known about the preservice preparation of science teachers, even less is known about the preservice preparation of science teacher educators (PSTE).

The lack of research in this area may suggest that the proximity of undergraduate, graduate, and advanced graduate programs in science education creates assumptions that affect program design. Conceivably, an overarching assumption is that the needs of the student vary little from one stage to another except for the addition of more course work in research, pedagogy, and (perhaps) science. Yet significant differences in the roles and responsibilities do indeed separate science teachers from science teacher educators. In a critique of the traditional model of teacher education programs, Feinman-Nemser (1990) charges that, largely, methods courses are taught largely by university professors rather than master teachers.

Thus, there is a need to examine the skills and knowledge required for an exemplary teacher educator. Feinman-Nemser's comment highlights the necessity of examining the assumptions that may be made regarding the education of the PSTE. These include that the PSTE:

1. was initially a good science teacher,
2. experienced an exemplary K12 science teacher preparation program,
3. possesses standards- and research-based skills and understandings about science, teaching, and learning, and
4. can teach, model, design curriculum, and create an appropriate classroom environment for preservice teachers.

This paper presents arguments for the need to examine such programs and discusses the importance and impact that exemplary mentoring has on the learning outcomes of the science teacher educator (STE). Second, this paper presents an exemplary mentor model from an STE preparation program and argues that a formal program of mentoring the preservice science teacher educator (PSTE) should be part of all advanced graduate programs. Finally, this paper explores the application of an exemplary mentor model to other dimensions within teacher preparation.

Standards for Science Teacher Educators

The Association for the Education of Teachers in Science (AETS) has recently developed Standards for those involved in the preparation of science teachers. These standards are designed to clearly articulate and define a framework for the "knowledge, skills, experiences, attitudes, and habits of mind essential for the successful science teacher educator" (Lederman et al., 1997). The domains within the standards include Knowledge of Science; Science Pedagogy; Curriculum, Instruction, and Assessment; Knowledge of Learning and Cognition; Research/Scholarly Activity; and Professional Development Activities. The Standards represent, in part, an outcome from pressures both within and outside the community of science teacher educators to ensure that all students studying to teach science have the opportunity to become well-prepared.

While the standards do help to identify the essential qualifications for the STE, they do not address the ways in which those skills and understandings are achieved. Thus, the question remains, how does the PSTE learn the skills and knowledge necessary for exemplary practice? The answer to this question has profound implications on the design and structure of programs that prepare science teacher educators. For, as Marton (1988) reminds researchers, what is learned (that is, the outcome or the result) and how it is learned (that is, the act or the process) are two inseparable aspects of learning.

In a way, AETS has recognized the importance of "how" future science teacher educators best learn the skills and knowledge of an exemplary STE. It has done so through the Outstanding Mentor Award. In establishing the annual award, AETS has explicitly placed high value on, and recognition of, superior mentor models in the preparation of future science teacher educators. The award also implicitly acknowledges that it is through the intense mentor-student relationship that effective and useful conceptual change practices can be applied. These conceptual changes are often necessary before current science education reform efforts can be meaningfully understood (Hurd, 1993; Yager 1991). Consequently, the theoretical framework underlying the mentoring process should also be clearly understood. Furthermore, effective models of mentoring programs that currently exist must be identified and shared within the professional community.

Theoretical Framework for Mentoring

Constructivism has been at the forefront of recent efforts to improve science education (Yager, 1996). Research in learning psychology continues to provide evidence that knowledge is constructed by the learner (Driver et. al., 1994; Glaserfeld, 1989; Pope, 1982). Constructivism, with deep roots in Ausubelian psychology, explains that knowledge is synthesized, modified, and is evolutionary in character (Novack, 1985). But the learner is not isolated in this interaction between perceptions and internal rules - the social construction of knowledge is critical (Driver et al., 1994; Hewson et al., 1992; West & Pines, 1985). As a consequence, much of what we believe to know or understand results from a process of socialization. The impact of the socialization process on individual perspectives and understandings has been well documented (e.g., Erickson, 1991; Sarason, 1981; Bandura, 1977; Lortie, 1975; Kuhn, 1970;). Constructivist theory and socialization theory can be interpreted as being deeply embedded in some pre-professional and professional development models for teachers.

In an overview of the existing paradigms for professional growth, Sparks and Loucks-Horsley (1989) identified five models of staff development. These include: a) individually guided staff development , b) observation/assessment, c) involvement in a development/improvement process, d) training, and e) inquiry.

Of these five, the model of Observation/Assessment draws largely on the power of social constructivist learning theory. Within this model, phases of activities include a pre-observation conference, observation (collection of data), analysis of data, post observation conference, and analysis of the observation/assessment process between teacher and observer (Sparks et al., 1989). Sparks and Loucks-Horsley (1989) describe fundamental assumptions underlying the Observation/Assessment model. These include:

1. that reflection and analysis are critical in the observation/assessment model,
2. that reflection by an individual is enhanced by another's observations,
3. that observation and assessment of classroom teaching can benefit both observer and observee, and
4. when teachers see positive results from their effort to change, they are more apt to continue to engage in improvement.

Variations of the Observation/Assessment model can be found in the Peer Coaching Model (Showers and Joyce, 1996) and Shon's (1987) Coach and Student Model. Galbraith and Anstrom (1995) define the peer coaching model as a confidential process by which expertise is shared, feedback and support is provided, and assistance in developing and refining classroom skills is given. Through companionship, feedback, adaptation, and support, the peer coaching model can promote a self-perpetuating process to improve teaching and professional development (Galbraith and Anstrom, 1995). Another variation of the socialization model for professional development can be found in the writings of Donald Shon.

Shon (1987) argues that settings such as classrooms are terribly more complex than the simple models often presented within pedagogical courses in preservice programs. Thus, the simple application of facts or knowledge is not all that simple. Shon argues further that professional education should focus on improving the teacher's ability for "reflection-in-action". In this model, the practitioner learns by doing and develops the ability for continued learning and problem-solving throughout his or her career. Shon draws, in part, upon the work of John Dewey as he advocates that the student cannot be taught what he needs to know nor can the learner simply be told what to see. Through the student and coach interactions the learner is provided a mechanism for meaning-making in the profession (Shon, 1987). Shon's argument finds support in the works of others. Marton (1988), in describing ways of improving learning (that is, when learning is described as a conceptual change) states,

> It is important that educators provide instructional means by which the students can obtain guidance to help them meet the expectations. "We cannot directly make someone acquire a certain meaning, but we can possibly aid him or her to impose one structure on a phenomena rather than another. One of the ways of doing so is

> to introduce a cognitive conflict which makes the learner reconsider his or her habitual way of delimiting the phenomena (pg. 78).

In the variations of the student/mentor models described above, cognitive conflicts can result through a program of exemplary, purposeful approaches to questioning and probing the learner in authentic context (i.e. classrooms).

Mentor Model In Practice

Having explored the theoretical framework of mentor programs, attention is now turned towards an examination of a superior model in practice as acknowledged by the 1997 Outstanding Mentor Award. At the Science Education Center at the University of Iowa, particularly through the sequence of science teaching methods courses, Dr. John Penick has nurtured and developed a mentoring program for future science teacher educators. In that program, the PSTE gain skills and understandings regarding the education of preservice science teachers and the supervision of practicum/student teaching experiences. The model is described as a series of phases including Framework Construction, Framework Evaluation in Context, and Framework Application.

Framework Construction

The exemplary mentor model begins with early and extensive involvement of the PSTE in the science teacher education program. Most often, involvement in the methods and practicum courses does not come by request nor requirement of the instructor. Rather, those motivated PSTEs who explicitly express interest in the program are invited by the professor to sit in on the first of three methods courses offered to preservice science teachers. The PSTE is expected to participate in class discussions, read the required readings for the course, and write a rationale paper (a research-based justification of intended approaches to teaching and learning science) just as the preservice teachers do.

In addition to fulfilling the expectations of the course from the preservice teachers perspective, the PSTE meets with the instructor before, after, and quite often during the class (when students are involved in cooperative exercises, for instance). During those sessions, matters of pedagogy, course design, and the roles of the instructor and students as they relate to the instructor's goals are discussed. Furthermore, the PSTE is questioned about his or her observations and interpretations of the classroom interactions. Responses to these questions reveal the PSTE's skills to assess classroom learning and provide insights into emerging frameworks of understanding.

Through purposeful questioning of the PSTE, the instructor both assesses the perceptions and understandings of the PSTE and provides the cognitive conflicts necessary for the PSTE to move to deeper understandings about pedagogy, curriculum, and approaches to teaching and learning. In the Iowa program, involvement in the methods program lasts as long as the PSTE maintains interest and involvement in the sequence of courses. Naturally, exemplary PSTEs maintain interest and involvement in the program throughout their studies. Following a progression through the courses and sustained involvement, more responsibilities are laid upon the PSTE. These responsibilities include initiating and maintaining focused discussions about science teaching and learning, modeling researched-based approaches and habits of teaching and questioning, and assessment.

Preservice teachers in the methods courses are constantly being assessed with regard to their skills and understandings about the teaching and learning of science, the final evaluation rests largely on an exit interview. In that interview, the students are questioned about their researched-based rationales for teaching science which they write and continue to hone throughout their program. Consistencies and inconsistencies are made apparent to both instructor and student during the interview which typically lasts from one hour to an hour and a half.

Ultimately, the students are asked to evaluate their own efforts and performance as a student in the course. They are asked to consider their ability to integrate relevant research into discussions, their ability to demonstrate effective classroom practices, and to weigh their self-perceived potential against their actual performance. In short, the students are requested to "grade" themselves and to defend that grade using appropriate evidence. Furthermore, the process is as instructional as it is evaluative to both student and instructor. The exit interview is a very difficult one for most students in that most students have never been given the responsibility for assessing themselves as learners.

If it can be said that the process is a difficult one for the student, it can also be said that the process requires special skills and understandings on the part of the interviewer. And, again, these skills and understandings are fostered by the mentor model of the instructor. Initially, the PSTE only sits in on the exit interviews of the students in the course. The PSTE listens to both instructor and student throughout the exchange. He or she makes notes of patterns of interactions and questions, tries to identify the purpose and direction the questioner is leading to, and listens for "gaps" in understandings on the part of the student.

Importantly, the instructor/interviewer models effective questioning strategies for the PSTE and assesses the preservice teacher at the same time. There is a debriefing following the conclusion of the exit interview when the student has left the room. The mentor questions the PSTE regarding his or her observations and inferences. The PSTE is probed for insights into understandings about the teaching and learning of science held by themselves as well as the student who was just interviewed. Equally important, the PSTE perceptions of patterns of questioning and the resulting responses are probed. The PSTE is asked to identify types of questions that are particularly fruitful in eliciting a student's understandings and/or misconceptions.

Framework Evaluation in Context

Integral to all science teacher preparation programs are field experiences that connect to either methods courses or application courses within the program. The practicum experiences can be viewed by both the instructor and student alike as some of the most important preservice experiences. In that students can often verbally describe behavior without actually performing it (Bandura, 1965), the practicum portion of the teacher preparation program provides invaluable insights into the propensity of the students to incorporate their understandings into practice. Also, observing and abstracting meaning from the complex environment called the classroom requires special cognitive skills on the part of the supervisor. And, again, these can be achieved through the mentoring process.

In the Iowa program, an intense integration of technology and instruction provides a superior vehicle for the mentoring model to take place in the K12 classroom setting. First, the preservice teachers from the methods class are divided into teams of three. The task of each team is to construct an appropriate science learning experience for middle school students. This learning experience is to take place for three consecutive days. Cooperatively, the team determines a set of goals, designs the curriculum, gathers the materials, teaches the class, and assesses the outcomes. All of the teams visit a cooperating teacher's classroom to teach their lesson - one team in a class followed by the next team in the next class until all teams and/or classes have been taught. Throughout the teaching experience, the practicum students are wired with wireless microphones, recorded, and videotaped. At the end of the three day teaching experience, the students first analyze their own videotapes and then the class analyzes the tapes together on campus.

The technology of the wireless microphone and videocamera allows the instructor to select any of the three team teachers at any given moment to listen in on the interactions between student teacher and learner. The wireless microphone provides access to audio interactions that otherwise are unobservable. The methods instructor listens in on the teacher-student interactions through a set of headphones that receives a signal through the an amplifier. As the teachers teach, the instructor, tethered by a long line connecting headphones to camera, takes notes regarding pedagogy, curriculum, and content of the lesson. As in previously described phases of the mentor model within the Iowa program, the PSTE accompanies the instructor to the field to also observe and supervise the practicum students.

In that observation is theory laden (e.g., Kuhn, 1970), the PSTE will not typically be able to observe what the experienced instructor observes in the complex setting of the classroom. Yet, again, through interacting with the PSTE, the instructor can help try the PSTE construct a theoretical framework that is compatible with the instructor's. As this is being accomplished, both the PSTE and the instructor are able to "see" the same thing in the classroom. To foster the development of an adequate framework, the PSTE is also tethered to a set of headphones which enable him or her to listen in on the teacher student interactions. Similar to the instructor, the PSTE takes notes about the pedagogy, curriculum, and content of the lesson.

There are frequent interactions between the instructor and PSTE. Notes are compared and the PSTE is questioned about his or her observations. The instructor will ask the PSTE to provide elaboration and pedagogical implications of the observations and assessments he or she is making. Furthermore, the PSTE is probed about his or her interpretations of the classroom interactions, student roles, and teacher roles both real and hypothetical.

What the preservice science teacher educator reports he or she observes while supervising student teachers, while watching the science teacher educator teach preservice teachers, and self-reflective feedback on their own models of teaching and supervision all provide the STE with evidence of the soundness of the PSTE's theoretical framework. Importantly, inconsistencies - which translate into weaknesses - in the theoretical framework then can be made apparent. At that point the STE, through purposeful questioning, can provide sufficient cognitive dissonance sufficient enough for the PSTE to become aware of his or her own inconsistencies. Through this Deweyan constructivist approach (Prawat and Floden, 1994), a conceptual change from inadequate ways of viewing the classroom, learning, and teaching of science to more adequate or useful (also theory-based, integrated) ways is fostered.

The technology also allows the PSTE to listen in on the exchange between the preservice teacher and instructor throughout the field experience. The instructor will, under appropriate conditions, provide feedback to the practicum student during and after the lesson. From the practicum student's perspective, the field experience is a particularly vulnerable and intimidating time. They often believe themselves to be under the scrutiny of the middle school students, the instructor and PSTE, as well as the host teacher. Yet on-site feedback provides unique opportunities to provide assessment and instruction to the student that otherwise might be dismissed or forgotten. And, due to the emotionally charged nature of the practicum experience, special skills and understandings, apart from purely pedagogical and curricular, are needed by the instructor. The PSTE has the opportunity to develop these skills and understandings through a process of observation, doing, and feedback from the instructor.

Framework Application

Nearing completion of the PSTE program and after multiple and continuous semesters of involvement in the methods sequence and supervised field experiences, the PSTE is considered a full co-instructor for the methods course. Responsibility for planning, instruction, and assessment is placed equally across the co-instructors. At the same time, the dialogue between the mentor and the pre-professional continues to provide instructional means for strengthening theoretical frameworks.

Conclusion

This paper has discussed ways in which the pre-professional science teacher educator gains the skills and understandings regarding science teaching and learning that are consistent with those of an expert science teacher educator. An obvious question that may be raised, of course, is how would one know that the mentor is an "expert" in the field of science education? Recall, however, that exemplary science teacher educators can be identified by their ability to provide evidence of their practice in accordance to the Standards for Science Teacher Educators. Earlier in this discussion, the Standards were defined as an articulation of the "knowledge, skills, experiences, attitudes, and habits of mind essential for the successful science teacher educator".

Furthermore, this paper discussed how the incorporation of technology in the mentor model, in particular the supervision of classroom practica, can greatly enhance the effectiveness of the mentoring process. Lauren Resnick (1992), in describing ways of cultivating the dispositions to higher order thinking, states that,

> ...interactions in the social situation can provide occasions for modeling effective thinking strategies. Furthermore, skilled thinkers can demonstrate desirable ways of attacking problems, analyzing texts, and constructing arguments (pg. 137).

It has been described in this paper how the incorporation of video camera, wireless microphones, and receivers allows the pre-professional to "listen" in on the thoughts and watch the problem-solving actions of an expert in a contextualized setting.

Implications for Other Dimensions Within Teacher Preparation Programs

Arguments for the mentor model have implications beyond those for the professional development of preservice science teacher educators. Findings from two major studies of teacher preparation programs (Yager et al., 1997 and Goodlad et. al., 1990) report that a high degree of incoherence exists across program features. Given that at some larger teacher preparation institutions more than forty field supervisors are responsible for evaluating the field experiences of the preservice teachers, it is not surprising to understand that a high degree of incoherence exists across the feedback provided to the students. Lacking congruent theoretical frameworks, forty different field supervisors will make very different sets of observations and provide very different kinds of feedback. Yet it is vitally important that the feedback and instruction the practicum student receives from a supervisor remains consistent with the philosophy and approaches exhibited in the on-campus methods courses. It is equally important that the person supervising the practicum student places appropriate attention to those things that the student thus far has been inculcated to value. Applications of the mentor model between methods instructor and field supervisors may be extremely useful in a) fostering similar theoretical frameworks regarding the teaching and learning of science and b) coordinating congruent and coherent approaches to supervising student teachers and practicum experiences.

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WHAT THE SCIENCE STANDARDS SAY: IMPLICATIONS FOR TEACHER EDUCATION

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Introduction

As teacher educators, we are all searching for the very best models of instruction to facilitate teacher candidates' conceptions of what it is to teach effectively. Remembering the reform of the 1960's, educators are reminded of the all too forgotten, here today, gone tomorrow, sentiment that followed. As Gerry Wheeler (1996) states, Systemic reform has a temporal character (p. 308). Reform has been on the national agenda in science education for over a decade, and key leaders have offered their perspectives of progress to date (Rutherford, 1996; Strassenburg, 1996; Vos, 1996). There is little disagreement among science educators about the need for reform but the same cannot be said about the specific modes suggested to achieve this reform (Linn, 1992). Most educators agree that it is not enough to have great materials, very good summer programs for teachers, and an incorporation of educational philosophy concerning the very best in the practice of educational methods. A commonly agreed upon theme for reform in science education is the active involvement of learners in the teaching and learning process. As teacher educators strive to embed the principles of the science reform initiatives into their classrooms, they must involve teacher candidates every step of the way. In doing so, teacher educators will involve teacher candidates in the process of reform. As Robert Yager (1992) states, teachers are central to any solutions and successes for current reform efforts (Yager, 1992, p. 907). Most importantly, this includes teacher candidates.

Due to the importance of promoting systemic reform, professional associations in science such as the National Resource Council (NRC) and the American Association for the Advancement of Science (AAAS) have developed national science standards for grades K-12: the *National Science Education Standards* (1996) and *Project 2061 Benchmarks for*

Science Literacy (1993), respectively. Both documents elaborate ideas emerging from Project 2061 (Rutherford & Ahlgren, 1990) and other efforts that have focused on the science knowledge and skills literate citizens should possess. Although developed by two separate groups, the projects share common goals and recommendations. Specifically, both aim to develop a nation of scientifically literate citizens.

It has been argued that teacher candidates need to gain an understanding of how science works (Bates & Culpepper, 1991; Ganem, 1993; Keeports & Morier, 1994; Rutherford & Ahlgren, 1990). This is especially true for elementary teacher candidates because of their limited science background. With the information explosion in science, teachers are confronted with tougher and tougher curricular choices of what topics to include and decisions about which models of instruction to emphasize to promote lifelong learning. Just as science is a dynamic process, so is teaching and learning. In reference to educating future science teachers, the national reform initiatives provide a framework that articulates the goal of supporting lifelong learning by addressing the conceptions teachers have about science, teaching, and learning (National Research Council, 1996; Rutherford & Ahlgren, 1990). By successfully infiltrating the science standards into science methods courses, teacher candidates will have a new and better understanding of science and how science is taught. As teacher candidates attempt to change their conceptions of what it is to teach effectively, teacher educators need to understand what their conceptions are, why they hold such conceptions, and what constraints they perceive in the course of changing their conceptions. Unless, teacher educators understand why teacher candidates hold such conceptions about science and teaching science effectively, it will be impossible to move from a reformed curriculum to a reformed practice (Bybee, 1993; Hurd, 1992).

Purpose

In this paper, I describe the conception changes of teacher candidates about science, teaching, and learning as they participate in a K-8 science methods course designed utilizing the principles reflected in the national reform initiatives at an Eastern Urban

University. The course focus was on the role of teachers as decision makers in promoting scientific literacy for all students. The overall goal was to familiarize teacher candidates with reform initiatives in science education, focusing particularly on their role as change agents in the reform. The overall goal was addressed through four phases where teacher candidates learned to apply the principles reflected in the national reform initiatives in designing, implementing, and evaluating curriculum, instruction, and assessment.

Phase One: Confront and Challenge

The first phase of the course was designed to enhance teacher candidates' knowledge and understanding of national reform initiatives in science education. Realizing that conceptions are difficult to change (Posner, Stike, Hewson, and Gertzong, 1982), the purpose of the first phase was to confront and challenge each teacher candidates' conception of science in order to structure the following phases of the course.

With the recognition that the understanding of the nature of science is a global conception that frames teacher candidates' understanding of science teaching (Bohm & Peat, 1989), the first activity was designed to confront and challenge teacher candidates' conceptions of the nature of science. The nature of science can be characterized as accepting that events in nature are knowable and predictable; that events that occur in nature are the same over time and can be applied to all parts of the world; and that knowledge is stable but also subject to change upon further evidence (American Association for the Advancement of Science, 1993). In order to elicit teacher candidates' conceptions of the nature of science, they participated in a cooperative controversy exercise designed to engage students in a debate of opposing conceptions of the nature of science (Hammrich, in press). Briefly, this exercise exposes teacher candidates to both traditional and alternative paradigms concerning the nature of science. Teacher candidates debate and reach consensus in groups on their conceptions of the nature of science based on their dialogue and reflections.

The second activity was designed to explore the existence of world views held by teacher candidates and discuss the impact of how world views influence the understanding of science. According to Kearney (1984) "The world view of a people is their way of looking at reality. It consists of basic assumptions and images that provide a more or less coherent, through not necessarily accurate, way of thinking about the world" (p. 41). World views, generally speaking, are what people presuppose about their world and they accordingly drive people's actions. Given a teacher's central role in the classroom, it is reasonable to hypothesize that classroom culture is a function of a teacher's world view. In teaching science, elementary teachers not only present scientific concepts, but tacitly create a context in which scientific concepts are presented, a context influenced by teachers' world view. Therefore, teacher candidates examined their world views to fully understand the cultural context created by the teacher within the classroom.

Teacher candidates' world views were elicited by a questionnaire and concept map activity. The world view questionnaire was comprised of thirty-three items selected from and based on various empirical research studies (Cobern, 1993, 1995; Lawrenz and Gray, 1995; Ogunniyi et al., 1995) as well as numerous theoretical works (Cobern, 1991, 1995; Jones, 1972; Kearney, 1984).The thirty-three questions were related to the following world view universals as described by Kearney (1984): Causality, Relationship, Self, Nonself, Classification, and Time.

Teacher candidates also participated in developing a concept map of thirty words that describe their conception of the nature of science. The teacher candidates were given thirty words to use in developing their concept map but they were also allowed to substitute other words not included in the list that they considered to be part of their conception of the nature of science.

The third activity was designed to expose teacher candidates to the notion of conceptual change. Teacher candidates watched the video *A Private Universe* (Schneps, 1987).The videotape gives an introduction to student misconceptions in science and selected grade level, explained how they will integrate the unit into other subject areas and identify any benchmarks/standards which will help them integrate, and develop authentic assessment measures for each lesson and the overall unit and describe how they plan to assess competency for the entire unit.

Phase Three: Evaluation. Phase three of the course was designed for teacher candidates to extend their learning by evaluating instructional resources and programs by applying the principles of in the national reform initiatives. In this phase, teacher candidates analyzed and reviewed curriculum packages and materials to assess the match between the content and pedagogy of the materials with those of the benchmarks/standards. All curriculum packages and materials were provided and previously evaluated by the instructor.

As recommended by Project 2061 of the American Association for the Advancement of Science this activity included five steps. In the first step teacher candidates identify benchmarks/standards that appear to be covered by the curriculum material. Next, teacher candidates spent a great amount of time going through the actual curriculum material page by page to locate instances where the possible benchmarks/standards they listed before are addressed. In step two, teacher candidates studied the benchmarks to clarify their meaning. They selected one benchmark/standard from their list and examined the relevant sections in *Science for All Americans* and *Benchmarks*. In step three, teacher candidates analyzed the curriculum material to determine the extent to which the activities actually addressed the actual content of the benchmarks/standards. In step four, teacher candidates analyzed how the curriculum addresses the pedagogy of the benchmarks/standards. In the last step, teacher candidates suggested ways to adapt and supplement the activities in the curriculum material.

Phase Four: Sharing

In phase four, teacher candidates taught lessons they designed utilizing the recommended principles reflected in the national reform initiatives. They spent four weeks, one class period a week, teaching lessons to 4th grade students in two Philadelphia elementary schools. Teacher candidates met with the classroom teachers before they presented their lessons and discussed with the teachers which content and process benchmarks/standards they identified for the lesson. The teacher candidates worked in pairs to present their lessons while four other teacher candidates were in each classroom during the lesson to work with each group of students throughout the lesson. The instructor was also in each classroom during the lessons.

In addition to teaching the lessons to 4th grade students, teacher candidates also provided in-service instruction for a Suburban School District. Fifteen of the thirty-five teacher candidates spent one day presenting their lessons to twenty-five K-8 teachers. After presenting the lessons, teacher candidates discussed how they decided upon the content and process benchmarks, how their assessment matched the instruction presented in the lesson.

Procedure

Sample

This newly designed course took place during Spring semester 1996, with thirty-five teacher candidates enrolled in *Science Education 150: Teaching K-8 Science* at an Eastern Urban University. The researcher was the instructor of this course. Ten of the teacher candidates participated in the interviews. Purposeful sampling was utilized for the initial study while a theoretical sample was used to select the ten students to be used as comparative case studies based on the recommendations of Strauss (1987). There were thirty-five teacher candidates in the initial purposeful sample. Twenty nine were female and six were male. Age ranged from twenty to thirty-one. All of the students were American citizens. There were nine African-Americans females, four Asian-American females, and sixteen Europe-American females. There were two African-American and four Europe-American males.

The students who participated in the case study interviews did so on a voluntary basis and were randomly selected from four groups determined from the initial instruments and activities completed by all thirty-five students. Pseudonyms were used and results were provided to participants. A biography of each of the fifteen students was prepared to summarize background information and information obtained while interacting with students both in and out of school.

Data Gathering Instruments

To gather data to complete descriptive and comparison case studies, ten students were randomly chosen to be interviewed. Interviews were semi-structured and open-ended. Interviews were conducted based on suggestions of Kvale (1987), Lythcott & Duschl (1990), and Roth (1989). The main questions that guided these interviews were concerning the conceptions of science, knowledge construction, and the principles implied in the national reform initiatives. In order to encourage student reflection and discussion of their conceptions these questions merely served as a starting point. While the probing questions may have differed for each interviewee, the main questions remained the same. Each interview lasted approximately one hour and was recorded and later transcribed verbatim. The second interview was conducted approximately two weeks after the initial interview upon preliminary coding and analysis of the first interview.

Methodology

The overall conception of the whole study is that of a micro-ethnography (Bogden & Biklin, 1982). As such, it was an emergent case study of a small part of a larger organization. The sample of teacher candidates that participated in the interviews were part of the larger micro-ethnography study. The use and analysis of all the data combines what Tesch (1990) has described as ethnographic content analysis and ethnoscience or cognitive anthropology. The larger study focused on teacher candidates as they interacted in the classroom but it also considered their life setting, their culture, and what they do and do not believe. This particular part of the study attempted to describe the context of teacher candidates' conceptions of science and science teaching and to describe the interactions of their conceptions as they learned and applied the principles of the national standards.

The background demographic instrument was developed in order to determine the personal context, understanding, and other information that would illuminate the formation of teacher candidates' conceptions of science and the teaching of science. A questionnaire was given with the demographic instrument that aided in the delineation of differing conceptions of science and science teaching. These open-ended questions were used to show how students understood or viewed science and science teaching. The responses to these two instruments were analyzed to determine teacher candidates' conceptions. Using the whole class as a case study aided in grouping students based on the initial instruments and activities and demographic instrument on science and science teaching. Based on analysis, teacher candidates were grouped into similar conceptions of science and science teaching.

Analysis. Grounded theory was used as the method of analysis for this study (Strauss, 1987). Commonalties and differences between cases were noted. From these, preliminary assertions were made and data from these cases were highlighted as to possible warrants to support these assertions. Upon reviewing the preliminary assertions, several themes emerged that were based on science and teaching, as well as groups of the assertions, within these areas four final assertions were made. The data were re-examined to report warrants that confirmed or disconfirmed the final assertions. The warrants and assertions were cross checked by interviewing students a second time in order to confirm or disconfirm data collected initially. The coding of notes and analysis of data included both inter-rater (92%) and intra-rater reliability (87%) as well as several other provisions for trustworthiness that included member checking and an instructors log.

Outcomes

Discussion of Assertions

Assertion # 1: While the teacher candidates participating in the interviews had varying conceptions of science, the majority revealed that their conception of effective science instruction is directly influenced by their conception of science. However, while teacher candidates are accepting of examining and even embracing new conceptions of science, they still cling to their prior conception of science when pressed with uncertainty in a teaching situation.

By the time teacher candidates enter science they have already developed a conception of teaching and learning (Perry, 1990). Quite often they have not reflected on their conception of science and how their conception of science influences their conception of effective science instruction. As this study shows while teacher candidates are accepting of examining and even embracing new conceptions of science, they still cling to their prior conception of science when pressed with uncertainty in a teaching situation. This maybe due to lack of practical experience, reflection, or lack of specific knowledge. *TA* is a good example of a teacher candidate that reflected the willingness to examine different ways of conceptualizing science but still relied heavily on her initial conception of science when posed with teaching something unfamiliar.

> *Interviewer:* What is your conception of science?
>
> *TA:* Before I participated in the cooperative controversy activity, I was not real sure what my conception was of science. Granted I have taken all the necessary science courses during my college career but I have never really been asked to reflect or debate my conception of science. I guess what after participating in this activity and then actually analyzing curriculum, developing and presenting science lessons I would have to say that science is a conquest of ideas and discovery.
>
> *Interviewer:* At the beginning of this course, what was your conception of science?
>
> *TA:* Well I wasn't sure...I guess I thought science was what I learned in school...you know facts and theories, finding out the right answers.

Interviewer: Why did you change your conception?

> *TA:* I guess just reflecting about my conception, learning about the national reform movement, and constantly re-examining my conception in class.

Interviewer: Is science ever about knowing facts, laws, or theories?

> *TA:* Oh, sure...when I was teaching lessons to the fourth grade students I found myself trying to follow the principals of the national reform initiatives...while trying to focus on the process of discovery in science...but I found that students would ask me questions I didn't not have an answer too and I would immediately show them the facts...I felt insecure.

While many of the teacher candidates expressed similar conceptions of science as *TA* there were four teacher candidates that expressed the conception that even if they don't understand a science process they will work with their students and learn together. This common conception held by these four teacher candidates is expressed in the following statement:

> *NH:* Science is just that...the process of exploration and formulating ideas. My view of science as a practice of discovery was strengthened by confronting areas that I didn't understand in science or in learning with the fourth grade students I taught. My conception was only strengthened as I discovered new understandings for myself or helping students construct their own understanding.

In summary, while many of the teacher candidates expressed their conception of science as a practice of discovery, they readily fell back on the conception of science as fact based when they were teaching a topic in science where they were unsure of the answer. Basically, teacher candidates were more readily accepting of the notion of the process of discovery involved in science if they understood the topic.

<u>Assertion #2: Teacher candidates articulated an intellectual understanding of the process of constructing knowledge but they expressed a difference in how to facilitate knowledge construction. Some teacher candidates expressed that individuals construct their own understanding while others expressed that teachers are responsible for an individuals construction of knowledge.</u>

It was not surprising that while teacher candidates understood the process of knowledge construction, they interpreted their understanding differently. While they acknowledge the pedagogical process implied in the national reform, many of them commented on their frustration in trying to facilitate instruction to help students sort and create new conceptions. This sentiment is expressed by *NB*:

> *Interviewer:* What is conceptual change?
>
> *NB:* Conceptual change is the process of constructing an environment that allows students to construct their own understanding...this is the part that I have trouble with...I mean what if students construct the wrong understanding...does that mean I failed as a teacher?
>
> *Interviewer:* Why do you feel this way?
>
> *NB:* Well...while I agree with the pedagogical approach of the national standards, I have a hard time understanding how it will lead to scientific literacy for all...I feel everyone will construct their own conceptions and nothing will be constant...meaning no one will have the same conception.
>
> *Interviewer:* How do you view your role in this situation?
>
> *NB:* Well, I guess that I have a professional responsibility to make sure all students understand the same things in science as in other subjects...I see my role as not so much as a facilitator but as a guide to understanding.
>
> *Interviewer:* What do you mean to guide?
>
> *NB:* To guide means to show students the correct understanding... Many other teacher candidates felt this same way about how students come to understand. There confusion came in making sure all students understood the same information in the same way.

Perhaps *DH* summarized this conception the best.

> *DH:* While I consider the reform movement to be a progressive approach toward scientific literacy...I find the pedagogical approach to be a bit vague...There is no guarantee that all students will learn...When I was teaching my lesson in the fourth grade classroom I had so many students at different levels of understanding that I didn't know where to begin...I mean what is a teacher to do when all students understand differently...there isn't enough time to help everyone individually.

There were also teacher candidates who had an entirely different interpretation on the facilitation of knowledge construction. These teacher candidates felt that if you provide enough experiences for students that challenge or confront what they understand then they will change their conception when they are ready. These teacher candidates saw learning as more fluid and not time or grade dependent.

> *Interviewer:* What is conceptual change?
>
> *LS:* Conceptual change is the process of confronting what you already know, discovering that it is wrong, and changing your conception...I feel that we all do this all the time not just in science...Learning is a personal endeavor where you are involved in experiences and gain knowledge through these experiences that help you change your conception.
>
> *Interviewer:* What is the teachers role in this process?
>
> *LS:* I think that learning is not just taking place in school...but...in the school environment teachers are responsible for creating an environment that promotes students to confront what they already know...actively having students participate...also modeling the learning process to students...ultimately, through, students are responsible for their own learning...teachers are just facilitating their understanding by providing experiences.

In summary, it was apparent that teacher candidates have not had enough practical experience to adequately resolve their understanding of facilitating the construction of knowledge. However, it was enlightening to discover that teacher candidates were beginning to confront their own conceptions of teaching constructively. While teacher candidates understood the notion of knowledge construction, they did not have a clear understanding of the process.

<u>Assertion #3: The principles reflected in the national reform initiatives are viewed by teacher candidates as being beneficial but very time consuming. Teacher candidates indicated that while they recognize the necessity of aligning curriculum to match the content and pedagogy implied by the national reform initiatives, they feel that the time needed to conduct such a process may out weigh the benefits.</u>

Although teacher candidates acknowledged that they gained an overwhelming amount of experience and knowledge from learning about and applying the principles reflected in the national reform initiatives; they were frustrated by the commitment and lack of time in the classroom to actually carrying out the lessons. Many of the teacher candidates stated that they never finished their lessons. This could be due in part to the time constraints of their visits or to their lack of understanding in how long it takes to actually conduct a single lesson. *MK* expressed the sentiment that many of the teacher candidates expressed.

> *Interviewer:* What was your experience in implementing the principles reflected in the national reform initiatives?
>
> *MK:* The curriculum analysis process was extremely helpful up to a point. It was a good way to become more familiar with both the curriculum and the benchmarks, however, the pedagogical analysis section seemed superfluous. I suggest, instead of a critique of the pedagogy for each benchmark, there should be a single pedagogical analysis which requires specific citations of appropriate benchmarks addressed by each category. This would appear to be more beneficial to those analyzing and using the analysis.
>
> *Interviewer:* What about your experience teaching the lessons?
>
> *MK:* I feel like that biggest obstacle in teaching lessons that address the intent of the benchmarks is the time factor. It seems like I never am able to finish an activity that I have designed. I find myself spending way too much time finding out what students know and listening to their questions. I know that finding out what students know is important but I only which it took less time.

Some of the teacher candidates understood the importance of focusing on the process of students thinking skills as opposed to the end product.

> *TW:* As I am teaching more and more lessons to the fourth graders...I am realizing that it is not about getting to the end of the lesson just to finish it....but that it is more important to focus on the process of understanding through exploration and discovery. This realization for me did not come easy but I a happy it did...I think I have finally conceptualized my own understanding of science and the teaching of science.

In summary, many of the teacher candidates expressed the sentiment that by understanding and utilizing the recommendations of the national reform initiatives, they were becoming more aware of the overall picture of teaching. This overall sentiment is best expressed by *KA*..

> *KA:* I never realized that their was so much preparation and design in entire curriculum. This model of designing curriculum and assessment really made me question as to why I am teaching this unit, what is it that I want students to understand, and where are

> students coming from as far as understanding and where are they going. I guess I never gave much consideration as to what the grade before or after the one I was teaching was covering. This process has helped me see the big picture of understanding science and how conceptual learning is built upon prior knowledge. I also realized that teaching is not just simply telling but it is more of facilitating students own learning experiences.

Summary

The call for systemic reform presents a great challenge to teacher educators in facilitating teacher candidates' conceptions of science and what it means to teach science effectively. Teacher candidates' conceptions of teaching science are guided by their conceptions of science. In order for teacher candidates to model practices of teaching and learning as outlined by the national reform initiatives, they need to participate in activities that cause reflection and they need to apply the standards to lessons that they can or will use. First, teacher candidates need to confront their conceptions of science and scientific thinking. Secondly, they need to be familiar with the pedagogical philosophy addressed in the standards that reflects current research in science education. Third, they must be familiar with the content of the standards. Finally, teacher candidates need the opportunity to work with the standards either through analysis of existing curricula or development of their own lessons and curriculum. Only in doing so will teacher candidates gain a new and better understanding of science and effective science instruction.

As teacher educators strive to embed the recommendations of the science reform initiatives into their methods courses they must actively involve teacher candidates in the process of reform. The implementation of the science reform initiatives has to have a reciprocal relationship with teacher candidates conceptions and actions, because teacher candidates will be the future agents of reform in the classrooms of tomorrow. How reform should be implemented into a methods course must be informed by teacher candidates conceptions of science and science teaching. Likewise, teacher candidates need to be informed by the reform recommendations.

The teachers candidate's reflections revealed support for the use of incorporating the principles reflected in the national reform initiatives in an K-8 science methods course. Their reflections have implications for the science education of teachers. If we hope to reform science teaching at the school level, we need to reform teacher education first. Unless prospective teachers experience reformed science teaching, it is unrealistic to expect change; that is to expect them to teach in a way that they have not experienced. Just telling teachers what pedagogical changes are desired is unlikely to have any effect. If students are to be taught in a way that helps them construct their own knowledge, then teachers need to learn science in the same manner. We cannot continue to teach undergraduate science by lecture and cookbook laboratory experiments and by providing brief, unrelated exposure to pedagogy in a methods course, and expect prospective teachers to teach differently. The study points out that science courses for prospective teachers need reforming before effective, long-term changes in classroom teaching are systemic. After incorporating the philosophy and intent of the national reform initiatives into my course, I am convinced that using the framework of the national reform initiatives is both necessary and essential in demonstrating the importance of promoting scientific literacy for both our students and teachers.

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STUDENT AND TEACHER CONCEPTIONS ABOUT ASTRONOMY: INFLUENCES ON CHANGES IN THEIR IDEAS

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Introduction

It is common knowledge that students bring their own ideas and understandings about science to the classroom (Driver, Guesne, & Tiberghien, 1985; Osborne & Freyburg, 1985; Scott & Driver, 1997). Children's ideas influence what students gain from instruction. Additionally, teachers have their own ideas of science content that may not always reflect accurate conceptions (Kruger & Summers, 1989; Lawrenz, 1986; Neale, Smith, & Johnson, 1990; Stoddart, Connell, Stofflett, & Peck, 1993). Thus, teacher conceptions can be related to what students learn. Teaching can be thought of as a way for a more knowledgeable person to transform understanding, skills, attitudes, or values, into representations or actions that allow a less experienced person to develop an understanding of a concept (Shulman, 1987). An awareness of the process of teaching begins with knowledge of teacher conceptions. What the teacher knows influences students' conceptions, but does what the students know influence teachers' ideas?

Purpose

The purpose of this study was to compare the content knowledge of two second grade teachers, one intern teacher, and their students during the course of instruction in an astronomy unit. The current study looked at the similarities and differences of children's and teachers' ideas about astronomy, and how those ideas changed during the course of an 8-week unit. Influences of the teachers' ideas on the students, and students' ideas on the teachers were sought and described.

Research Methodology, Design, and Procedures

As part of a larger project, two second grade teachers, one teacher intern, and their classrooms were selected to participate in a study tracking content knowledge of astronomy. The teachers who participated in this study did not use a professional curriculum from which to teach their astronomy unit. Instead they pulled from a variety of sources to develop a unit they determined fit their own students.

Pre-instruction content knowledge was determined by pre-instruction interviews. A panel of expert science educators and research scientists validated interview protocols (see Appendix A). Ten of twenty students in each classroom were selected by each teacher to participate in the interviews. Each teacher also participated in pre-instruction interviews. Students were interviewed individually at an undisturbed location between both teachers' classrooms. The teachers were interviewed in their own classrooms after school. The interview questions were divided into two sections: (a) questions that addressed teacher goals for the students, and (b) questions that addressed *Benchmarks* goals for students to know about astronomy by the end of second grade (See Appendix B). All interviews were audio and video-taped and later transcribed. The transcriptions were coded to find patterns among conceptions. These conceptions were used to describe the content knowledge held by the students in both classrooms.

Teacher and student ideas were compared at the beginning of the study. As would be expected, the teachers held a more sophisticated level of knowledge than did the students. The students' views were compared to earlier studies conducted by Nussbaum and Novak (1976) and Mali and Howe (1979) (See Table 1). The ideas held by students in the current study were similar to the students' knowledge described in the earlier studies (Nussbaum & Novak, 1976; Mali & Howe, 1979).

Table 1
Second grade student post-instruction knowledge comparison of notions of the Earth compared to Nussbaum and Novak (1976) and Mali and Howe (1979).

	Notion 1	Notion 2	Notion 3	Notion 4	Notion 5
Current Study	T1[a]: 0	T1: 1	T1: 4	T1: 4	T1: 1
(1997)	T2[b]: 1	T2: 2	T2: 2	T2: 4	T2: 1
Nussbaum &	I[c]: 3	I: 7	I: 3	I: 7	I: 6
Novak (1976)	U[d]: 3	U: 7	U: 6	U: 6	U: 4
Mali & Rowe	K[e]: 36	K: 2	K:1	K: 1	K: 0
(1979)	P[f]: 39	P: 4	P: 4	P: 1	P: 0

Note. Numbers indicate the total students who fit into each notion category. [a]Response of students from Teacher One's classroom. [b]Responses of students from Teacher Two's classroom. [c]Responses of instructed students. [d]Responses of uninstructed students. [e]Response of students from Kathmandu, Nepali. [f]Response of students from Pokhara, Nepali

All science lessons during the 8-week units were observed and videotaped for transcription. The transcripts were coded to find instances of student expression of ideas, teacher recognition of student ideas, teacher action on student ideas, the effect of teacher action on student conceptions, and the influence of students on teacher conceptions.

At the conclusion of the unit teachers and students were again interviewed for their conceptions of astronomy. Interview protocols contained questions from the pre-instruction interviews as well as new questions developed from the astronomy unit. The post-instruction interviews proceeded in the same locations and fashion as the pre-instruction interviews. Transcripts were analyzed to find patterns of conceptions within the classrooms and the teachers. Comparisons were made of teacher and student knowledge, and the change in their conceptions over time.

Results

Change in Conceptions—Students from Classroom One

There was no difference in how students defined astronomy at the pre and post instruction interviews. Students all defined astronomy as a study of space. At the post-instruction interview all students could name, illustrate, and label the planets in order from the sun. Students were unable to do this at the pre-instruction interview.

All students believed the Earth was round. This belief represented no change from pre-instruction knowledge. However, at the post-instruction interview all students responded that gravity holds things to the Earth, where at the pre-instruction interview only seven students held that belief. Students seemed to have a more accurate understanding of gravity after instruction given responses like "the amount of gravity depends on the mass of the planet—bigger mass has more gravity." However, it was evident that most students did not have a scientifically accurate understanding of gravity, but simply that it was the force that held us on the planet, either by pushing or pulling on us. All students believed a dropped ball would land at your feet, and that gravity would let a ball roll, but not fall off the planet. Seven of the ten students drew pictures and described gravity as pulling toward the center of the Earth. The other three students believed gravity pulled things toward the "bottom" of the Earth.

Invariably, all students interpreted the question that asked for a response to what can be seen in the sky at night and during the day, as asking what creates day and night at the pre-instruction interview. Students generally had inaccurate conceptions of day and night. Three students believed the sun would move to the other side of the Earth so it would be night on one side. Three additional students believed the moon made night, and the sun made day. One child personified the sun, stating it would be night when the "sun went to bed." The moon and the clouds blocking the sun was a response given by one student as a description of why it became night. At the post-instruction interview students did not misinterpret the question. This time students responded with different celestial bodies they could see at day and night. Most conceptions were accurate, with most students in both classrooms responding they could see the sun in the day, but not other stars because the brightness of the sun makes it difficult to see other stars. One student believed she would be able to see other stars during the day if she looked carefully enough. All students noted they could see the stars and moon at night. All students in believed they would never see the sun at night, and three believed they could sometimes see the moon during the day.

Students were asked to select balls to represent the Earth, moon, and sun, and show the interviewer how they moved in space. At the pre-instruction interview nine students accurately selected the balls according to relative sizes. The other student used color as a selection criterion. At the post-instruction interview all students selected the balls according to relative sizes and most believed the Earth rotates around its axis and revolves in an orbit around the sun, with the moon rotating around its axis, revolving in an orbit around the Earth. Most students knew the length of time it takes for the Earth to rotate and make a day, and for it to revolve around the sun and make a year.

None of the students believed the moon looked the same in the sky each night at either the pre or post instruction interview. At the pre-instruction interviews seven students agreed that the moon does not really change shapes, it just looks different in the sky. One seemed to have a fairly conventional viewpoint of why the moon looks different in the sky, believing it was light from the sun shining on the moon in differing amounts, causing parts of the moon to show up in the sky. About half the students (4) believed something such as clouds, other planets, the darkness, or the sun covers the moon, causing parts of it not to be seen on the Earth. In Classroom One there was no formal instruction regarding the moon. There were no activities and students were not asked to watch the moon in the sky. Only one student at the post-instruction interview continued to believe parts of the moon broke off and go away and come back to create changes in how the moon looks. Eight students believed the moon looked different because of shadows from the Earth or other planets, or from clouds blocking the moon, which represents no change from pre-instruction interviews. Only one student mentioned an order in which the moon looked like it got "skinnier and then thicker."

All students thought there were more stars than could be counted. One student gave a definite answer of '100.' At the post-instruction interview there was no change in ideas, except the student now gave the response of '500.' Students often believed that the stars could not be counted because there were stars on the other side of the Earth that could not be seen from their side. Also, there was a general belief that there were so many stars that it would be hard to keep your place if you were counting them, and you could not count them in one night and would not know where to start counting again the next day. Nine students, at the pre, and all at the post-interview, believed that stars were balls of gas and fire. At the pre instruction interview eight students believed stars were actually circular, but that people draw them with points because it makes it look like they are sparkling, not how they really are shaped. Nine students believed stars were circular rather than five-pointed at the post-instruction interview.

When students were allowed to tell anything they wanted about astronomy, only three students responded at the pre-instruction interview. Seven responded at the post-instruction interview. At both interviews students generally responded with factual information they had heard or learned, though one student at the pre-instruction interview explained his theory about why we changed the clock back in relation to the spinning of the Earth and daylight savings time.

In general, student knowledge improved from their experiences in their astronomy unit. At both settings most students had ideas they could share and discuss. All students could talk intelligibly about what they knew. What they knew was not always in line with current scientific ideas. However, students had more accurate conceptions to most questions than prior to instruction. The area at which they had their most difficulty was regarding why the moon does not look the same each night.

Changes in Conceptions—Students from Classroom Two

Knowledge change in Classroom Two was dependent on both Teacher Two and the Intern Teacher actions. Teacher Two orchestrated most of the class discussions, including debriefs of the activities presented by the Intern Teacher. The Intern Teacher presented all the hands-on activities in the class. Teacher Two gave the topics to the Intern, but the Intern developed and presented them independently.

Prior to studying the unit only six students in Classroom Two had a conception of what "astronomy" meant. Students continued to lack a definition until the Intern Teacher presented a lesson on the final day of the unit during which students were asked to define and apply the definition. All students understood that astronomy was the study of "stuff in space" at the conclusion of the unit. Each student was able to draw and name all the planets in order from the sun at the post-instruction interview.

Students improved in their understandings of gravity, though four students believed gravity "pushed on you" from the air above. The Intern Teacher told students this idea several times during her instruction. Teacher Two did not address the concept of gravity with the class, but a guest speaker presented an activity designed to help students understand that air resistance affected how things fell to the Earth, not the mass. Only three students understood that gravity pulled toward the center of the Earth at the conclusion of the unit. The other seven interviewed believed that things were pulled toward the bottom of the Earth.

Students had better understandings of the relationship of the Earth, moon, and sun at the post-instruction interview. All students used relative size as the criterion for selecting balls to represent the bodies. Only seven students used this criterion at the pre-instruction interview. Students understood that the Earth spins and revolves around the sun, with the moon spinning and revolving around the Earth.

Students had a better understanding at the post-instruction interview of why the moon looks differently in the sky. Seven students understood it had something to do with the reflection of light from the sun and the "way the moon and Earth were in the sky." Teacher Two assigned homework to the students to track the way the moon looked in the sky each night, and held discussions nearly every day to allow students to describe the differences they saw. Thus, the idea of the apparent changes in the moon was revisited many times during the unit. Students recognized the changes occurred in a certain order.

In addition, the Intern Teacher delivered a lesson during which students participated as the Earth and parts of the moon's orbit so they could see how where the moon was receiving light from the sun affected what they part they could see "lit up" on the Earth. The conceptions represent a significant change from the pre-instruction responses where five students believed something like clouds, other planets, or even the sun, covered the moon, causing it to look different.

At the post-instruction interview only three students responded to the final question asking them to tell anything more about astronomy they wanted. These students responded with factual information they had gathered from studying their individual topics. Student knowledge seemed to improve, but to a lesser degree than students in Classroom One. The greatest areas of improvement were the conceptions of what caused the moon to look different.

Changes in Conceptions—Teachers

Teacher One

Teacher One holds a master's degree in early childhood education. She has 24 years of teaching experience, sixteen of which at the first or second grade levels. She has experience teaching high school and college mathematics courses. She also has experience teaching special education. She considers her specialty reading, and enjoys teaching the primary grades in particular because her skills in reading are used to their best advantage. She has taught at her current school for sixteen years.

Teacher One's knowledge was fairly substantial and scientifically accurate. When she was unsure of a content question she felt comfortable stating her uncertainty. Her content knowledge did not change substantially over the course of the study as evidenced by her post-instruction interview responses. However, she researched other content areas not measured by the protocol in response to students' queries. Thus, her knowledge of astronomy also grew.

Teacher One defined astronomy as a study of "all heavenly bodies," by which she meant all naturally occurring things in space. Teacher One accurately named and drew the nine planets using relative size in order from the sun.

Teacher One agreed that the Earth is spherical, and related the pull of gravity to the mass of objects. She believed that objects with greater masses had a greater pull of gravity, but did not further explain her ideas. She understood that a ball dropped on the Earth would fall toward the center of the Earth.

When selecting balls to represent the sun, moon, and Earth, Teacher One chose relative size as the criterion. She held the conventional idea about what causes day and night, stating that the side of the Earth that is rotated to face the sun is at day, while the other side is night. Regarding the movement of the Earth, sun, and moon in space, she talked about everything in space moving, with the universe expanding, claiming this knowledge by red light tests conducted by scientists. She discussed the orbiting of the Earth around the sun and moon around the Earth, along with spinning on their axes.

Teacher One believed the moon does not always look the same in the sky. She described the changes in terms of phases of the moon. She discussed the moon phases in terms of the moon 'waxing and waning' in a cyclical way. She described the apparent change in the shape of the moon in terms of the Earth blocking some of the sunlight, and the moon getting only some of the reflected light.

Teacher One believed there is a countless number of stars. She stated that at the current level of knowledge it is impossible to know whether the universe is really infinite, or whether it is finite, and if it is finite perhaps we could someday count the stars. She responded to the final question that allowed her to express her own ideas about astronomy in relationship to teaching astronomy to children. She discussed the importance of elementary teachers feeling confident in their abilities to teach a wide variety of science concepts, and to continue fostering in children interest in knowing about the world.

Teacher Two

Teacher Two has a master's degree in early childhood education and has taught for ten years at grades one and two. She most enjoys teaching mathematics and language arts, and searches for ways to combine both subjects. She was a 1994 nominee for the Presidential Awards for Excellence in Mathematics Teaching. All of her ten years of experience teaching has been at the school she is now teaching. She is the lead instructor with Teacher One at math inservices they conduct for primary teachers, and is the lead author for the mathematics activity book both teachers wrote in 1994.

Teacher Two was concerned that she did not appear knowledgeable. She had difficulty responding to several of the questions. She had more accurate responses at the post-instruction interview. She said she remembered information as she delivered lessons each time that she taught the unit. It is also the case that she reviewed and studied astronomy books prior to teaching each portion of the unit.

Teacher Two called astronomy a study of things in space. Her view of astronomy included the study of space travel and rocketry as she discussed helping her students to learn about what it might be like to live in space. She had some difficulty naming all the planets accurately in order from the sun. She began to sing a song as a mnemonic, and still could not recall the 9th planet until her Intern Teacher stated from across the room "It begins with an 'N'." The teacher then remembered the planet Neptune. She did not discuss any of the orbits, and did not list all planets in the correct order. She was able to accurately name all the planets at the conclusion of the unit.

Teacher Two agreed the Earth was spherical, and that gravity keeps us on the Earth. Teacher Two was unsure how gravity worked, and tried to explain gravity using many science terms, such as 'pressure,' 'weight,' and 'force.' She talked a bit about what it would be like to be on a planet with less gravity, but did not discuss her ideas about gravity. She was visibly flustered at explaining her ideas about gravity, stating she knew this was the "gravity question," but was unable to explain her ideas. She understood that a ball dropped anywhere around the surface of the Earth would fall toward the center, but attributed it to pressure from outside. At the post instruction interview she spoke of gravity as "a force with the ability to keep things in place."

Teacher Two held conventional ideas about what causes day and night, stating that the side of the Earth that is rotated to face the sun is at day, while the other side would be night. She extrapolated to explain what might happen if the sun exploded, that pieces of the sun would go into space and "envelope other areas." She thought children might also talk about the sun exploding. However, no child discussed the sun exploding in response to this question.

When selecting balls to represent the sun, moon, and Earth, Teacher Two chose relative size as the criterion. She discussed the movement of the three in a traditional fashion, stating that the Earth and the moon spin on their axes, and that the Earth orbits the sun with the moon orbiting it. She was unsure whether the sun rotated on an axis. She was unsure in which direction the moon and sun revolved. At this point Teacher Two mentioned being concerned she would look inadequate with her responses, showing lack of confidence in her knowledge.

Teacher Two agreed the moon does not always look the same in the sky. She described the changes in terms of phases of the moon. She viewed the apparent changes in the moon in terms of changing toward one direction, increasing in size. She did not mention a cyclical attribute to the phases. She also held an unscientific idea about the phases of the moon, stating that the part of the moon that cannot be seen is in the shadow of the Earth. At the post-instruction interview she recognized that the apparent changes were from the sun's reflection on the moon from different positions.

Teacher Two thought it was impossible to count all the stars because some stars are being formed, and others are dying out. Because of the continual change in numbers it would not be possible to count them. She stated stars were made of debris pulled in with gas. She agreed that stars were circular, and thought it interesting that people do not draw them that way. She thought people probably draw the points on stars to represent solar flares coming off the balls of gas.

Teacher Two chose to respond to the final question, which allowed her to share what she wanted to add about astronomy. She responded by relating her ideas to teaching astronomy to children. She talked about wanting children to know more about astronomy than looking about in the sky. She wanted children to know about all the advantages research in space has given to people on Earth. She discussed ideas such as dehydrated foods, new materials that can create comfortable mattresses for use on Earth, and medicines that can help the sick.

Intern Teacher

The Intern Teacher was working toward a Master of Arts in elementary Teaching (M. A. T.) degree. Her internship in Classroom Two played a major role in obtaining her degree. She holds a Bachelor of Arts (B. A.) degree in liberal studies. The only teaching she has ever done has been as an intern, and the only science she has ever taught was in this second grade classroom. She recently took and received an 'A' in a college astronomy course at the same university at which she was earning her master's degree. She was amazed that she had received an "A" in astronomy because she did not believe she learned very much. At the post-instruction interview her content knowledge seemed much stronger than at her pre-instruction interview. It appeared she was reminded of information that she had previously learned through her own delivery of content. She grew quite excited about astronomy, even intending to teach it in her own classroom.

True to the Intern Teacher's perception of her knowledge, her pre-instruction content knowledge was not very strong. She was hesitant about her responses, and concerned that she appeared not to know very much. She was present during Teacher Two's pre-instruction interview and may have been influenced in her responses by knowledge of questions that were asked. Some of her responses below seemed stronger than they would have been had she not studied the topic in preparation shortly before her interview.

The Intern Teacher defined astronomy as a study of space and everything in space. She included in her definition "everything involved with space." She correctly named all the planets in order of distance from the sun.

The Intern Teacher believed the Earth was spherical, and that gravity keeps us on the Earth. She believed that gravity pushed from above us in the atmosphere to hold all things on the Earth. This conception was apparent in her lessons when she taught students that gravity pushed down from above us.

When selecting balls to represent the sun, moon, and Earth, the Intern Teacher chose relative size as the criterion. She discussed the movement of the three in a traditional fashion, stating that the Earth and the moon spin on their axes, and that the Earth orbits the sun with the moon orbiting it. She was certain the sun did not spin, but was positive the Earth and moon rotated in a counterclockwise clockwise direction because she had seen it on *Bill Nye the Science Guy*.

The Intern Teacher believed the moon does not always look the same in the sky. She studied this topic prior to the interview in preparation for the lesson she was to teach. She described the perceived changes in terms of phases of the moon. She stated the moon looked different because the sun reflects only on part of the moon, and depending on where the Earth is in relation to the sun and moon we see only part of the reflected portion. She recognized that it took about a month for the moon to proceed through a cycle of first appearing to grow larger, and then appearing to become smaller.

The Intern Teacher believed there is a countless number of stars. She believed that stars are made of gas, explicitly stating it was hydrogen gas that caused explosions on the sun. She agreed that stars were circular. She agreed that people probably draw the points to represent solar flares coming off the balls of gas.

The Intern Teacher chose to respond to the final question and share whatever she wanted about astronomy. It is interesting to note that like Teachers One and Two, the Intern Teacher responded in relation to teaching about astronomy to children. She stated that astronomy was "hard to teach!" but that it is important to teach about astronomers and what they do.

Influences in Change in Conceptions

Students

From this study it was found that student ideas about astronomy did change over the course of the unit. Their ideas became more conventional. Student ideas became more in line with their teacher's ideas, which would be expected considering it is the teacher who is providing the instruction. Some of the students' comments were very similar to expressions teachers used when describing their own ideas.

Classroom One

Teacher One influenced her students' ideas in many ways. She elicited students' ideas at the start of each lesson by using an Idea Invitation question that encouraged them to share their own thoughts about the science content that they were to study. She planned to address specific ideas through development of lessons following the elicitation of ideas. One such example is that of recognizing that students believed that Neptune and Pluto physically switched places in their orbits. Teacher One planned a demonstration and modeling activity specifically to help students understand that it was the oddity of Pluto's orbit that made it seem like Pluto and Neptune switched places, but that it did not mean they were trading orbits. Once she gained an understanding of their ideas she used several strategies to help students develop more accurate ideas, such as reading non-fiction tradebooks to give students new content ideas, explaining the content to the students, and scaffolding new ideas onto old understandings.

Another manner in which Teacher One influenced children's ideas was through cycling the ideas by eliciting and addressing the same ideas repeatedly during the course of the unit. Her pattern consisted of eliciting ideas in a whole group setting, addressing ideas shared by a majority of students, eliciting the ideas again within small groups to check for individual understandings, addressing ideas in small groups, and raising the question again in a large group setting. The cyclical revisiting of science content and confrontation of ideas seemed to influence students in Classroom One in developing their more accurate understandings of astronomy content.

Classroom Two

Teacher knowledge of astronomy influenced the learning of students in Classroom Two. Both the Intern and Teacher Two had lower levels of astronomy knowledge than did Teacher One. Students in Classroom Two had lower levels of astronomy knowledge than did students in Classroom One at the end of the unit.

Students were influenced to share ideas by the Intern Teacher, but when they did share their ideas it surprised the Intern Teacher and she was not able to effectively address them. The Intern Teacher claimed to be aware of the importance of prior knowledge and did use an Idea Invitation question to elicit student ideas. However, she was very surprised by their ideas, and believed if she could just phrase her questions better she would obtain the types of responses she believed she should receive. She did not attempt to address student ideas in instruction, but instead ignored or only partially acknowledged their ideas by picking up on portions of their statements that helped support her instruction.

Teacher Two, on the other hand, did attempt to influence student ideas using several strategies. She elicited children's ideas through a question that invited them to share their thoughts. This Idea Invitation question was raised at the beginning of each lesson. When she collected student ideas she chose to respond to them in several ways to help improve their knowledge of astronomy. She read a non-fiction tradebook, provided an explanation, or debriefed the Intern's activity lesson. These strategies were used in the arenas in which ideas were elicited. When ideas were raised in small groups, they were addressed in small groups. When elicited in large groups, they were addressed in large group settings. Occasionally while raising questions and conducting discussions with students Teacher Two did not have sufficient knowledge to respond to their statements, and thus, the conversation surrounding the content was dropped.

The students in Classroom Two were thus influenced in two different ways: (1) encouraged by Teacher Two to share ideas which were addressed in instruction by Teacher Two, and (2) verbally encouraged to share ideas by the Intern Teacher, but also inhibited from sharing ideas by the responses given them by the Intern.

Teachers

The teachers' ideas about astronomy also changed during the course of the unit. The teachers' conceptions became more in-depth and scientifically accurate. It was found that not only did student expression of ideas influence how the teachers presented future lessons, but also influenced teacher thinking about science content. Teachers noted that questions and ideas raised by students caused them to reconsider their own thinking about scientific ideas. In this study it was found that not only did teachers influence student conceptions, but students also influenced teacher conceptions.

Teacher One was influenced by students' ideas to increase her knowledge of certain astronomy concepts. Several times during the course of instruction students raised questions for which Teacher One had no answer. Instead of dropping the ideas, she chose to research the information and bring it back to the students. One such example is when she studied the definition of 'galaxy' to share with students, and what it meant to be a 'spiral galaxy.' She claimed that each time she taught this astronomy unit she learned more, simply because of the research students conducted and the questions they raised.

Teacher Two was influenced by her students enough to elicit their ideas about astronomy. Though she was weaker in her astronomy content knowledge than Teacher One, she was not influenced by her students' questions to go beyond a moderate level of knowledge. She was, however, influenced to learn more about the content that she was going to teach to address their ideas. She had a much stronger level of knowledge at the end of the unit than at the beginning. She had a more accurate idea of why the moon seems to change shape, which was a concept that was addressed several times during instruction. She had no greater understanding of gravity, which was a concept she did not teach to her students. She had a better understanding of the planets and their relationship to the sun at the end of the unit, largely because she taught the students a song about the planets. Thus, the concepts she taught to the class influenced her own understandings, and those she did not teach did not impact her knowledge at the end of the unit.

The Intern Teacher was also influenced to learn more content, but not specifically by what the students raised. She was influenced to learn more about astronomy by the curriculum she was given by Teacher Two. Because she was required to teach certain subjects she endeavored to learn more about them to be able to present them to the students. She was able to effectively increase her own knowledge of astronomy. However, her presentation of information to students was not as effective. She did not have a good idea of the developmental appropriateness of certain activities she chose to present to the students, nor of the importance of listening to and addressing their own theories about the astronomy content. She was influenced by the students in the manner that she was surprised about what they said, and indeed, believed if she could only improve her questioning technique she would get better and more accurate responses from the students.

It is apparent that the act of teaching enabled all three teachers to improve in their own knowledge of subject matter. Teacher One, who already held a substantial knowledge of astronomy, increased her knowledge beyond that addressed in the interview protocols by questions raised by her students. Teacher Two improved in her knowledge based on what topics she taught in her unit and ideas raised by the students. The Intern Teacher also improved her knowledge based on the curriculum she was to cover in her activities. She was not influenced to know more about astronomy by questions or ideas raised by the students.

Implications

From this study it can be stated that not only do teachers influence students in developing their knowledge, but also students influence teachers in their knowledge. The teacher with the greatest level of content knowledge, and with the greatest ease in addressing student ideas, was influenced most by her students. The Intern Teacher and Teacher Two were also influenced in their knowledge by students, or at least by the curriculum in the case of the Intern Teacher. One of the complaints about elementary science teachers is that they lack content knowledge (Perkes, 1975; Tobin, Briscoe, & Holman,1990). By helping elementary teachers become more aware of student ideas and their importance in student learning it is possible we can help elementary teachers become more knowledgeable themselves because they will seek to address student questions and ideas. Another way to improve content knowledge may be to have interns practice teaching the content. At the conclusion of the current study the Intern Teacher held more accurate content knowledge of astronomy, and planned to teach it again when she had her own classroom. Scholz (1996) found that the act of teaching influences subject matter knowledge. Having teachers practice lessons in content areas could improve their knowledge in those areas. This finding implies that providing time for preservice teachers to practice lessons can improve not only their pedagogical knowledge, but also their subject matter knowledge.

Children's ideas influenced teacher planning. All three teachers planned to elicit student ideas, and the experienced teachers intended to address those ideas. Teacher One was so influenced by student ideas that she even developed lessons to address specific ideas. Student ideas influenced instruction in Classroom One such that their ideas about different astronomy concepts were revisited throughout the unit. Teacher One cycled the ideas several times through her instruction, in both large and small group settings. This revisiting of ideas seemed to help students improve in their knowledge of astronomy.

Students in Classroom One had the highest level of knowledge. The continual checking for change in ideas allowed Teacher One to continue addressing the ideas with a variety of strategies. Indeed, the one idea revisited in Classroom Two that was not revisited in Classroom One, that of moon phases, was the one concept understood better by students in Classroom Two than those in Classroom One.

Related to planning to elicit student ideas, inservice and preservice teachers can learn strategies for eliciting student ideas. Both teachers in this study elicited students' ideas as a starting point to every lesson by asking them to share their ideas. Strategies that appeared to be useful were initial Idea Invitation and Probing Question strategies that required students to discuss ideas and negotiate meanings and understandings of content and experiences in their classrooms. The strategies used by the teachers were specifically directed to knowing student ideas. A further recommendation about eliciting student ideas from this study is that it is not necessary to elicit all ideas in the classroom, but to find out which ideas are shared by the most students and use those ideas in planning ways for addressing student ideas. It is important that teachers recognize the influence student ideas have on student learning, and to develop strategies for identifying conceptions that are held by the majority of students, followed by strategies for dealing with those conceptions (Berliner, 1987; Bromme, 1987).

Secondly, teachers in the current study provided many paths for students to change their ideas toward more accurate conceptions. The experienced teachers in this study used several strategies for helping students change their ideas, such as developing specific lessons, providing demonstrations, reading children's non-fiction literature books, explaining the content, and scaffolding new ideas on old understandings. Both preservice and inservice teachers can be introduced to different methods of addressing student ideas based on the success of these experienced teachers, particularly Teacher One. Teacher One cycled ideas through her classroom, addressing them several times in many different ways, while Teacher Two and the Intern Teacher's strategies did not include cycling the ideas. Teacher One's manner of listening and reacting to ideas in the classroom guided her delivery of content. She depended on creating an atmosphere, in which students would share and discuss ideas, so she could address them in instruction. Her cyclical method of eliciting and addressing student ideas can inform the use of the Learning Cycle (Karplus & Thier, 1967) in the primary grades. An implication from this study is that an additional component of the learning cycle should contain a revisiting of ideas over time. Student ideas can be elicited, addressed, and checked again for more accurate conceptions that develop over time. It is appropriate to educate the teachers to recognize the importance of student ideas as persistent alternative conceptions, and to use them as springboards for developing lessons. Revisiting ideas was an important component as a springboard in the most Teacher One's classroom. Previous research has shown that primary aged students hold surprisingly similar conceptions about a variety of science content. Even students in the current study held ideas that were similar to ideas found in previous studies of children's ideas of astronomy (Mali & Howe, 1979; Nussbaum & Novick, 1976). Teachers must have sufficient knowledge to help students confront their ideas, and that knowledge can take more forms than simple content knowledge.

It must be remembered that not all interns can handle the sophistication of responding to children's ideas. There are differences between novices and expert teachers, and responding to student ideas may be a skill that develops with experience. Because of these differences and the process of becoming a teacher is difficult, interns are concerned with many other factors (Hollingsworth, 1989). For instance, the Intern Teacher did not expect nor anticipate the types of responses she received from the students. Thus, though she was influenced by the curriculum to increase her knowledge of astronomy, her students did not influence her to increase her knowledge. A future study could explore how preservice teachers who are given thorough background and a reason to anticipate student ideas would approach instruction. Perhaps it may be found that student ideas influence teachers who expect students to have such prior knowledge of science concepts.

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Appendix A
Pre and Post-Instruction Interview Protocols for Students and Teachers

Teacher goals:

1. Your teacher has told me and has talked to you about studying astronomy. What is astronomy? What kinds of things do you think you will be learning about?
2. When you grow up, what kinds of jobs might you have if you studied astronomy?
3. Can you tell me the names of the planets? Which do you think is the largest? The smallest? Which is the hottest? The coldest?
4. Can you draw me a picture of how the planets are in the sky? (provide paper, pencils, crayons.) Can you put the sun in your picture? Where would it go in relation to the planets you have drawn (probe for names of planets the student has drawn).

Benchmarks objectives:

5. Provide a new sheet of paper.) What shape is the earth? Can you please draw a picture of the earth? On your drawing, please point to where you stand on the earth. (Using the child's drawing) What if you dropped a ball—which way would it fall?
6. What kinds of things do you see in the sky during the day? (Do you ever see the moon in the sky during the day? When?) What kinds of things do you see in the sky at night? (Do you ever see the sun in the sky at night?)
7. (Provide a variety of sizes of balls) Please choose one of these balls to be the sun, one to be the earth, and one to be the moon. Does the sun, earth, and moon move in space? Can you show me how they move using the balls? (Provide a new sheet of paper) Can you please draw a picture of how you think they move in space?
8. Does the moon always look the same in the sky? Why does it sometimes look different? What different shapes have you seen? Can you please draw some of those shapes? How often does the moon change shapes?
9. Tell me what you know about stars. How many stars are there? What colors can they be? What are stars? How bright are they? Are they all the same brightness? Why or why not?
10. Is there anything else you want to tell me about astronomy?

Appendix B

Teacher and *Benchmarks* Goals for Instruction

Teacher goals for instruction:

- Students should know various vocations in astronomy.
- Students should know the names of the planets, the smallest planet, the largest planet, and the coldest and hottest planets. They should know the make-up of the planets.
- Students will understand the order of the planets and their relationship to the sun.
- Students will know lots of information about planet earth.
- Students will know the sun is the center of the solar system and the earth revolves around it, and the moon revolves around the earth.
- Students will know the earth spins
- Students will learn how to pick a topic within astronomy to study independently, and how to find out information about that topic.

From Benchmarks and Standards:

- The moon looks a little different every day, but looks the same again about every four weeks.
- The sun can be seen only in the daytime, but the moon can be seen sometimes at night and sometimes during the day.
- The sun, moon, and stars appear to move slowly across the sky
- There are more stars in the sky than anyone can easily count, but they are not scattered evenly, nor are they all the same in brightness and color.
- The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.
- The sun provides the light and heat necessary to maintain the temperature of the earth.
- Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.

LITERACY THROUGH THE LEARNING CYCLE

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What is the nature of science? What are the national standards for science education? What is the nature of human learning? What teaching procedure matches the nature of science, the national standards for science education, and the nature of human learning? Addressing these questions has guided us in the development and maintenance of a theory-based program for preparing science teachers for the 21st century. The primary components of a theory-based, teacher education program in science education are fourfold.

Science is the quest for knowledge. Such a description infers the processes and products of science and that science should be experienced by students as it is practiced by scientists.

National Science Education Standards (NSES) is a comprehensive guide for translating the processes and products of science into the preparation of 1) scientifically literate students; 2) teachers with theoretical and practical knowledge about science, learning, and science teaching; 3) sound assessment strategies; and 4) developmentally appropriate science content.

Learning is constructing knowledge from experiences. This tenet is central to the cognitive developmental model of Piaget and is the derivative for the learning cycle.

The *Learning Cycle* is a teaching procedure that 1) parallels the nature of science, 2) applies the NSES, and 3) translates a model of cognitive development. Our expansion of the learning cycle has resulted in a version of that teaching procedure which includes social/psychological models of Vygotsky and Ausubel.

The learning cycle is *not* a teaching *method*. The learning cycle is a teaching *procedure* which allows for many methods of teaching (e.g., laboratory experiments, questioning strategies, demonstrations, group work, field trips, the use of modern technologies). All of these common science teaching methodologies can be used within the three phases of the learning cycle--*exploring concepts, naming concepts, and expanding concepts.*

How and when can the theory-base components be introduced and developed in science "methods" courses? If teacher-preparation ("methods") courses are organized and delivered as learning cycles, then the preservice teachers discover that the learning cycle is an instructional model that 1) allows science to be taught as it is structured, 2) implements the recommendations of the National Science Education Standards, and 3) reflects current constructivist learning theories.

Four science education courses serve as vehicles for our students as they prepare to teach science, two for elementary education majors and two for secondary education majors, respectively: EDSC 4093 Inquiry Based Science Teaching, EDSC 4193 Teaching Science in the Elementary Schools, EDSC 4513 Teaching Science in the Secondary Schools, and EDSC 5514

Science Curricula Implementation in the Secondary Schools. Within these courses--and student teaching--our preservice teachers explore seven fundamental questions as they prepare to teach science.

1. What is the nature of science and science teaching?
2. What are the goals of science education?
3. What is the nature of the learner?
4. What are the relationships among the nature of the science, science teaching, the goals of science and the nature of the learner, i.e. the theory base of school science?
5. How do we develop learning cycles?

6. How are various methods and technologies used within the learning cycle?

7. What is an authentic assessment plan for theory based school science?

The Nature of Science and Science Teaching

We begin the methods courses by asking our students (preservice science teachers) to construct their own ideas about the nature of science. We ask them to describe or define science, first individually and then collaboratively in small groups. Their definitions are compared to those of known scientists such as Albert Einstein, Niels Bohr, and Maria Mitchell. The students easily recognize that their descriptions of science closely match those of scientists. That is, the nature of science is to investigate through experiences and then to logically explain the data gained through those experiences. Science is not merely facts, laws, principles, and concepts but rather the process of finding them. Our students gravitate to this simple and concise description of science provided by an historian of science, Duane Roller: Science is the quest for knowledge, not the knowledge itself"; but what is the nature of a quest?

Our students are now prepared to experience a teaching procedure consistent with their description of science, therefore we engage our students in a "model" learning cycle investigation. Following the investigation, our students (through class discussion) describe each phase of the learning cycle they have just experienced. We, the instructors, supply the learning cycle terminology which is descriptive of each phase of the learning cycle--exploration, term introduction, concept application (Marek and Cavallo, 1997). The term learning cycle is introduced as the name of the teaching procedure that the students just experienced. Students now describe how the learning cycle is consistent with their description of the nature of science. With their fundamental understandings of the relationship between the learning cycle and the nature of science, our students now expand their understandings by examining the goals and purposes of science education.

The Goals of Science Education

Students explore selected readings from The Central Purpose of American Education (EPC, 1961), Science for All Americans (AAAS, 1990), and the National Science Education Standards (NRC, 1996). By examining these documents, our students discover that the *central* purpose of our educational system is the development of critical thinking abilities and that school activities should be designed to lead students toward this goal. Thinking abilities are defined in the EPC document as the rational powers of recalling, comparing, inferring, generalizing, deducing, classifying, analyzing, imagining, synthesizing, and evaluating. We engage our students in a variety of activities--learning cycles--that use and apply the rational powers. Following these activities, our students develop a table showing science experiences teachers can provide for their students that will incorporate the use of the rational powers and lead to the development of critical thinking abilities (Figure 1).

Science Process Activities	Rational Powers Used
Collecting Data Observing Describing Experimenting	Comparing, Inferring, Recalling
Organizing Data Making tables Graphing Grouping Serial ordering Classifying	Classifying, Analyzing, Recalling
Interpreting Data Looking for relationships Constructing meaning	Inferring, Comparing, Recalling
Generalizing from Data Discerning a pattern Summarizing and proposing a trend Drawing a conclusion	Inferring, Generalizing, Synthesizing, Recalling
Explaining Generalizations from Data Making a model Creating or formulating a concept or idea Presenting data and conclusions to others	Imagining, Inferring, Recalling, Synthesizing, Evaluating
Predicting from Models or Patterns Deducing from a generalization Forming a hypothesis Testing a hypothesis, generalization or model	Deducing, Inferring, Recalling, Synthesizing, Evaluating

The Development of Logical Thinking

Figure 1. The rational powers used in science process activities to develop logical thinking (adapted from Renner, 1985)

(Figure 1 is FIG. 2-6 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

The Nature of the Learner

Our students begin to develop a model of cognitive development--learning--by gathering data from children and adolescents. Our preservice teachers interview students in area schools using an array of tasks. For example, the elementary education majors interview elementary school children using Piagetian Conservation Tasks while the secondary, science education majors use the Test of Logical Thinking (TOLT) with middle and high school students: These data are then used to construct the Piagetian "stages" model. Our students begin to develop understandings of preoperational thought, concrete (intuitive) thought processes and formal (reflective) operations. From this developmental stages model, our preservice teachers construct a model of intelligence as depicted in Figure 2. This is our representation of a model of intelligence; our students are assigned the task of developing their own models or representations of the nature of human learning. These models and essays are used to assess students' understandings of Piaget's model of intelligence.

The Theory Base of School Science

At this point in our students' preparation for science teaching, they have developed understandings of the nature of science and science teaching, the goals of science education, and the nature of human learning. The next logical question: What are the relationships among these elements? For example the learning cycle was derived from the mental functioning model defined as assimilation>disequilibration>accommodation>organization. One way of depicting the relationship between the phases of the learning cycle and mental functioning can be seen in Figure 3.

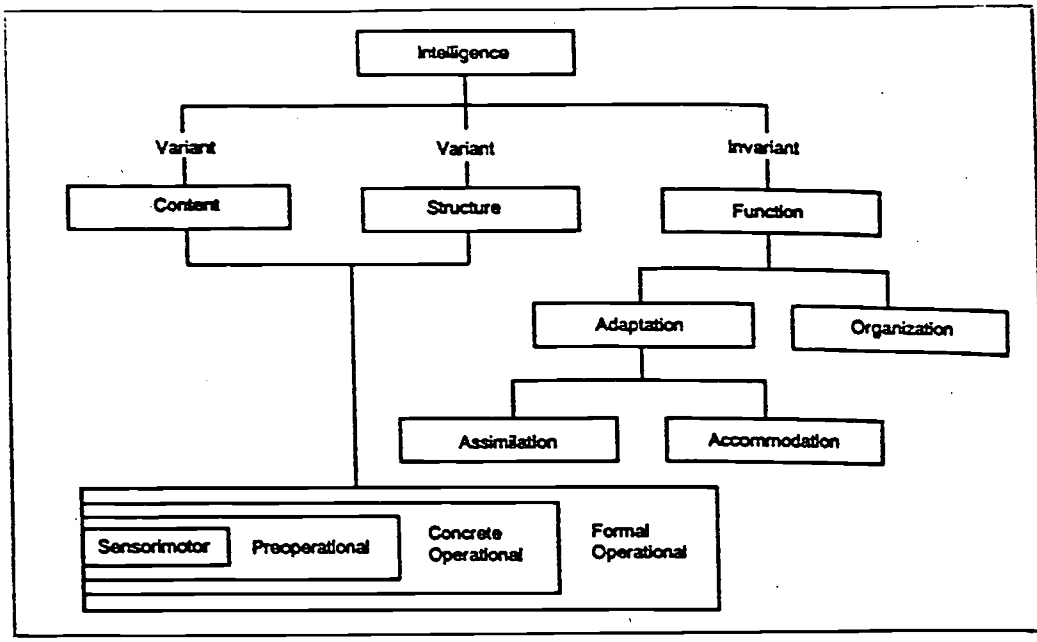

Figure 2. An interpretation of the relationships within Piaget's model of intelligence

(Figure 2 is FIG. 3-10 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

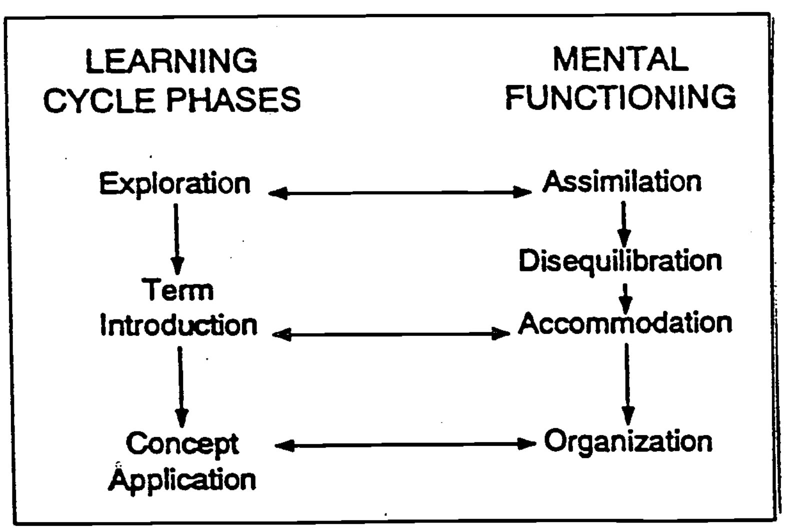

Figure 3. The learning cycle and Piaget's model of mental functioning

(Figure 3 is FIG. 4-1 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

Although originally based on Piagetian theory, the learning cycle also embodies other constructivist paradigms of learning and development. These paradigms include social constructivist theory (Vygotsky, 1978) and meaningful learning theory (Ausubel, 1963). Our preservice teachers engage in a variety of activities in which they examine how these paradigms are embedded in the learning cycle.

Consistent with social constructivist theory, the preservice teachers discover that *scaffolding* is used throughout the learning cycle. Scaffolding occurs as classroom teachers use questions, models, analogies and clues to help their students interpret data and form understandings of concepts. In the learning cycle, classroom teachers work within each students *zone of proximal development* toward attaining new levels of development.

Through our modeling of the learning cycle, preservice teachers become immersed in the *scientific subculture* as they make observations, collect data, discuss and interpret findings, state concepts and apply concepts. Such experiences help them recognize that by engaging in learning cycles, their future students will become adept at the language and thinking processes of science, and therefore members of this unique discourse community.

The preservice teachers also discover the relevance of meaningful learning in the learning cycle, particularly when they experience, and later develop, application (expansion) activities. They discover how learning cycles fulfill the three criteria of meaningful learning by providing application activities *(meaningful learning tasks)* that help students link their understanding of the concept *(relevant prior knowledge)* to other experiences in science and in everyday life (Ausubel, 1963; Novak, 1988). Since students are active in the learning process *(meaningful learning set)*, the learning cycle promotes the use of students' meaningful learning strategies as opposed to rote strategies.

Our students are at a crucial point in their learning about theory based school science; therefore they are asked to prepare and compare concept maps. Their concept maps link the learning cycle with: the nature of science, purpose and goals of science education, and theories of learning and development. The thinking and dialogue involved in constructing these maps helps our teachers meaningfully understand the theoretical and practical underpinnings of the learning cycle. We are now prepared to develop learning cycles.

Developing Learning Cycles

The preservice teachers have access to our large collection of learning cycle and non-learning cycle curriculum materials, which are housed in the Science Education Center. The preservice teachers frequently review and use learning cycle based curricula in their field experiences (e.g., SCIS-3, FOSS, Investigations in Natural Science, BSCS). However, our students also experience the challenge of developing original learning cycles. This process involves adapting learning cycles from non-learning cycle activities and materials. The preservice teachers construct teachers' and students' guides in complete and thorough form, then test their curricula in videotaped, peer teaching sessions within our courses. Using peer and instructor feedback, and their own self-reflections, they revise their learning cycles. The revised learning cycles are then field tested with students in the schools.

The preservice teachers also develop and teach learning cycles integrated with other subjects in the school curricula, and learning cycles in other disciplines such as mathematics, art and music. The teachers frequently present their original, field tested learning cycles at professional conferences, or submit them for publication.

Methods and Technologies Within the Learning Cycle

The learning cycle is not a teaching *method*. It is much greater in scope and philosophy than that. The learning cycle is a *teaching procedure* which, by design, allows for many methods of teaching (e.g., questioning strategies, demonstrations, group work). For example, our students participate in a learning cycle in which questioning strategies are featured and emphasized. Students analyze the question types, cognitive load, and preplanned placement of questions throughout the lesson. In other learning cycles, technology is featured. In other words, students are involved in learning cycles which use slow motion, video imaging technology and measurements of pH using probes interfaced with computers. The key point is that different teaching methods and technologies are "compatible" and *necessary* within the learning cycle teaching procedure.

The learning cycles described here are conducted in the local schools by model teachers of science and this modeling is the vehicle for our students to gain direct experiences with various methods and technologies. *The model teachers are an essential and vital part of our teacher education program.*

The variety of methods and technologies used in learning cycles makes traditional forms of assessment inadequate. It is at this point in the "methods" courses that our students explore alternative forms of assessment for the learning cycle science classroom.

Assessment

The techniques we use to measure students' progress must *match* the form and nature of the instruction. Consequently, the use of authentic assessment is clearly consistent with the learning cycle teaching procedure. Such assessment may include conventional tests, but most often utilize alternative and innovative evaluation techniques. Most importantly, assessment must be streamed throughout learning cycles to measure students' progress *as learning occurs.* Our preservice teachers develop a variety of authentic assessments with their learning cycles. These assessments may include: journals or learning logs, concept maps, laboratory practical experiences, diagrams, three-dimensional models, analogies, oral presentations, poster presentations, teacher observations, oral quizzes, mental model or open-ended essays, and library research.

Summary

Our preservice teachers' science education courses are purposefully, of course, designed in learning cycles. That is, our students learn about the learning cycle by *engaging in learning cycles* about the theory-base and implementation of this teaching procedure. To match our teaching, we (the instructors) use authentic assessment, both as models for teachers, and to measure our students' progress as they learn about theory based school science.

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Laboratory Skills and Competencies for Secondary Science Teachers

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Introduction

In recent years, the emphasis on laboratory activities for science students has increased. The *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) stress that students need to adopt methods of inquiry and the thinking skills similar to those used by active scientists. Implied in this directive is the assumption that the teacher has the skills to plan, prepare and carry out, laboratory activities for their students.

Science teachers may not always have the skills needed. The authors observed that, in many cases, common laboratory techniques were performed by laboratory assistants and were not performed by the undergraduate student in class. As the first year teacher enters the work force, he or she may not have adequate experience to plan and set-up laboratory activities. Thus, the focus of this research was to determine which laboratory skills and competencies are viewed by current teachers as necessary for the pre-service teacher. Our goal was to create a list of laboratory skills and competencies that could serve as a **minimum** standard. We believe this list could be used to improve teacher education programs.

Very little research has been done to determine what technical skills beginning teachers need. In 1970, Beisenherz noted that there was a need for a special course in laboratory skills and preparation techniques for prospective biology teachers. Students he interviewed expressed frustration that they did not have adequate skills to plan and prepare laboratories. He proposed a specific course designed to alleviate these deficiencies. Later that decade, James and Schaff (1975) administered a survey to practicing physical science teachers concerning skills needed for laboratories in chemistry, physics and physical science. From this survey, a list of general competencies was generated along with values representing need and desired instruction. James and Stallings (1977) followed with a similar study of biology laboratory competencies. Again, this survey was administered to practicing teachers. Voltmer and James (1982) surveyed college and university educators and determined the 70 most appropriate laboratory skills from a list of 85. Apparently, these studies have had little impact on teaching practices. James and Crawley (1985) reported that prospective teachers in most institutions did not receive instruction in basic laboratory skills. They describe teacher training programs at Kansas State University and the University of Texas at Austin which were designed to provide students with an opportunity to learn a prescribed list of laboratory competencies.

The authors of this study proposed to survey a range of stakeholders, including teacher educators, science content instructors in higher education institutions, pre-service teachers, and experienced teachers. We wanted to determine which specific skills are important for beginning teachers to know and be able to demonstrate prior to entering a secondary classroom as a proficient novice teacher so that diverse and effective learning experience may be safely offered in their classrooms.

Methods

Items for the survey were generated by the participants during a graduate course in science curriculum at the University of Northern Colorado. The developers included individuals with varying amounts of secondary teaching experience in chemistry, biology, earth science, space science, and physics. The initial list of competencies was generated by the authors from a combination of personal experience, interviews with selected in-service teachers and reviewing commonly used laboratory manuals.

The respondents for the first round included practicing middle and high school teachers, university faculty, and pre-service teachers. Teachers were selected based upon recommendations of the developers or colleagues. Criteria for selection were based on the likelihood of receiving a response and the teachers emphasis on laboratory activities in their courses. The majority of the middle school teachers' responses were collected from teachers participating in the UNC Institute for

Chemical Education in the summer of 1997. University faculty responses were obtained during various presentations of the survey at professional meetings in Colorado. Pre-service teachers' responses were collected from students in a science methods course at the University of Nebraska, Lincoln and at the University of Northern Colorado.

The skills and competencies survey included 145 items in three categories (general, biological science, and physical, earth, and space science). These were further divided into 11 sub-categories. Additional skills and competencies were also solicited from respondents. Participants were asked to evaluate each skill or competency using the following scale: 3- essential, 2- high priority, 1- beneficial to know, 0- not necessary to know. Arithmetic means and variance (pooled samples) were calculated. Respondents were asked to respond to the sections they personally felt qualified. This accounts for the variation in number of responses to each item.

Results

Each item was rated by a minimum of 63 respondents, some items had a total of 111 respondents. Mean scores range from a high of 2.89 to a low of 0.99. The results of the survey are presented in Tables 1-11.

Discussion

Our results show that knowledge of hazardous material handling and laboratory safety skills and competencies were of the greatest importance to pre-service teachers. This was not surprising considering the current climate of safety consciousnes within our schools. As far as the other skills and competencies are concerned there was a continuum of importance. We would suggest that any skill with a mean of 1.5 or greater be considered essential for pre-service teachers. Skills and competencies with a mean less than 1.5 could be learned on the job.

There are several alternatives for pre-service teacher education programs to include such skills and competencies. One alternative is a specially designed techniques and methods course to address these skills. Others have suggested that these skills and competencies should be incorporated into the current curriculum of the program. Student portfolios demonstrating competency in all areas could also be utilized. If we would like to improve the quality of pre-service teacher programs these skills and competencies must be addressed.

Clearly these skills and competencies are ever-changing. Efforts should be made to include new technology and methodology as it appropriately evolves. The list of expected skills and competencies must be viewed as a dynamic rather than static target. We would encourage all educators of pre-service teachers to stay abreast of new developments within the field. For example, use of global positioning systems (GPS) was not part of our original survey. However, due to the sharp reduction in the cost of a GPS system (< $200) many schools can now afford them. Clearly pre-service science education programs should be prepared to provide pre-service teachers with the laboratory skills and competencies necessary to successfully enter the work force..

Skills are placed in rank order of importance from most to least important, based on survey responses. A space is place between what the author's interpret to be essential laboratory skills and those perceived to be non-essential laboratory skills. A mean response score of 2.0 was used for the division point.

Table 1
General Science Laboratory Skills

	Total Respondents	Mean	Variance
Proper use and safety of Bunsen and/or alcohol burners	111	2.76	0.13
Scales and balances, use, care, calibration	111	2.67	0.18
Location of common "recipes" and source books	108	2.56	0.25
General knowledge of audio visual equipment	111	2.54	0.25
Proper use of volumetric glassware, and reading a meniscus	110	2.54	0.23
Reading maps, (all type, topographic, weather, etc.)	111	2.47	0.27
Thermometers, calibration, limitations, and uses	110	2.43	0.27
Use and care of microscope including basic repairs	110	2.40	0.30
pH meters and paper, use and calibration	111	2.39	0.22
Proper dilution of solutions	110	2.26	0.27
Preparation of Molar, Normal, Percent vol/vol, mass/vol solutions	109	2.12	0.28
Proper solution filtration	104	1.85	0.29
Standard directional compass, use and care	110	1.83	0.37
Chromatography	112	1.76	0.26
Water test kits	110	1.68	0.29
Soil test kits	110	1.61	0.26
Distillation/Deionized water production	111	1.41	0.26
Proper use of a centrifuge	109	1.27	0.25
Super Glue, uses and limitations	108	1.24	0.33
Spectrophotometer operation, care and use	107	1.20	0.23
Photography, general skills	108	1.15	0.19
Spectrophotometer calibration	107	1.08	0.21

Table 2
Computer Skills

	Total Respondents	Mean	Variance
Internet skills	108	2.50	0.26
Charting, graphing, and tables with computers	108	2.43	0.25
Selection of educational programs	102	2.20	0.27
Computer integration-slaving a computer for data logging	105	1.83	0.32
Connecting two computers together	108	1.67	0.30

180

Table 3
Safety and Hazardous Material Handling

	Total Respondents	Mean	Variance
Proper emergency procedures	109	2.89	0.07
Proper storage of chemicals	110	2.85	0.08
Proper disposal of chemicals (including organic solvents)	110	2.83	0.08
First aid	110	2.83	0.09
Identification of known toxic substances	109	2.71	0.12
Proper disposal of sharps and broken glass	107	2.55	0.23
Proper disposal of preserved specimens	107	2.48	0.26
Goggle sanitation	109	2.30	0.27

Table 4
Chemistry Skills

	Total Respondents	Mean	Variance
pH meters, calibration, maintenance, and use	84	2.42	0.22
Selection of appropriate level of precision measuring devices	81	2.40	0.24
Filtration techniques	81	2.35	0.27
Pipeting technique	82	2.29	0.32
Conductivity testing	78	2.18	0.30
Burettes, calibration and maintenance	82	2.07	0.36
Electrodes, use and maintenance	80	1.99	0.29
Sampling protocols, liquid	82	1.94	0.27
Calorimeters, use	82	1.94	0.32
Pressure measurements	82	1.91	0.30
Spectroscope and discharge tubes, use	83	1.87	0.34
Graphing calculator, operation and use	83	1.83	0.30
Sampling protocols, gas	81	1.81	0.31
Vacuum pump, use and maintenance	81	1.75	0.29
Spectrophotometers, use and maintenance	79	1.65	0.27

Table 5
Physics Skills

	Total Respondents	Mean	Variance
Timing devices, operation	77	2.58	0.18
Selection of appropriate level of precision measuring devices	75	2.55	0.20
Power supplies, operation and use	76	2.53	0.18
Volt and ammeters, operation and use	77	2.49	0.20
Design and build simple electronic devices	77	2.45	0.26
Construction of multiple pulley systems	82	2.45	0.24
Lasers, operation and use	78	2.29	0.26
Optics bench, operation and use	73	2.18	0.24
Conductivity testing	76	2.14	0.33
Oscilloscopes, care, use, and calibration	77	2.12	0.23
Graphing calculator, operation and use	74	2.08	0.34
Spectroscope and discharge tubes, use and care	73	2.07	0.26
Calorimeters, operation and use	74	2.01	0.37
Thermal expansion device, operation and use	73	1.92	0.34
Air tracks	68	1.90	0.28
Vacuum pump, use and maintenance	74	1.88	0.36
Van De Graaf generator, operation and use	72	1.88	0.39
Signal generators, operation and use	70	1.86	0.30
Hooke's Law apparatus	68	1.84	0.40
Geiger counter, operation and calibration	75	1.80	0.34
Cloud chamber, operation and use	71	1.59	0.39
Wimshurst, operation and use	64	1.42	0.36

Table 6
Astronomy Skills

	Total Respondents	Mean	Variance
Telescope, ability to locate objects	73	2.56	0.23
Telescope, use and care	73	2.47	0.26
Astronomical charts, reading	71	2.41	0.25
Celestial globe, reading and use	69	2.16	0.31
Pendulum, operation and use	70	2.14	0.32
Spectroscope and spectrum tubes, operation and care	69	2.01	0.29
Construction of sextant from protractor	68	1.75	0.34
Inflatable planetarium, use	70	1.73	0.34
Astrolab (sextant) use	69	1.67	0.29

Table 7
Geology Skills

	Total Respondents	Mean	Variance
Mineral and rock identification, use of keys	78	2.67	0.18
Mineral test kits, assembly and use	75	2.55	0.22
Plotting latitude and longitude	75	2.52	0.28
Standard directional compass, use and care	77	2.34	0.28
Setup and operation of a stream table	77	2.05	0.29
Sorting and identification of soil types	77	2.03	0.28
Preparing a fossil sample for use	77	1.82	0.24
Seismograph, operation and tracing reading	78	1.81	0.26
Stereoscope, map reading	75	1.77	0.36
Clinometer or Brunton compass, use and care	75	1.56	0.34
Fence diagrams, reading and use	65	1.45	0.29
Tree coring, procedure and reading	75	1.40	0.19
Sterilization of owl casts (pellets)	73	1.25	0.31

Table 8
Meteorology Skills

	Total Respondents	Mean	Variance
Barometer, use and calibration	75	2.52	0.18
Rain gauge, use and calibration	74	2.43	0.26
Hydrometer, use and calibration	74	2.28	0.20
Setting up a weather station	76	2.22	0.27
Anemometer, use and calibration	74	2.20	0.40
Sling psychrometer, use and calibration	72	2.19	0.37
Calculation of wind chill, heat stress	73	2.12	0.30
Tide chart, calculations and uses	73	1.93	0.31
Cloud chamber, operation	73	1.74	0.31
Vacuum pump, operation	73	1.71	0.31
Van De Graaf Generator, use, care and basic repair	68	1.71	0.33
Wimshurst, use and care	64	1.25	0.37

Tables 9-11 summarize Life Science skills

Table 9
Genetics and Physiology

	Total Respondents	Mean	Variance
Indicators, preparation and use	63	2.51	0.25
Animal organs, procurement, storage, and disposal	66	2.35	0.31
Frog dissection	70	2.03	0.33
Synthetic blood, typing and obtaining	68	1.81	0.47
Blood typing	70	1.69	0.34
Karyotype, reading and acquisition	70	1.64	0.37
Electrophoresis, performing	71	1.63	0.32
Electrode operation, safety, and care	68	1.63	0.33
Genetic computer simulation, selection and operation	69	1.59	0.25
Sphygmomanometer operation	66	1.56	0.39
Fruit Flies, care and culture	70	1.50	0.28
PCR (Polymerized chain reaction) experimentation	68	1.47	0.40
Fermentation chambers, use and operation	69	1.41	0.37
Metabolic chambers, use and operation	72	1.32	0.35
Ability to pith properly	68	1.16	0.48

Table 10
Microbiology Skills

	Total Respondents	Mean	Variance
Specimens, care, culture, and disposal	69	2.45	0.25
Microscopes, basic repair	70	2.41	0.25
Specimens, identification	70	2.37	0.27
Acquisition of cultures	69	2.30	0.23
Media preparation	69	2.26	0.30
Plate/Tube preparation	68	2.15	0.33
Autoclave, sterilization techniques	68	2.15	0.42
Pressure cooker, sterilization techniques	67	2.09	0.39
Gram stain preparation	69	2.00	0.35
Acid fast stain preparation	67	1.64	0.46
Preparation of hay infusions	67	1.63	0.44
Flagella stain preparation	68	1.54	0.35

Table 11
Botany/Ecology/Field Biology Skills

	Total Respondents	Mean	Variance
Use of dichotomous keys (plants, trees, animals)	71	2.63	0.22
Specimen handling, including ventilation, storage, disposal	70	2.40	0.26
Specimen identification	71	2.37	0.24
Specimen collection	71	2.35	0.25
Location of local plants (elodea, seeds, etc.)	71	2.35	0.24
Animals, care and culture	70	2.31	0.28
Plants, care and culture	72	2.24	0.34
Ability to plot latitude and longitude	71	1.99	0.42
Specimen preservation	65	1.98	0.32
Greenhouse/hothouse operation (lighting, pesticides)	70	1.77	0.35
Basic vegetation measurements(% cover, point quarter)	66	1.67	0.34
Museum curation	69	0.99	0.22

Request for Participation

The authors encourage readers to provide feedback and contribute to the ongoing refinement of this competencies list through participation in the survey at <http://www.unco.edu/biology/PTEP/skills/skills.html>. Current survey results may be obtained at <http://www.unco.edu/biology/PTEP/skills/results.html>.

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MAXIMIZING THE IMPACT OF YOUR INSERVICE: DESIGNING THE INSERVICE AND SELECTING PARTICIPANTS

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Introduction

This study took place within the context of the Science: Parents, Activities and Literature (Science PALs) Project. Science PALs was a four year systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and a local school district. Key features of Science PALs included the use of children's literature as a springboard into inquiry based science investigations, activities to increase parents' involvement in children's science learning and extensive inservice opportunities for elementary teachers. The overarching goal of this elementary science teacher enhancement project was to move teachers towards an interactive-constructivist model of teaching and learning.

What can be learned from Science PALs to inform other inservice projects? This paper summarizes the research base for effective inservice and then shares additional features of the Science PALs inservice most responsible for success. The selection of participants along with a cascading model of leadership is shared as finding participants who show early signs of success enhances the likelihood of project success.

History of Reform

The last large-scale science education reform occurred in the 1960's. This post-Sputnik reform effort included the release of multiple curricula, millions of dollars spent on teacher inservice sessions related to the new curricula and a call for Americans to move forward in science instruction to meet a perceived future crisis for scientists and engineers. Many of the curricula created in that era were highly regarded, several have had a long market life, still being sold in the 90's (e.g. SCIS III and Delta Science - ESS). Good curricula, inservice efforts and a national call for reform seem to be an ideal combination. Why, then, were not these reform efforts wider spread and longer lasting? What lessons can be learned from the failed efforts of past reforms to inform the leaders of current reforms?

The 1960's curriculum development efforts resulted in materials which were to be 'teacher proof' (Hall, 1992; Yager, 1992). Science curricula were produced that promoted hands-on discovery activities. Although the curricula included effective activities for learning science, teachers did not know what to do with them. Studies show that the curricula were generally more effective than traditional programs but they did not get into classrooms (Sivertsen, 1993). It is now known that 'teacher proof' curricula is a misnomer. If excellent teachers with excellent curricula do not always produce the desired results (e.g. Smith & Anderson, 1984), uninformed teachers with good curricula cannot be expected to have positive results. Teachers need to have knowledge of the content they are teaching (content knowledge) supplemented with general teaching knowledge (pedagogical knowledge) and content specific teaching knowledge (content-pedagogical knowledge). Students differ, which means that teachers must tailor lessons to meet the needs of diverse learners. This can only be done when the teachers have an understanding of the curricula they are using and the curricula are sensitive to the cognitive needs of the students.

The post-Sputnik reforms tried to help teachers gain an understanding of the new curricula so that they could be successfully implemented. Massive inservice efforts were mounted to help teachers learn both the curricula and appropriate teaching methods. At the height of the post-Sputnik effort, equal money was spent for curriculum development and teacher workshops and institutes (Yager, 1992), increasing likelihood of lasting change (Hall, 1992).

The lack of clearly stated, known and agreed upon goals is but one reason the reform effort of the 60's failed (Yager, 1992). Reform efforts and changes are most successful when the policy makers, practitioners and researchers share goals, and are partners who all meaningfully contribute to the same effort (Hall, 1992; Linn, 1986). Teachers were not stakeholders in the reform effort nor did they fully understand the project's goals. As a result, they had little incentive to implement the reforms.

The Current Reform Movement In Science Education

A Nation at Risk (1983), *Educating Americans for the 21st Century* (1983) and other reports investigating American education spawned several standards documents, including the creation of standards for science education K-12 (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) and for teaching (National Board for Professional Teaching Standards [NBPTS], 1990, 1993, 1994, 1996). These standards describe the content and concepts to be taught at various grade levels; they describe how teachers should teach; they give guidelines for professional development and professional standards for teachers. The need for better qualified science teachers who meet high performance standards is imperative (AAAS, 1993; NBPTS, 1993, 1994, 1996; NCTAF, 1996; NRC, 1996). The teacher's professional quality and performance, is the single best predictor of, and most important contributor to, a child's performance (NCTAF, 1996). In order to help the masses of teachers perform better massive change must occur.

Numerous studies have been undertaken to investigate the nature of school reform and the role of teacher as a change agent (e.g. Berman & McLaughlin, 1976; Fullan & Eastabrook, 1973; Fullan & Stiegelbauer, 1991; Hall, 1992; Hall & Hord, 1987; Sarason, 1990). Among the findings are the need for teachers and administrators to work together; a school climate conducive to change; teachers willing to serve as change agents; and understanding that change takes time.

Teacher Inservice Programs

Just as current reform efforts can learn lessons from the failures of past reforms, inservice planners can gain insight by comparing features of successful and unsuccessful professional development efforts (Kirst & Meister, 1985). A failure to learn from the past will result in millions of dollars spent in vain, thousands of hours of teachers' time wasted and millions of students leaving school with missed opportunities to learn (Sarason, 1995).

Teacher inservice, staff development, professional development, or continuing professional education consists of ongoing, systematic growth processes for teachers to improve their in order to benefit students (Burke, 1994; Dillon, 1978). The length and duration of inservice activities vary, depending upon the goals of those who planned the inservice. Teacher roles within the inservice activity vary as well. "It is still widely accepted that staff learning takes place primarily at a series of workshops, at a conference, or with the help of a long-term consultant" (Lieberman, 1995, p. 591). Generally accepted as necessary, inservice programs are often viewed as a waste of time by the teacher participants (Bradley, 1996a; Sparks & Loucks-Horsley, 1990).

Elements Of Successful Inservice

Current professional development begs for reform if lasting changes are to take place (Pogrow, 1996). Most efforts are not successful at implementing long term change (Sykes, 1996). Few reforms have considered the support needed by teachers to fully understand the reform and to substantiate the innovation (NCTAF, 1996; NRC, 1996). There are, however, several components common to successful inservice programs which can be used to improve the likelihood of program implementation. This section discusses these components.

Time Duration

Professional development projects must be of sufficient length and duration to allow for: acquisition, practice, feedback, follow-up, and maintenance (Burke, 1994). Change does not take place if participants cannot become adequately acquainted with the innovation and its implementation (Showers & Joyce, 1996). Once they understand the basic tenets and goals of the project they must try them out, revise their understanding and collectively redefine goals (Burke, 1994; Fullan & Pomfret, 1977; Lieberman, 1995). This cannot occur in a one-shot inservice program. Ball (1996) argues for "a stance of critique and inquiry" within inservice; a shift from rote implementation of the innovation towards a constructivist emphasis of adaptation and generation of new knowledge. Teachers need to test suggested approaches in their classrooms, modify and adapt them for their own needs and then share their results with other concerned teachers. This verification approach allows teachers to act as researchers, something called for by various standards (NBPTS, 1990, 1993; NRC, 1996; Sivertsen, 1993).

This idea of inviting teachers to be involved, having them take part in articulating and evaluating the goals, incorporating the changes in their classes and revisiting goals with colleagues only occurs when there are follow-up meetings, long term support and shared understanding of desired change (MacGilchrist, 1996). When substantial amounts of time are spent meaningfully sharing ideas and generating knowledge teachers view their peers as partners and they see themselves as part of a professional learning community (Lieberman, 1995). It should be noted that simply increasing the time allotted to inservice efforts does not guarantee that the innovation will be implemented, but without long term efforts the likelihood is reduced (Hall, 1992).

Reflection

More and more educators are espousing the value of reflective practice within the confines of professional development (Ball, 1996; Darling-Hammond & McLaughlin, 1995; Lieberman, 1995; Muscella, 1992; Russell, 1992; Schifter, 1996; Schön, 1982; Wilson, Peterson, Ball & Cohen, 1996). Teachers seeking to enhance students' metacognitive skills are themselves rarely given the time to reflect on their own learning, thinking and understanding. Time ought to be allocated for reflection when a new innovation is being introduced (Johnston, Guice, Baker, Malone & Michelson, 1995; Russell, 1992). This reflection allows teachers and institutions to assess the significance of the innovation and to plan, monitor and regulate strategies for implementation. It also provides time for internalization and self-articulation of goals and beliefs (Duckworth, 1987, 1991; Johnston et al., 1995; Muscella, 1992; Russell, 1992). Constructivist practices dictate that learners be provided time to reflect on their emerging ideas (NRC, 1996; Sivertsen, 1993). The time set aside for reflection promotes reflective practices by allowing teachers to think about their own learning as a springboard to thinking about their teaching practices. This juxtaposition between teacher and learner is a critical element of reflection (Muscella, 1992). Assigning priority and time on the inservice agenda for reflection underscores to participants its importance.

The Modeling Of Exemplary Practices

Inservice programs and reform efforts are ways to introduce teachers to new pedagogical approaches. Unfortunately, the common 'do as I say, not as I do' method of instruction is counter-productive. Teachers learn in ways similar to students (Ball, 1996; Lieberman, 1995; Shymansky, 1992; Wilson et al., 1996) yet they are not taught in ways which recognize them as being students.

In most cases teachers are passive recipients of information about which they have no familiarity (Darling-Hammond & McLaughlin, 1995). The constructivist methods of teaching are ones that the teachers themselves have never seen and likely a manner in which they have not been taught. In these cases, the leaders are trying to construct situations in which teachers 'unlearn' common practices as they develop a need for new ones (Darling-Hammond & McLaughlin, 1995). Teachers with little or no experience with a new practice are well served by experiencing examples of the espoused approaches (Ball, 1996). Modeling is more effective than telling teachers how to teach. The modeling of ideal behaviors is important if teachers are going to see the merits and technical issues involved in teaching in a new way. By recognizing the teachers in the role of students the teachers become better able to implement the strategy with their own students (Schifter, 1996). Just as modeling is an approach that works well with students (Good & Brophy, 1991), it also works well with teachers-as-learners (Bailey & James, 1978; NRC, 1996; Shymansky, 1992).

Not all aspects of an inservice program lend themselves to an inquiry based or active approach on the part of the learner. Some information must be told. This format should be used on an as needed basis. While telling is not teaching, the telling part of an inservice should be clear, concise and include concrete examples (Ball, 1996; Sparks, 1983). In other words, the didactic aspects of teaching ought to be well modeled, too.

Opportunities For Networking And Team Building

Effective professional development involves teachers working together in communities of effective practitioners. This varies from the traditional model in that it requires teachers to be active, communicate with each other, and collaborate. In order for teachers to successfully facilitate children's science learning they must get support from their teaching colleagues and the greater professional community (NRC, 1996; Sivertsen, 1993). Too often, teachers are isolated. They teach behind closed doors and rarely discuss pedagogical issues with each other. According to Darling-Hammond and McLaughlin (1995), there must be a collaborative effort, involving the sharing of knowledge among educators with a focus on teachers' communities of practice rather than on individual teachers. When teachers are members of learning communities they learn, develop and grow with each other (Duke, 1993; NCTAF, 1996; Raizen & Michelsohn, 1994). As part of a learning community, teachers have a network which acts as a support mechanism. This provides a place to share ideas, problems and concerns in a non-threatening environment (O'Brien, 1992; Richardson, 1996). Working together the teachers help each other with the difficulties that arise when implementing a new teaching approach. The results include a decrease in the amount of teacher isolation, new opportunities for growth and reflection, and the development of an environment that is conducive and supportive of change (Lieberman, 1995; Richardson, 1996). The format for the networking can include peer mentoring, electronic mail communications, two-way interactive video cameras, computer bulletin boards, and regularly scheduled meetings. The common denominator is that teachers are involved in substantive discussions about their practice (Darling-Hammond & McLaughlin, 1995; Lieberman, 1995; NBPTS, 1994; NCTAF, 1996; Richardson, 1996; Showers & Joyce, 1996). These communities of practitioners empower each other to personalize innovations and provide objective, creditable analysis and feedback (NRC, 1996).

Inservice Project Goals

Without clearly articulated and agreed upon goals chaos is likely to occur (Burke, 1994; Wood, McQuarrie & Thompson, 1982) and little or no long term change will be effected (Cornett, 1995; van Lakerveld & Nentwig, 1996; Sparks & Loucks-Horsley, 1990). In order to maximize the impact of an inservice effort teachers, leaders and administrators must have a common vision (Burke, 1994; Darling-Hammond, 1996; Dillon, 1978; Sarason, 1995). Unsuccessful inservice projects often have goals which are imposed by administrators. Successful programs have goals based on teacher input, needs assessments and evaluative information from previous inservice efforts (Ball, 1996; Darling-Hammond & McLaughlin, 1995; Dillon, 1978). These data are used to construct desired goals or target concepts and to establish an indication of current states. The difference, if any, between current state and desired state identifies the magnitude and direction of the required change (Ford, Yore & Anthony, 1997). Frequently the required change must be achieved by several smaller achievable increments rather than one large change (MacGilchrist, 1996; Schmoker, 1996)

The suggested small, easily attainable goals along the way to large scale reform efforts allows all involved to feel a sense of accomplishment and provide a way to reduce stress (MacGilchrist, 1996; Schmoker, 1995). When goals are reached and hard data collected to prove the goal's attainment everyone feels a sense of achievement. Smaller goals within the realm of the larger goal allow teachers and administrators to consolidate gains and continually reexamine their priorities and methods for reaching the larger goal. As teachers begin to implement an innovation their understanding of the project changes. The project and its goals must be flexible enough to allow for the refining and revising that accompanies implementation attempts (Burke, 1994; MacGilchrist, 1996; Schmoker, 1996; Sparks, 1983). The shift is from rote implementation towards an emphasis of adaptation and generation of new knowledge (Ball, 1996). Teachers must assess the desirability of the original innovation and redirect the innovation if needed. This practice supports the guidelines suggested in the *National Science Education Standards* (NRC, 1996) regarding professional development.

Program Evaluation

When innovations are to be implemented into a school there needs to be some way to monitor change. Too often the evidence used to monitor such implementation is anecdotal. While the 'trust us' or 'take my word for it, we say it is good' method may convince some teachers about the innovation it is not likely to impress many (Schmoker, 1996; Shanker, 1995). Data which have been purposefully and systematically collected work better.

Ongoing assessment of project impact, teacher change, and student performance is the feedback loop needed for effective change implementation (Burke, 1994; NRC, 1996). It is the mechanism that provides for mid-project changes and adjustments based on informed considerations not just on belief. This would allow reforms to be redefined or redirected.

The ongoing assessment serves many purposes. First and foremost, it informs and guides the ongoing inservice efforts. Problems and concerns can be addressed when they are known about.

Without some form of ongoing assessment inservice projects would flounder. While most inservice leaders do informal needs assessments throughout the project, they are missing opportunities by not participating in a more systematic data collection process. While most teachers do not want to have their performance assessed it is critical to have some form of formal, systematic evaluation taking place (Cornett, 1995). One way to collect data in a way that teachers find valuable is through action research. When teacher participate in reflective practice and action research projects they focus on 'good practices' as learned in the inservice. Through their reflection they are defining the innovation as they implement it and monitoring their growth towards the defined goals (Schmoker, 1996). This method is suggested because it helps focus teachers' reflection and implementation while serving as a measurement for project implementation (NRC, 1996).

Role of Administrators, Teachers and Leaders in Successful Inservice Endeavors

Successful inservice programs have participants playing different roles (Showers & Joyce, 1996; van Lakerveld & Nentwig, 1996). Traditional roles are changed so that teachers and administrators work together towards commonly accepted and agreed upon goals (Darling-Hammond, 1996). The changes in roles within the organization are considered as part of the planning process (Fullan & Pomfret, 1977).

The restructured roles represent a team approach (van Lakerveld & Nentwig, 1996). The triad of administrator, teacher and leader working together is synergistic as they move towards a common set of goals. Together they are more powerful and ultimately more successful than any of the individuals working alone (Darling-Hammond, 1996; van Lakerveld & Nentwig, 1996).

The administrator's role in today's school is ideally one of supporting change. The alteration in power relationships is necessary but not sufficient for change to take place (Sarason, 1995). Teachers and administrators working together are able to define and address needs better than one group alone (AFT, 1995; Bradley, 1996b; MacGilchrist, 1996; Sparks & Loucks-Horsley, 1990). When teachers are involved with administrators and project leaders from the start they are more likely to 'buy-in' than if the innovation is created from without (Fullan & Eastabrook, 1973; Sparks & Loucks-Horsley, 1990).

The Leaders of Successful Inservice Efforts.

Successful leaders are ones who are trusted by the teachers. Often the leaders are teachers themselves. This is important to many teachers as they want to know that the leaders understand the day-to-day realities of their world. This leads to trust and a greater likelihood of an immediate buy-in to the ideas presented (Dillon, 1978). Their role is that of a facilitator rather than a leader. They work alongside the teacher-participants helping them achieve their goals. Good inservice facilitators model the innovations they are espousing (Darling-Hammond & McLaughlin, 1995; NRC, 1996; Rudolph & Preston, 1995). This serves two purposes. It demonstrates to teachers what the innovation looks like and it gives the leaders/guides increased credibility. When it comes time for the lecture or 'telling' part of an inservice the leaders should be able to clearly describe the innovation or content, they should be experts in their field (Rudolph & Preston, 1995). The leaders should be able to provide feedback and assistance to teachers who request it (Sparks & Loucks-Horsley, 1990).

The Administrator's New Role

Principals' or administrators' support of an innovation and the subsequent degree of implementation are correlated (Fullan & Pomfret, 1977). Administrative support is *the* major factor affecting success of staff development programs (Sparks, 1983).

The new role as a 'facilitator of change' requires administrators to be involved in goal setting and goal reaching alongside their teachers. Small, easily attainable goals within the long term project goals ought to be articulated (Schmoker, 1996). The new role includes data keeping and coaching (Schmoker, 1996; van Lakerveld & Nentwig, 1996). When starting a new initiative records should be kept so that growth and change is documented, monitored and reported to the teacher teams (Dillon, 1978; Schmoker, 1996). In this way, small increments of change are noted, teachers feel that progress is being made and they are more likely to remain enthusiastic about the long term project.

In this role, the administrator must offer formative evaluation, feedback, and facilitation not simply summative information. This is a new way for teachers and administrators to work therefore it is important for the shift to take place if meaningful change is to take place (Schmoker, 1996). This collaborative environment of problem solving and decision making promotes professional growth and development. The administrator helps this process by providing feedback and the teachers utilize the feedback to reflect on practices. It is important that the feedback and evaluation be used to help the teacher grow and not for punitive purposes (Seldin, 1991; Seldin & associates, 1993).

The administrator who wants the initiative to be implemented and lasting must provide a climate conducive for change (Showers & Joyce, 1996). This is a school climate that promotes risk taking, expects failures along the way to moving forward, and rewards innovation. Administrators who provide effective leadership through collegiality and communications are more likely to have a climate conducive for change. Their schools have a better chance that innovations will be well received and implemented (Sparks & Loucks-Horsley, 1990). One way to augment change is for administrators, and their schools, to set aside time for teachers to network, share ideas and concerns; value and encourage a long term, on-going relationship between project leaders and teachers; provide feedback to teachers; revisit and revise project goals; and share results of progress to date (Fullan & Pomfret, 1977; Fullan & Eastabrook, 1973; Miles, 1977; Schmoker, 1996; Showers & Joyce, 1996; Sparks & Loucks-Horsley, 1990; van Lakerveld & Nentwig, 1996).

It is suggested by many that the ultimate goal of any inservice effort or long term professional growth project be improvement in student achievement (Burke, 1994; MacGilchrist, 1996; Joyce & Showers, 1995; Schmoker, 1996). This goal has the added benefit of supplying data that is easier to collect and monitor change, since teachers are reluctant to have their own performance evaluated and monitored but are willing to use student data as a substitute (Cornett, 1995; Schmoker, 1996; Shymansky, 1995b).

The Teacher's New And Expanded Role

Traditional teacher enhancement programs have an external expert telling teachers what they need to know and do. Regardless of the participating teachers' needs, the experts tell them how to fix their problems. The new ideas about professional development take a different tack. After doing a needs assessment, there may not be a problem that needs to be fixed, but rather teachers' desire to become more effective and enhance already successful practices. In these newer approaches, teacher-participants no longer sit passively, they are actively involved in identifying their visions, defining these visions, and addressing their needs (Darling-Hammond, 1996; Darling-Hammond & McLaughlin, 1995; Fullan & Eastabrook, 1973; Fullan & Pomfret, 1977; Sparks & Loucks-Horsley, 1990). Teachers should be involved in the articulating, refining, planning, and decision making of an innovation from the start. When teachers have a voice that is listened to, their needs are met. When the inservice programs and innovations are meeting a need, participants are more engaged and more likely to view the experience positively.

Factors Affecting Implementation Of Science Innovations

Teacher-related variables which have been found to influence level of implementation are: number of years experience (Burry-Stock & Oxford, 1994; Mahmoud & White, 1980; Nelson & White, 1975; White, 1970; Zuzovsky, Tamir & Chen, 1989); academic preparation - degrees earned, number of science and science education classes taken (Burry-Stock & Oxford, 1994; Mahmoud & White, 1980; Nelson & White, 1975; White, 1970; Zuzovsky et. al, 1989); extent to which the teacher has been involved with other professional development activities (Burry-Stock & Oxford, 1994; Nelson & White, 1975; White, 1970); the perceived costs and benefits of the innovation (Doyle & Ponder, 1977; Fullan & Pomfret, 1977); the extent to which participating teachers understood the innovation, were familiar with the ideas and had philosophical congruence with the ideas presented (Czerniak & Lumpe, 1997; Doyle & Ponder, 1977; Fullan & Eastabrook, 1973; Fullan & Pomfret, 1977; Guskey, 1988; Mohlman, Coladarci & Gage, 1982); and the teachers' reasons for joining the project (Shokere & Wright, 1995).

Factors relating to the school which have been found to impact levels of implementation are: how much and how often science is taught (Burry-Stock & Oxford, 1994; Nelson & White, 1975; White, 1970); number and type of students in the class (Burry-Stock & Oxford, 1994; Mahmoud & White, 1980; Nelson & White, 1975; White, 1970; Zuzovsky et. al, 1989); the level of support from administrators (Fullan & Pomfret, 1977); the political structure and climate of the school (Fullan & Eastabrook, 1973; Fullan & Pomfret, 1977); the extent to which the voice of the teacher is listened to during the reform process and curricular changes (Fullan & Pomfret, 1977); and whether or not the teacher is viewed as an expert by his or her colleagues (White, 1970).

Factors examined which have yielded inconclusive results include the strategies employed by the teacher, school size, make-up of the student body, the amount of time spent disciplining students, the percentage of time spent on various tasks during a lesson, and the age of the curriculum (Doyle & Ponder, 1977; Fullan & Eastabrook, 1973; Fullan & Pomfret, 1977; Mahmoud & White, 1980; Mohlman et al., 1982; Nelson & White, 1975; Shokere & Wright, 1995; White, 1970; Zuzovsky et. al, 1989).

Context

This study took place within the Science PALs project. Science PALs was funded by the National Science Foundation (NSF) and the Howard Hughes Medical Foundation. The partnership between university and school district began in 1994 with the induction of 16 teachers, one from each of the elementary schools in the district. Along with the teachers' growing understanding of constructivism, other project goals included enhancing teachers' science content understanding; learning new strategies for involving children's literature in the classroom and at home; and involving and including hands-on activities, discussions, debates and investigations which support and challenge students' understanding of science content. The project was based on the findings of the Focus on Children's Ideas in Science Project (FOCIS), a previous NSF grant (Shymansky, 1987). The FOCIS project found that teachers increase their own science content knowledge while addressing their students' ideas about science and while honing their science-pedagogical skills (Shymansky, 1992; Shymansky, et al, 1993).

The structure and design of the Science PALs project was carefully planned using the results of FOCIS, planned change literature and continuing professional education research. Its format was congruent with recommendations for teacher professional development activities (America Federation of Teachers [AFT], 1995; Darling-Hammond, 1996; Darling-Hammond & McLaughlin, 1995; Goodlad, 1994; Lieberman, 1995; Rudolph & Preston, 1995; Showers & Joyce, 1996; Shulman, 1987). The Science PALs project called for: an interactive-constructivist approach to teaching and learning science; collaborative, long-term involvement shared by school district and university personnel; teacher input and ownership; personalization of project goals; on-going support; and a cascading leadership structure to transfer responsibilities and administrative duties. These were anchored in the reality of classroom teaching, giving the project ecological validity.

Another important feature was that the interactive-constructivist teaching and learning which took place during the teacher enhancement meetings were consistent with project goals giving philosophical and strategic alignment (Darling-Hammond, 1995; Lieberman, 1995; Shymansky, 1992; Shymansky et al., 1993). The overarching goal of the project was a shift in classroom science instruction towards interactive-constructivism. As a result, teachers were themselves learners in a constructivist context. Project leaders and 'science expert' facilitators did not 'tell the teachers what they needed to know'. Instead, the teachers interactively worked through curricula and activities as they sought to construct answers, find new problems and craft new questions.

Methods

Data was collected from teachers during their first 1.5 years in the project. Data relating to teachers' beliefs and perceptions of teaching were compared to their actual teaching. Demographic information, survey responses, interview and written responses to scenarios were among the data collected as source variables. These were scored using a professional growth matrix designed to measure interactive-constructivist practices in science teaching (Shymansky et al., 1995, 1997). Field notes generated by project staff at inservice sessions, classroom observations and individual teacher-staff meetings were also used to record change and implementation. These were also scored using the professional growth matrix. Videotapes of science teaching and revised science curricula were collected as output variables and scored using the ESTEEM (Burry-Stock, 1995) observational rubric and the project developed rubric.

In order to ascertain the validity of using the ESTEEM classroom observational rubric external rankings of the teachers were collected. The rankings from four experts knowledgeable with the project and the teachers were averaged and compared to the rankings obtained with ESTEEM. There is excellent agreement between ESTEEM and external rankings for the top and bottom quartile; and reasonable agreement for the middle group (Henriques, 1997).

A purposeful sample of teacher, top and bottom quartile, was examined to gain further insight into differences between implementors and nonimplementors. Data collected from these teachers and staff generated field notes highlight differences between the groups.

Interviews with project staff and Science PALs teachers gave insight into aspects of the inservice deemed most important to the project's success. Comparisons between Science PALs and other inservice efforts were made by participants to further illuminate those features.

Discussion

Results from Science PALs data indicate that newer teachers were more likely to implement the Science PALs model ($r= -.621$, $p= .013$ years of experience versus level of implementation). This can be interpreted in different ways. One scenario is that the newer teachers would adopt anything as they search for successful teaching strategies while the more experienced teachers have already found successful ways to teach. The more experienced teacher, therefore, can afford to be more critical of an innovation and slower to adopt. Another interpretation is that the more tenured teachers are less likely to implement an innovation because they are comfortable with where they are professionally. Unless the innovation appears to be a drastic improvement over current practices it is not worth the effort to change.

Those teachers who were philosophically aligned with project goals prior to project involvement were also more likely to implement ($r= .335$, $p= .241$, self-reported level of philosophical congruence). Data show that teachers reported much higher levels of implementation than their teaching performance would indicate. There is a negative, non-significant correlation between self reported and actual levels of implementation ($r= -.120$, $p= .893$).

Science PALs had an extremely high staff to teacher ratio during the first year. There were only 16 teachers in the first cadre to join the project. On staff there were three science education faculty or staff, a district level science coordinator, six science education graduate students and miscellaneous science content faculty from the university. As such, Science PALs teachers had access to frequent visitations to their classroom in addition to the monthly inservice sessions. Since the first round of teachers to join the project were district level 'science advocates' they had additional monthly meetings without Science PALs staff present. The frequent inservice sessions and advocate meetings enabled teachers to develop extensive networking systems with each other and with project staff. High school science teachers eventually joined the project as the science experts, replacing the graduate students and university faculty. This enabled another layer of networking and connections to be built. Not all Science PALs teachers wanted project staff to visit their classrooms. While they were required to permit some visits, the frequency of visits varied greatly among teachers. Visitation data from spring semester 1995: range 3-37, mean ≥9.3 visits, median = 7.5 visits (Shymansky, 1995b). The correlation between visitation by project staff and subsequent levels of implementation is almost zero ($r= -.054$, $p= .854$). This could be an argument for NOT having a high staff to teacher ratio (even though teachers cite this ratio as a positive factor in their implementation). More likely, it represents the differences in styles and personalities of the teachers and graduate students in their rooms. Some pairs were very effective and others less so. Teachers who were implementing would welcome the graduate student as a function of their relationship. Those struggling to implement would welcome anyone to help them. No formal instruction was given regarding peer coaching or mentoring. Additionally, some teachers did not view the graduate student staff as a coach, mentor or peer.

With the top and bottom quartile of teachers a significant correlation between the number of graduate student visits and the teacher's initial philosophical congruence with Science PALs was found($r= .819$, $p=.024$). The correlation between initial congruence and subsequent teaching performance was also positive (r= .503, p=.250). The degree to which graduate students' visits to classrooms impacted teaching performance, however, is questionable. Virtually no correlation between the number of visits and subsequent teaching performance was found (r= .080, p= .864).

There are at least two possibilities that might explain the pattern of graduate student visits to classrooms. Teachers who were initially aligned with the project philosophically might have been more open to having visitors in their classroom. They might be more confident in their ability to implement the project because it matched what they already valued in education. Their open door policy could have lead to more visits. If they were aligned philosophically they would have been more likely to want feedback and suggestions about how to implement the Science PALs model.

Another possibility is that project staff were more likely to visit classrooms where Science PALs was taking place or accepted. This bias would have resulted in staff making more visits to teachers who embraced project goals. In this way, project staff would be surrounding themselves by teachers who were at least talking about the virtues of Science PALs even if they were not implementing it well.

Another possibility is that project staff were not consistent in documenting visits to classrooms. Those staff members who were more conscientious about recording visits may also have been more conscientious about helping Science PALs teachers implement.

The fact that graduate student visits to the classrooms were virtually unrelated to how well a teacher implemented the model is a significant finding on its own, and it contradicts earlier findings related to use of staff to help teachers implement (Mahmoud & White, 1980). There are two possible explanations for this finding. The first is that simply sending graduate students or coaches to classrooms makes no difference. The second is that the quality of the visit is what is important, not the quantity. The field notes kept by graduate students visiting the classrooms are insufficient to make judgments about what occurred between the teacher and the graduate student. If project staff visiting the classroom acted as science experts, telling students the answers, the time was not spent modeling project goals appropriately. If project staff worked with the teacher, demonstrating interactive-constructive teaching strategies, the time would presumably be more valuable to the teacher. The nature of the relationships between project staff, in this case graduate students, and Advocates varied greatly. In some instances the relationship could be classified as partners, coaches or mentors. In others, the lack of teaching experience by some graduate students paired with highly experienced teachers hindered a respectful partnership. Data do not allow a conclusion to be reached at this point.

Teacher willingness or ability to relinquish control seemed to be an overriding difference in the groups. Those teachers that were best at implementing Science PALs were the ones who were confident enough in their abilities to change lesson midstream. They took advantage of the teachable moments, knew their students and what would work with them. These teachers had sufficient content and content-pedagogical knowledge to be able modify lessons on the fly, offer alternative explanations and ask probing, thought provoking questions. Many of these teachers cite the intensive, ongoing inservice provided by Science PALs as the source of their increased content and content-pedagogical knowledge. The changes these teachers made 'on the fly' are documented in videotaped lessons and field notes.

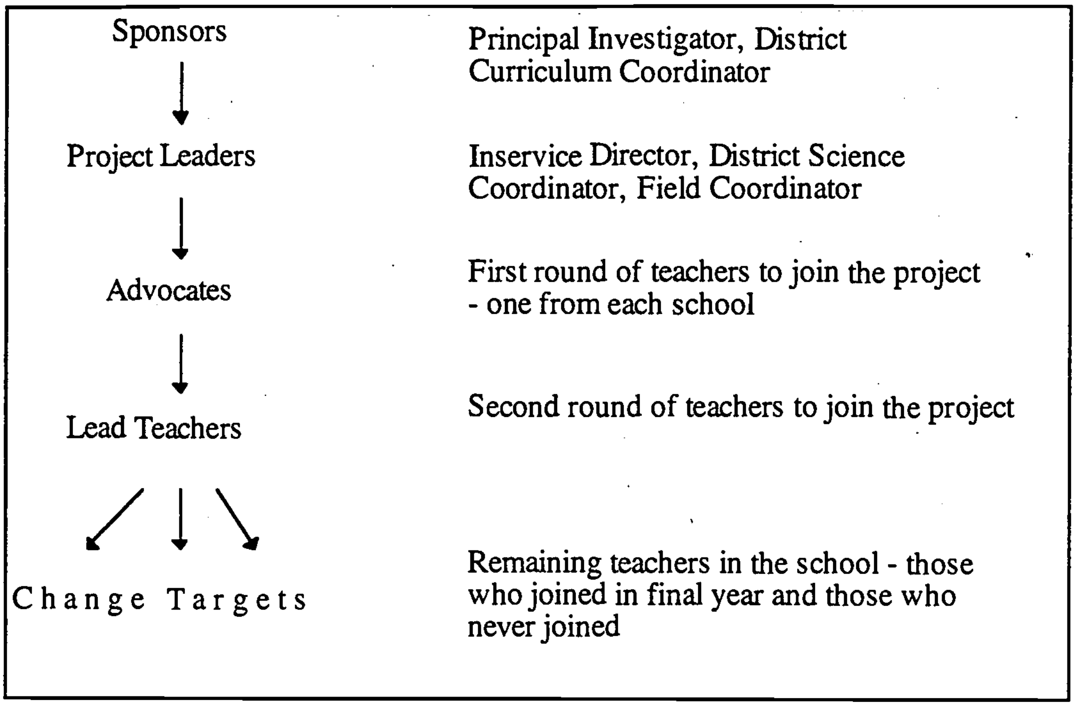
Features of Science PALs which facilitated implementation were discovered. Among the most important features were: elements of time, teacher reflection, teacher input, teachers as leaders and project leaders' modeling of advocated practices. A method to transfer leadership and ownership of the project will help enhance the longevity of the innovation. Teachers having a strong voice in the direction of the project was also viewed as an important aspect of success. Respecting the teacher as a professional was regularly cited as a contributing factor to project success.

Science PALs had a ten day summer inservice followed by monthly day-long inservice workshops during the school year. In addition to the inservice sessions there were classroom visits and district level "advocate" meetings. This cycle repeated each of the four years of NSF funding (although classroom visits decreased each year). The fact that teachers were forced to revisit ideas throughout the project enabled them to try out various aspects of the project one at a time rather than trying to change everything at once. The revisitation of ideas also forced participants to reflect and modify their own understanding of the project. The inservice sessions were of sufficient length (two-week intensive sessions and full-day workshops) and lasted over a long enough time (four years) to allow teachers to try the innovation, reflect on what worked, modify, try again, reflect, etc.

Teachers in the Science PALs project had a very loud voice. Their ideas were sought for agenda items and then used. Evaluations of individual inservice sessions provided direction for future meetings. Teachers repeatedly mentioned that they were willing to spend time critiquing inservice sessions and giving suggestions because they knew their ideas would be listened to. Whenever a change was to teaching resources the teachers were given updated copies immediately. It was, therefore, worth their time to make changes because they would be implemented promptly. Teachers in this project compared their experiences with Science PALs to other long term, large scale projects in which they had participated. The recurring theme is that they were treated as professionals in Science PALs. Their ideas and input were sought and used. As much as the teachers hated to be out of the classroom, they loved Science PALs inservice days because they left rejuvenated, more informed and feeling as if they'd contributed to the project. Graduate students and a half-time field coordinator were largely responsible for the prompt updating and dispersal of materials. Time and money was committed to this purpose from the start.

Science PALs utilized a cascading leadership model. In the first phase of the project the sponsors were in charge. In this type of model, leadership, responsibility and ownership ultimately resides with the 'targets', the Advocates and Lead Teachers. In this way, those responsible for maintaining and encouraging change after funding expires are within the school district and in the schools. The original sponsors, who instigated change, are able to help ease the Advocates into leadership positions while project funding still exists. The roles of teachers evolve as the locus of control shifts from project leaders to Advocates, to Lead Teachers and to teachers. The flow of power, responsibility and ownership in the Science PALs project can be seen in the flow chart in Figure 1. This cascading leadership model not only transfers power, responsibility and ownership, but it allows the innovation to be customized to reflect input and perspectives of each new level of involvement.

Figure 1
Model of Cascading Leadership within the Science PALs Project.



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SCIENCE, PARENTS, ACTIVITIES, AND LITERATURE: OVERVIEW, RESULTS, AND REFLECTIONS

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Research Questions

This study examined elementary school students', parents', and teachers' reactions to instruction implemented by teachers participating in a special professional development program — Science: Parents, Activities and Literature (Science PALs). Specifically, this paper focuses on students' perceptions of their science instruction and attitudes toward science learning and parents' and teachers' perceptions about science instruction as a function of their experience with an interactive-constructivist teaching approach designed to focus on student ideas, utilization of literature connections, and incorporation of parents as partners. The following questions were addressed:

- Do perceptions and attitudes differ between students in Science PALs and non-Science PALs classrooms?
- Are students' perceptions and attitudes within Science PALs classrooms influenced by grade-level and gender?
- What do parents' and teachers' comments reveal about Science PALs?

The Science PALs Project was a four-year systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and the Iowa City

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Community School District. The overarching goal of the project was to move teachers towards a middle-of-the-road, interactive-constructivist model of teaching and learning (sometimes referred to as soft-constructivism). This model differs from the extreme interpretations of social constructivism, which assumes understanding is constructed at the group level, and radical constructivism, which assumes all ideas are of equal veracity. As many of the teachers in the project had little or no experience with constructivist classrooms, the project leaders sought to promote teaching strategies consistent with interactive-constructivist views of learning by modeling these strategies in the teacher inservice activities.

Background

Constructivism, an old epistemic theory (not an instructional theory), has many interpretations (faces) in education (Good, Wandersee, & St. Julien, 1993; Phillips, 1995). The faces of constructivism provide a "range of accounts of the processes by which knowledge construction takes place. Some clarification of these distinct perspectives and how they may interrelate" is needed as this epistemic theory is used to construct compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). Without such clarification, teachers and researchers have little predictive potential and nearly any form of instruction can be justified.

The individual faces of constructivism do have some common basic assumptions and important differences. Accounts of the various interpretations of constructivism agree that understanding is actively made out of, invented from, or imposed on personal experiences (Fosnot, 1996). The construction processes and the resulting constructs are influenced by the learners' prior knowledge, memory, cognitive abilities, metacognition, interpretative framework, and sociocultural context. Each interpretation encourages meaningful learning of integrated knowledge networks through active debate and reflection, and each has discounted rote learning and drill-practice. Furthermore, each interpretation agrees that people have misconceptions within their prior knowledge and that these misconceptions are not indications of stupidity; are found across age groupings, content areas, cultures, and national boundaries; and are resistant to change. Replacement of misconceptions with more scientifically acceptable conceptions requires that the new concept be sensible, rational, usable, and powerful.

The individual faces of constructivism, however, also differ in their philosophical, psychological, epistemic, and pedagogical profiles (Table 1, Yore & Shymansky, 1997).

- **World view** involves ways of thinking about how the world works — mechanistic, organistic, contextualistic and hybrid (Prawat & Floden, 1994). **Mechanistic** views stress the important role of antecedent events as influence on behavior. **Contextualistic** views stress the importance of situation and environment where the meaning of an act may have situation-specific features, may undergo changes as it unfolds in a dynamic environment, and the pattern of events in a sociocultural context have low predictability. **Organistic** views stress the importance of the organism as a whole. Reality is only what the organism subjectively perceives; knowing is an individualistic event. **Hybrid** views stress the importance of interactions with the physical world (natural and people-built) as well as the sociocultural context and recognize that interpretations reflect lived experiences and cultural beliefs of the knowers.
- **Epistemic view of science** represents the structure of knowledge and ways of knowing (Hofer & Pintrich, 1997; Kuhn, 1993) — **absolutist** (a single right answer is proven), **evaluatist** (multiple interpretations are tested and supported or disconfirmed), and **relativist** (multiple interpretations are equally valid).

- **Locus of mental activity** represents the beliefs about where understanding is created — **privately**, deep within the mind and brain of the individual (activity flows from periphery to core where irrelevant stimuli are discarded leaving abstract representations of critical and essential information or activity focuses on subjective experiences, extracting internal coherence and where rightness is seen as the fit with personally established order); **publicly** within the dynamics of the group (activity is on the interface between the individual and the environment where the collective wisdom of the group and craft knowledge of the group construct understanding); and **publicly and privately** in which possibilities are surfaced, clarified, and narrowed by group negotiations but actual meaning is made privately by individuals reflecting on these possibilities (Hennessey, 1994; Prawat & Floden, 1994).
- **Locus of structure/control** represents a pedagogical feature and the pragmatics of classroom teaching dealing with who sets the agenda for study within a specific epistemology — **teachers, students**, or **shared**. An implicit source of structure imposed on the learning comes from the content area under consideration: physical sciences or biological sciences (Yore, 1984; 1986).
- **Discourse** represents the combined psychological-pedagogical feature of type and purpose of communications in the classroom — **one-way interpersonal** communications of expert to novice, **one-way intrapersonal** communications of person to self (inner speech the language tool of thinking and spontaneous conception), and **two-way interpersonal** communications among people to negotiate clarity or consensus (Fosnot, 1996; Prawat & Floden, 1994).

Table 1
Philosophical, Psychological, Epistemic, and Pedagogical Features of Information Processing, Interactive-Constructivist, Social Constructivist, and Radical Constructivist Approaches (Yore & Shymansky, 1997).

Feature	Information Processing	Interactive-Constructivist	Social Constructivist	Radical Constructivist
World View	Mechanistic	Hybrid	Contextualistic	Organistic
Epistemic View of Science	Absolutist (traditional) Nature as Judge	Evaluative (modern) Nature as Judge	Evaluative (postmodern) Social Agreement as Judge	Relativist (postmodern) Self as Judge
Locus of Mental Activity	Private	Public and Private	Public	Private
Locus of Structure/Control	Teacher	Shared: Teacher and Individuals	Group	Individual
Discourse	One-Way: Teacher to Student	Two-Way: Negotiations to Surface Alternatives and to Clarify	Two-Way: Negotiations Leading to Consensus	One-Way: Individual to Self (inner speech)

Henriques (1997) established a comparative framework for four faces of constructivism — information processing, social constructivist, radical constructivist, and interactive-constructivist. She provided parallel descriptions of the approaches and their implications for teaching elementary school science:

1. **Information processing** utilizes a computer metaphor to illustrate learning in which a series of micro-processes generates ideas and analyzes errors, which lead to closer and closer approximations of the right answer. Learning is a process of identifying causal relationships between antecedents and outcome, establishing critical (essential, necessary, and sufficient) attributes of a concept, and acquiring accurate understanding of fixed entities and relationships that exist independent of human activity.
2. **Social constructivism** utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are resolved by social negotiations resulting

in consensus and common understanding at the group level. Knowledge is perceived as a social artifact, not as a representation of reality.

3. **Radical constructivism** utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency. Knowledge is perceived as an individualistic snapshot of a multiple reality.

4. The **interactive-constructive model** utilizes a ecology metaphor to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence and privately integrated (assimilated or accommodated) into the person's knowledge network. Knowledge is perceived as individualistic conceptions that have been verified by the epistemic traditions of a community of learners.

The vision described in the *National Science Education Standards* (NRC, 1996) is of science teaching that engages all students in a quest for science literacy involving the abilities and habits-of-mind to construct understanding of the big ideas and unifying concepts of science and the communications to share with and persuade other people about these ideas (Ford, Yore, & Anthony, 1997). The science teaching standards envision changes in emphasis (NRC, 1996, p. 52):

Less Emphasis on	**More Emphasis on**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes

Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

When these changing emphases in teaching (children's attributes, rigidity of curriculum, relevant learning outcomes, active quest, alternative assessment, locus of control, and collaboration) are considered in the context of science and technology standards (science as inquiry and technology as design) and the epistemology described by the nature of scientific knowledge standards ("Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for best possible explanations about the natural world"), it becomes apparent that an interactive-constructivist perspective is supported by the *National Science Education Standards* (NRC, 1996, p. 201).

Treatment

At the beginning of the Science PALs Project, the Iowa City Community School District had an extensive hands-on, kit-based elementary school science curriculum in place. This kit-based curriculum was supported by a district science coordinator and a material distribution center. The kits contained exemplary National Science Foundation (NSF) supported materials, such as FOSS (Full Option Science System), NSRC/STC (National Science Resource Center/Science and Technology for Children), and the INSIGHTS series (Educational Development Center). The kits were delivered to the teacher on a rotating basis with minimal professional development focused mainly on mechanics and activity deployment. While the students enjoyed the kits and curriculum, there was a strong sense among the teachers that students were not developing meaningful science understandings from the experience. A primary reason for this belief was that the typical elementary school teacher in the district had little understanding of the science concepts the kits explored and was uncomfortable teaching science. It was determined that, in order for teachers to become more effective, a comprehensive professional development program to increase science content knowledge and science content-pedagogical knowledge, to enrich the cross-curricular connections of the science units, and to promote meaningful parental involvement was needed.

The first year (1994-95) of the Science PALs Project began with 16 elementary school teachers designated as science advocates — one from each elementary school in the district. These teachers were selected in part for their willingness to serve as science leaders in their schools as well as their interest in participating in the teacher enhancement project. Around these common attributes, the science advocates had diverse demographics, teaching experiences, and academic backgrounds (Henriques, 1997).

The science advocates began the project by attending a special, problem-centered summer workshop similar to the Focus on Children's Ideas in Science project (FOCIS) (Shymansky, Woodworth, Norman, Dunkhase, Matthews, & Liu, 1993). The FOCIS project utilized middle school science teachers' interest in children's misconceptions and their sincere desire to promote conceptual change in their students as an authentic problem focus for the summer workshop and multiyear collaboration with a science content mentor. The focus on children's ideas served as the "straw man" in the FOCIS project, since enhancement of the teachers' science content knowledge and content-pedagogical knowledge were the actual goals of the project. The FOCIS project was effective in achieving meaningful science and science pedagogical learning among the middle school teachers on science topics of their choice.

The Science PALs workshop was designed to help participants explore selected curriculum units (NSF-supported versions), and activities using students' ideas again as the "straw man". The workshop matched science content consultants with small groups of science advocates to explore the science concepts in specific units and to promote interactive-constructivist teaching strategies among the teachers. The Science PALs activities attempted "to create optimal, collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers" (NRC, 1996, p. 58). In the workshop and the ensuing school year inservice sessions, various strategies were employed to have the science advocates articulate their alternative frameworks for the science concepts related to the school district's science units, and additional extension activities to challenge these understandings were implemented. The ultimate objective was to address the teachers' personal misconceptions and have them rethink their understandings to develop more accurate scientific conceptions critical to teaching the unit. These science advocates then supplemented the specific FOSS, INSIGHTS, and NSRC units with understandings of the science reforms, misconception literature, additional science activities, children's literature, and interdisciplinary connections to produce teacher resource binders (TRBs) for each science unit.

They field-tested the enriched units (field-test versions) in their own classrooms in the fall and attended three one-day workshops during and after teaching the units. The field-test experiences were shared with colleagues and science content consultants to further clarify science understandings and explore other activities to challenge additional student misconceptions they had uncovered while teaching the unit. These insights were used to revise the TRBs for each science unit (final version) and to develop home science activity bags. The activity bags consisted of a children's literature selection related to the central science topic of the unit, simple science equipment, and a parent interview and activity guide. The activity bags were used by parents to assess their children's prior science conceptions and to provide this information to their children's teachers. Parents and children read the story together and explored various science challenges in the story as they occurred, using the activity guide and equipment provided in the activity bags. The feedback from parents was used to make adjustments to the science instruction that more accurately reflected their students' prior knowledge. Parent orientation meetings were developed to introduce parents to the Science PALs project and activity bags. A Science PALs project newsletter was published to keep the community informed about the project's progress and to maintain contact with students' families.

The cascading leadership design of Science PALs involves a progression of participating teachers and an evolution of their specific leadership roles. April 1994-April 1995 focused on recruiting and working with the 16 science advocates. Fourteen of these original advocates remained active in the project during the 1995-96 cycle. Thirteen of the original advocates continue to serve in the advocate capacity, while one is active in the project but no longer as an advocate and two have left the school district. April 1995-May 1996 activities focused on recruiting and working with 24 lead teachers to complement and share leadership responsibilities with the advocates in a school. Eighteen of the original lead teachers remained active as of December 1996; four are still affiliated with the project but are not actively teaching Science

PALs units during the 1996-97 school year and two have left the project. May-December 1996 activities focused on 37 additional teachers recruited as Year 3 (1996-97) cohort teachers to increase the cadre of Science PALs teachers in each school. One hundred forty teachers were recruited as the Year 4 (1997-98) cohort, but these teachers are not considered as part of this study.

The summer workshop with follow-up inservice cycle was repeated in subsequent years with approximately 40 teachers in the second year, 80 teachers in the third, and 140 teachers in the fourth year (Table 2). These numbers represent about 70% of the elementary teachers in the school district and about 90% of those that taught science on a regular basis. The cascading leadership model used meant that the advocates and lead teachers progressively assumed greater responsibility for the summer workshop, professional development activities, and science decisions.

One professional development activity worthy of specific note is the collaborative development of the Professional Development System (PDS). This activity was critical in defining the science teaching model associated with the Science PALs project. Science advocates, project staff, and external consultants progressively refined the fundamental dimensions of the project (planning, implementation, leadership), the artifacts (points of evidence) used to inform each dimension, and the four categorical examples for each dimension (Figure 1). This system provided the definition and catalyst for much of the inservice activities (Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen, & Yore, 1997). The categorical examples for each dimension served as analytical scoring rubrics for any point of evidence (lesson plans, field notes, videotapes, teacher journals, peer interactions, students' work, etc.) used to inform the dimension. The PDS was used to assess instructional planning artifacts,

Table 2
Science PALs Professional Development Activities

Dates (month, day, year)	Focus
5-18-94 & 5-19-94	2-day retreat of science advocates, project staff, and district administrators to clarify project goals and introduce critical features
6-10-94 to 7-9-94	Select and explore science units: Light and Shadow (1-2), Floating and Sinking (3-4), and Experiments with Plants (5-6)
8-16-94	Share unit plans and organize implementation
9-20-94	Clarify Science PALs model and constructivism
10-17-94	Cross-curricular connections and assessment
11-29-94	Share implementation results and start on spring units: Growing Things (1-2), Earth Materials (3-4), Magnets and Motors (5-6), and Optics (5-6)
12-16-94	Continue work on spring units
1-24-95	Continue work on spring units and discuss teacher portfolios
1-31-95	Initiate scoring rubric for artifacts—Professional Development System (PDS)
2-28-95	Discuss PDS and literature component
4-18-95	Continue work on spring unit and analyze stories
5-11-95	Introduce lead teachers and establish focus for summer workshop
5-18-95 & 5-19-95	Multiple intelligences, planned change, and reflections on year 1
6-12-95 to 6-23-95	Revise fall and spring units (all but Optics) and develop new units: Balls and Ramps (1), Life Cycle of Butterflies (2), Lifting Heavy Things (3), Crawling Creatures (4), and Levers and Pulleys (5)
9-25-95 & 9-26-95	Parent components: Activity bags and orientation meetings
10-16-95 & 10-17-95	Language Arts connections and continue work on new science units
12-4-95 & 12-5-95	Alternative assessment
2-13-96	Follow-up on Parent Orientation Guide and assessment ideas
3-12-96	Children's literature and science
4-22-96	Technology applications in science
5-19-96 & 5-20-96	Science advocates' retreat—Leadership responsibilities
6-10-96 to 6-19-96	Introduce 65 new teachers and develop new science units: Living Things (1), Pebbles, Sand and Dirt (1), Habitats (2), Water (3), and Microworlds (5)
9-23-96 & 9-24-96	National Science Education Standards
10-16-96	Iowa State Science Teachers Conference
10-24-96 & 10-25-96	Statewide Dissemination Conference

Figure 1
Science PALs Professional Development System

	POINTS OF EVIDENCE						LEVEL
	Lesson Material	Participant Observations	Lesson Video Tapes	Teacher Journals	Other Interactions	Classroom Documents (student work, etc.)	
Organizes Instruction							
Goals							
Materials							
Strategies							
Time							
Connection							
Evaluation							
Resources							
Reflective Planning							
Science Component							
Implements Instruction							
Student Differences							
Student Understanding							
Students as Self-Directed Learners							
Parent Involvement							
Reflective Teaching							
Science Component							
Time							
Leadership							
Communications							
Networking							
Attitudes							
Mentoring							

examples of classroom teaching, and leadership evidence on a 4-point scale (1 = low-level of Science PALs to 4 = high-level of Science PALs). The "student differences" dimension was evaluated according to the following ordinal categories (traditional to constructivist):

1. The teacher demonstrates a lack of interest in understanding why it is important to become familiar with students' backgrounds or misuses information such that there is interference with effective high-quality learning.
2. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds but does not use this information to enhance the quality of learning for all students.
3. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds and uses this information to enhance the quality of learning for some students.
4. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds and uses this information to enhance the quality of the learning experiences for all students. (Shymansky, et al., 1997, p. 37)

Collectively, the level 4 exemplars for the 9 planning dimensions, the 7 teaching dimensions, and the 4 leadership dimensions describe the prototypical Science PALs teacher (Henriques, 1997).

The Prototypical Science PALs Teacher

The prototypical Science PALs teacher is one who has a working knowledge about inquiry, the nature of science, and science topics in elementary school science. The teacher's content knowledge is married with age-appropriate and topic-specific pedagogical knowledge (content-pedagogical knowledge) that informs instructional planning, classroom teaching, and assessment. "Learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at the individual level" (Driver, et al., 1994, p. 6). Science PALs teachers, as more experienced members of the scientific learning community, collaborate with the less experienced members (students, others teachers) to seek problems, ask questions, set tasks, structure experiences, and scaffold performances such that the less experienced persons can internalize and assume control of the processes. Science PALs teachers, as interlocutor, constantly seek to understand what the students know; to support, stimulate, question, and monitor conceptual growth and changes; and to provide just-in-time expertise. The interlocutor role involves a balancing act of being a co-investigator at times and a mentor who demonstrates, guides, and directs at other times. They are encouraged to be spontaneous, flexible, and anticipate learners' interests, questions, and problems. They use holistic teaching strategies that emphasize contextual learning and well-defined concept goals. They plan interactions with literature, activities, and prior experiences (including misconceptions) in a sociocultural context in which learners are encouraged to talk science, share alternative interpretations, and negotiate clarity. They focus on the value of children's ideas and how to utilize those ideas to plan, modify, and design concrete experiences to help children consolidate and integrate new ideas with prior knowledge structures. They involve parents in assessing their children's science ideas, promoting science education and supporting classroom learning as an instructional resource. Finally, the prototypical Science PALs teacher is a professional who is responsible for their continued growth as a teacher of children and science.

Design

The research questions were addressed using a multiple-source survey approach. Students from classrooms with teachers having Science PALs project experience and students from classrooms with teachers having no project experience were given surveys constructed expressly for this project to assess their perceptions of science teaching and attitudes toward science learning (Dunkhase, Hand, Shymansky, & Yore, 1997). Parents' and teachers' comments about specific features of Science PALs were collected with a variety of questionnaires and informal surveys. Analyses of instructional artifacts (TRBs) were used to document changes in planning for science teaching.

Instruments

Students' Perceptions of Science Teaching and Attitudes toward Science Learning

Students' perceptions of science teaching was composed of: (a) view of constructivist approach, (b) parents' interest, (c) teacher's use of children's literature in science, and (d) relevance of science. Students' attitudes toward science learning was composed of: (a) attitudes towards school science, (b) self confidence, (c) nature of science, and (d) science careers. These eight factors were established using factor analyses techniques. Original items were scored as disagree (1), do not know (2), and 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 37 items, a Grade 3-4 survey of 57 items, and a Grade 5-6 survey of 72 items. Table 3 provides the number of items in each factor and the internal consistency based on data collected for Grades 1-2 (N = 831), 3-4 (N = 722), and 5-6 (N = 999) in the spring of 1996. Internal consistencies ranged from marginal (0.45-0.60) on 9 data sets to reasonable (0.61-0.88) on 21 data sets. Generally, the instrument has reasonable validity and reliability for exploratory research, but further verification is planned to explore construct and predictive validities (Yore, Shymansky, Henriques, Hand, Dunkhase, & Lewis, 1998).

Parents' Comments

Parental perceptions were assessed using an 8-item questionnaire included by the 16 science advocates in the activity bags sent home. The 5-point Likert items were designed to assess parents' strong disagreement (1) to strong agreement (5) on the value of the activity bags

Table 3
Internal Consistencies of and Number of Items in the Likert Item Factors used to Assess Students' Perceptions and Attitudes

Scale and Factors	Grade-Level Groupings 1-2	3-4	5-6
Perceptions of Science Teaching	0.83(20)	0.85(34)	0.88(35)
Constructivist Approach	0.67(8)	0.81(21)	0.85(17)
Parental Interest	0.70(6)	0.68(5)	0.72(7)
Use of Literature in Science	0.52(3)	0.49(3)	0.61(5)
Relevance of Science	0.50(3)	0.56(5)	0.74(6)
Attitudes toward Science Learning	0.71(17)	0.79(23)	0.84(37)
Attitudes toward School Science	0.58(6)	0.74(5)	0.81(21)
Self-concept	0.54(3)	0.64(6)	0.63(6)
Nature of Science	0.60(4)	0.53(9)	0.51(7)
Careers in Science	0.68(4)	0.72(3)	0.79(4)

and related activities, parent orientation meetings, need for additional information, and the transfer to other content areas. One hundred eighty-six completed questionnaires were returned (46.5% response rate). The respondents indicated that 66% had attended a Science PALs orientation meeting.

Teachers' Comments

Teachers' comments were obtained by informal surveys as part of the 1995 and 1996 professional development activities and program evaluations. The comments were collected on specific features of an inservice activity at the end of each activity and about general features of Science PALs at retreats and at the end of the summer workshops. These comments were recorded retaining general category of the respondent (advocate, lead teacher, year 3 teacher) and date.

Analysis of Instructional Artifacts

Teacher Resource Binders (TRBs) developed by the teachers were evaluated on the 9 organizing instruction dimensions of the PDS. The three versions (NSF-supported version, field-test version, and final version) of the 1995 TRBs were evaluated to determine the impact of inservice activities and field testing. The final versions of the 1996 TRBs were evaluated to determine the impact of the increased science advocates' leadership and of the 1995-96 Science PALs activities on the curriculum development component. Collectively, the TRBs provide evidence about Science PALs teachers' planning for science teaching.

Data Analyses

The primary research focus of this study was to explore the influence of Science PALs teacher enhancement activities on students' perceptions of science teaching and attitudes toward science learning. The analyses provide descriptive data for students in classrooms in which the teachers were or were not involved in the Science PALs project. Since the perceptions and attitudes were assessed by different but similar items, the average perception and attitude for each factor was used to allow cross-grade comparisons. Differences in perceptions and attitudes were tested using a 3-way Analyses of Variance (ANOVA). Survey data and comments from parents and teachers were summarized using descriptive and qualitative techniques in an attempt to detect strengths and weaknesses and to establish general patterns. Percentage responses for each category of agreement/disagreement were calculated, and common patterns of comments were determined using constant comparison and expressed as assertions. The TRBs data were compared to the desired goals of the PDS (1 denotes traditional/low Science PALs alignment and 4 denotes constructivist/high Science PALs alignment).

Results

Students' Perceptions and Attitudes

Dunkhase, et al. (1997) provided a comprehensive report of the descriptive statistics and ANOVA results, while the general results are reported here. The treatment effects (Table 4) generally favored the Science PALs teachers over the non-Science PALs teachers for perceptions of science teaching (except "parental involvement") and for attitudes toward science learning (except "attitude toward school science" and "careers in science"). The Science PALs approach appeared to be more influential at the Grades 3-4 and 5-6 levels than at the Grades 1-2 level, but only the treatment effect for "using literature in science" was significant ($p \leq 0.05$). The treatment by grade level interaction for "using literature in science" was significant. There were no significant treatment by gender interactions, but females' perceptions were more positive than males' perceptions about science teaching while males' attitudes were more positive than females' attitudes toward science learning within the Science PALs treatment. These results appear to indicate that the strategies utilized in Science PALs are similar to those used by most Grades 1-2 teachers, (i.e., using literature-based instruction, listening to children's ideas, using small-groups discussion, promoting self-directed inquiries, etc.) but different from the standard approaches in Grades 3-6.

The impact of the Science PALs approach may not be fully realized until the compound effects are explored as children have multiple exposures to the treatment over their elementary school years. Furthermore, the Science PALs approach involves the common basics of constructivism and the unique features of the interactive-constructivist approach — using literature in science, parental involvement, shared control, critically positioned teacher

Table 4
Means and Standard Deviations of Science PALs and Non-Science PALs Students' Perceptions and Attitudes

Dimensions	Science PALs X SD	Non-Science PALs X SD
Perceptions of Science Teaching	2.44, 0.33	2.43, 0.34
Constructivist Approach	2.62, 0.35	2.61, 0.36
Parental Interest	2.15, 0.53	2.16, 0.56
Use of Literature in Science	2.31, 0.66	2.24, 0.66
Relevance of Science	2.50, 0.54	2.38, 0.60
Attitudes toward Science Learning	2.40, 0.33	2.38, 0.34
Attitude toward School Science	2.32, 0.53	2.37, 0.54
Self-concept	2.62, 0.44	2.59, 0.45
Nature of Science	2.40, 0.56	2.23, 0.62
Careers in Science	2.13, 0.65	2.16, 0.66

interventions, etc. It is likely that these unique features will become more influential with repeated teacher use.

Parents' Responses

A survey of parent participants in the Science PALs project revealed overwhelming support (>70% agree to strongly agree) from the 186 respondents. Table 5 summarizes the respondents' belief 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. The response patterns were consistent except for the usefulness of parent orientation meetings (likely caused by the fact that 34% of the respondents had not attended the scheduled meetings). Written comments indicated that parents had concerns about time requirements, advance notice, and lead time; that activity bags were more effective with younger children; that some literature selections were not explicitly connected to science ideas; and

Table 5
Parent Participation Survey

	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%

clarity and value of parent directions and training sessions. Several parents expressed a willingness to help develop activity bags, orient new parents, and participate in workshops for new teachers.

Parental involvement and the activity bags have been the most positive aspects of the Science PALs project. These components have been significant public relations successes, but their actual educational impact has not been fully documented. The feedback provided by parents about their children's prior knowledge at best allows teachers to make adjustments to their planning due to timing. Students' perceptions of their parents' interest in Science PALs classrooms is less positive than for students not involved in Science PALs classrooms at the Grades 1-2 level, while students for Grades 3-6 perceive their parents' interest more positively.

Teachers' Comments

Teachers' comments were examined using key ideas and constant comparison techniques to establish assertions. Source (advocate, lead teacher, year 3 teacher), date, and professional development activity's purpose (unit development, leadership, parental involvement, etc.) were used to help cluster comments and analyze the comments' message. Five assertions were detected, which are provided with some of the supporting teacher comments.

Assertion 1: Understanding the science concepts embedded in and the practical reform ideas related to selected science units in an authentic classroom-centered context, focusing on children's ideas and developing TRBs, allowed teachers to construct their own content-pedagogical knowledge about specific science topics.

Science Content and Reform Ideas

An especially effective part of the school year inservices was to be able to learn new science.

The most beneficial part of the inservice was working through the lessons and science concepts; developing/working on concept maps; sharing ideas/activities with peers.

*Especially effective part of the summer inservice was finding **Benchmarks** and key concepts. You know what and why you are doing the activities with the students.*

Children's Ideas and TRBs

By focusing on the science concepts I can better focus on the student ideas and understand how they relate to the KEY concepts of the unit.

The focus on student thinking encourages concept development in language that kids generate as they investigate rather than just receive information from the teacher.

Addressing student preconceptions starts the unit at the students' developmental level and their ideas are direct starting points for unit activities.

Starting with what the student already knows allows the student to build a more sophisticated understanding of the concept.

I feel very strongly about having the opportunity to learn more science and also having the opportunity to change and improve units..

The most beneficial part of the inservice was learning the science content and fixing the parts of the unit that didn't work before.

The TRBs are an excellent resource to refer back to and pull from. However, it will take me a few times through the unit to be able to utilize all it offers and to make good "pick and choose" decisions.

The TRBs will be useful to a new teacher but this will require that the teacher take more initiative since he/she won't have created it.

Clearly the teachers' comments assign priority to their concerns about content knowledge and practicality. Elementary teachers were comfortable learning science content since it was linked to real issues regarding their teaching responsibility and their students. Children's misconceptions and improving the science units addressed these concerns. They also realized that the process was likely as important as the product.

Assertion 2: Planning science instruction involved focusing on a few important concepts, identifying cross-curricular connections and developing multiple forms of assessment.

The focus on the "big ideas" encourages students to mental map several experiences that are hooked to one concept.

It was very beneficial to go through each activity and write ways of connecting them to other areas.

Having time to collaborate with colleagues and to have specialists available to answer science questions was very helpful. Also, having time to go through the unit activities and to discuss ideas and extensions to make it most meaningful for students.

I think that the task of creating an assessment will help me focus on specific concepts and I will assess throughout the unit instead of just assessing at the end of the unit. This should improve my teaching – it definitely raised my awareness.

My understanding of assessment has been quite broadened. I will look at methods of assessing students and evaluate these more critically.

Students can demonstrate their knowledge in creative, hands-on tests and need not be restricted to paper-pencil tests.

Teachers' comments regarding planning demonstrate concern for some of the content and assessment standards (NRC, 1996). Some teachers recognize the need to be focused and to provide in-depth instruction, relevant applications, and compatible assessments. The cross-curricular aspects of planning appear to be a priority of the self-contained elementary school classroom culture and a feature of generalist elementary teachers.

Assertion 3: Using children's literature as a springboard into science teachings required selection that reflects potential challenges, inquiry as well as content, and impact on students and thoughtful planning and guidance.

Selection

There are good picture books for the 5/6 level. They're not always written for inquiry, length is a problem.

We had evaluated books for science only. Now we (as a result of inservice) will look for skills and processes.

We should reserve judgment before dismissing a piece of literature. It may be more useful than immediately evident.

Planning and Guidance

Literature is great for increasing student interest and motivation.

It is important not to overemphasize the literature.

I don't use literature for a rigid 50-minute science period.

Literature provides examples of explaining science in narrative.

When they respond to literature, kids are reacting to the story, not the science.

If we give our students literature and let them immerse themselves in it, we need to give them time to investigate their questions.

Teachers recognize that the purposes of the children's literature are to challenge prior conceptions and to motivate students; it is not necessarily a source of information. Selection is critical in that the literature has to resonate with the children. Furthermore, when the literature is used in the activity bags, parents must be informed of the anticipated connection since it might be based on children's interest, inquiry skills, or other subtle features.

Assertion 4: Parents were perceived by teachers as parents and resources, and the Science PALs activity bags as quality parent-child experiences.

[Activity bags are effective] at keeping parents involved in the curriculum.

[Parent involvement is especially effective] as an opportunity for parent and child to interact academically.

[Activity bags provide] an opportunity for parent and teacher interaction and to promote science with parents.

Parent involvement is effective for discussing student understanding prior to the start of the unit and previewing kids' thinking.

Teachers' comments suggest that they value parents as partners. Clearly, the comments indicate that parental support increased when parents understood what the science instruction was trying to do, how difficult it was, and how they could be meaningfully involved. The Science PALs' parent component was viewed positively by teachers and parents, and it establishes a foundation for continued involvement in their children's later schooling (Hoover-Dempsey & Sandler, 1997).

<u>Assertion 5</u>: Science advocates defined their leadership roles as being an exemplary model of science teaching and as a consultant to help enhance other teachers' science knowledge and classroom practices.

<u>Exemplary Model</u>

One of my roles as an Advocate is to become more knowledgeable of constructivist structure and practice.

Part of my role as an Advocate is to focus on the identification of preconceptions of my students and work on them (ideas) during activities.

To develop a greater understanding of the science in the units I teach.

To learn more about the big concepts in our science units.

Part of my role as an Advocate is to develop appropriate assessment tools to assess student growth in science literacy.

No longer do I measure "success" as a whole class activity or achievement; but rather daily/weekly formative assessment to show current understanding, student discussion topics, problems, etc.

Consultant

Part of my role as an Advocate is to work with science teachers at other grade levels to enhance science teaching in our building.

Part of my role as an Advocate is to better able to support more individuals in the building. This year was spent trying to get more discussions going about science and children.

To continue to work with my building team to develop an all-school interest in science among all students.

To grow more in my own understanding of science concepts, issues, and reform recommendations – then to be able to help my staff in this area.

Although little explicit effort was devoted to developing leadership roles and skills in the first two years, science advocates appeared to develop an operational definition of their responsibilities from the actions of the project staff and science consultants. They believed that leadership by example would have the greatest impact on their fellow elementary teachers. Therefore, they planned to develop the classroom expertise in interactive-constructivist approaches, science reform, children's ideas, and assessment. Furthermore, once this expertise was realized, they would direct their leadership efforts to helping other teachers enhance their science teaching.

Teacher Resource Binders

The teacher resource binders (TRBs) represent a point-of-evidence for content-pedagogical knowledge. Teachers utilized their content insights and instructional insights on specific topics to revise, elaborate, and enhance the NSF-supported science units. The resulting effectiveness of the Science PALs project was indirectly assessed by evaluating the TRBs against predetermined planning attributes referenced to the "desired image" of teaching described by the project goals and specified in the PDS (1 denotes low Science PALs alignment and 4 denotes high Science PALs alignment).

The three versions (NSF-supported, field test, and final) of the target science units for the 1994-95 phase were assessed according to the 9 organizes instructions dimensions of the PDS. The original NSF-funded versions served as the basic reference frame, while the field test versions served as examples of the 1994 summer workshops' effectiveness, and the final versions served as examples of the first complete professional development cycle's effectiveness. The three versions of *Growing Things* (Grade 2), *Floating and Sinking* (Grade 4), and *Experiments with Plants* (Grade 6) were evaluated.

Growth in the direction of the Science PALs "desired image" became progressively more evident across the versions. The original versions were evaluated as 0-2 on the 4-point scale, while the final versions were evaluated as 3-4 on the same scale. Only the resources dimension did not reach acceptable levels in the final versions. The following trends were found:

1. Connections to the misconception literature are apparent in the later versions but these ideas do not appear to have influenced lesson design and actual instructional recommendations of the original units. The final versions provide additional activities but

do not explicitly provide teachers with suggestions for addressing predictable misconceptions.

2. Connections to the science reform documents are apparent in the final versions and frequently are illustrated in activities, but critical ideas do not seem to be assigned greatest influence. Key concepts are identified but are not expanded or connected to other related or generalized cases.

3. All versions contain evidence of a strong hands-on experience, but the final versions are weak in specific strategies for scaffolding the construction of understanding.

4. As judged from the ultimate user's perspective of a generalist classroom teacher, the unit modifications to date still have work to be done. Comprehensive lesson plans that illustrate the Science PALs desired image should be provided.

Five new science units were identified for development during the 1996 summer workshop: *Pebbles, Sand & Silt* (Grade 1), *Living Things* (Grade 1), *Habitats* (Grade 2), *Water* (Grade 3), *Microworlds* (Grade 5). These five units were again evaluated using the PDS organizing instruction dimensions, and scoring rubrics. The results of the 1995 and 1996 evaluations are provided in Table 6.

The TRBs provided evidence that Science PALs teachers were using the content standards (NRC, 1996). The unit goals, activities, and resources represent a balance between the inquiry, physical science, life science, earth and space science, technology, personal perspective and society, and nature of science. The hands-on inquiry activities are question-initiated. Students conduct investigations, gather data, use tools to extend their senses, and share their results and findings to other students.

Table 6
Evaluation of 1995 and 1996 TRBs based on 2 or 3 Evaluators' Judgments

Dimension	1995 Final TRBs			1996 Final TRBs				
	Growing Things	Floating and Sinking	Experi-menting with Plants	Living Things	Habitats	Pebbles, Sand & Silt	Water	Micro-world
Goals	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
Materials	3.5	3.0	3.0	3.5	3.5	3.5	3.5	3.5
Strategies	3.0	3.0	2.5	3.5	3.0	3.5	3.5	3.5
Time	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Connections	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0
Evaluation	3.0	3.0	3.0	4.0	3.0	4.0	4.0	4.0
Resources	2.0	0.0	1.0	3.0	3.5	3.5	3.5	3.5
Reflective Planning	3.0	3.0	3.0	3.5	3.5	3.5	3.5	3.5
Science Component	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5

The 1996 TRBs also provided evidence of marked improvement over the 1995 TRBs. The Science PALs teachers were incorporating a larger variety of materials and encouraging students to add different materials to expand their explorations and to aid in the formulation of reasonable explanations. External human resources provided another means to check and confirm their results and explanations.

The 1996 TRBs identified explicitly a variety of strategies to engage, explore, and consolidate students' ideas. Students used the coordinated skills of mathematics and science to collect and manipulate data from observations, draw conclusions, share these in pair/share groups, and predict what they will find in new situations.

Cross-curricular connections made to mathematics, arts, social studies, and language arts are also evident in the TRBs. Students explored examples as to why people derive pleasure from science (nature of science) when they experience art and music. Curricular connections with social studies, geography, mathematics, literature, writing, research skills, or reading, and real-world connections to home, family, or local community can be found in the 1996 units.

Reflecting planning is also evidenced in the TRBs, as teachers discussed lesson goals, salient science concepts, and common students ideas from the *Benchmarks for Science Literary* (AAAS, 1993) and *National Science Education Standards* (NRC, 1996). Teachers reflected on integrated resources, activity bags and story analyses, and systematic data collection.

Reflections

The Science PALs project has successfully improved teachers' content-pedagogical knowledge about specific science units, pedagogical skills, and attitudes toward teaching science; increased parental involvement and support of elementary school science; and developed a cadre of leaders and a district-wide infrastructure to support elementary school science. The analyses of the TRBs and teachers' comments consistently indicate that teachers have improved understanding of science concepts embedded in the selected science units, children's misconceptions about these topics, the science reform and science education standards, and the potential of specific teaching strategies, assessment techniques, and cross-curricular connections. The Science PALs teachers' implementation of these planning ideas into actual classroom teaching and assessment practices are not fully documented. The overwhelming belief that more hands-on activities as the singular solution to the science literacy issue appears to be under question. The importance of certain reflective activities designed to get students to consolidate their new ideas and prior knowledge networks, to monitor and regulate learning, and to seek real-world applications has increased. Science PALs teachers are using children's ideas as the focus for their questions and activities and using children's incomplete and incorrect responses to guide discussion and group interactions. They are refocusing their assessment on understanding and knowledge production rather than recall of shallow ideas. Science PALs teachers are talking about science and are demonstrating a more relaxed and positive disposition toward teaching science.

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 Science PALs Project has demonstrated that family involvement can be achieved by designing meaningful, time-efficient, and worthwhile take-home science activities. The activity bags provide a natural, safe, inquiry 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 opportunities as "work"; rather they truly enjoy this context as an opportunity to demonstrate their knowledge and skills. Teachers also view these opportunities as positive chances to establish working relationships, rapport, and lines of communication with parents that might be utilized to address much more difficult tasks at a later time. These features are in agreement with the National Parent and Teacher Association recently released handbook of standards for parent involvement in children's education (NSTA, 1997):

- 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.

Incorporating parents as partners to share cultural insights, customs, and traditions, and to enrich and connect school learning and family life experiences will ensure relevance. Developing effective interfaces between schools and families is critical for minority, non-English speaking parents.

Science PALs has produced a group of science advocates and lead teachers who have demonstrated leadership for the 16 elementary schools in Iowa City. They have collaborated with their colleagues on science education projects and professional development activities. They have presented workshops at regional science teachers conferences and promoted the needs of elementary school science reform within the school system and community. Likewise, Science

PALs has improved the kit distribution and maintenance facility. The school district has redesigned and staffed a resource center to support classroom teaching.

Science PALs successes are numerous, but effort needs to be given to the less successful aspects of the project. Likewise, steps need to be taken to maintain and improve the inservice activities. Teachers suggested:

Greater focus on research trends in science education would be useful (or maybe just handouts). You guys know all this which means YOU understand why constructivism or assessment, etc. is critical. We don't always know that.

I look forward to inservices to continue to get regular infusions of focus and energy.

Some objectives were more valuable earlier and have become less so as I feel more competent to do them independently. The new participants need to go through the development process themselves.

*I feel this inservice was a valuable source for me. I feel confident about this unit and that all the **Benchmarks** and concepts will be met fully. I also feel there are wonderful connections made that will provide real-life learning.*

I always enjoy the collaborative work of small groups of teachers working together and the wealth of teaching ideas rendered in the process.

The opportunity to develop meaningful curriculum in a wonderful professional atmosphere and to talk with colleagues about the ideas, concepts, issues, and pedagogy that <u>really matters</u> in what we do with children made this worthwhile.

The Iowa City Community School District superintendent summarized the effects of Science PALs as "one of the most important and successful programs in our schools" (Grohe, 1996, p. 1). She suggested that the success is due to the power of partnerships – university and schools, parents and teachers, secondary science teachers and elementary teachers, interdisciplinary, school and real world. These partnerships are based on collaboration, respect, and trust where the agenda was jointly set by all groups involved (Dunkhase, 1996).

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STUDENTS' PERCEPTIONS OF SCIENCE TEACHING AND ATTITUDES TOWARD SCIENCE LEARNING AND TEACHERS' SELF-REPORT OF USING CHILDREN'S IDEAS, APPLICATIONS OF SCIENCE, AND USE OF PRINT RESOURCES AS INDICATORS OF INTERACTIVE-CONSTRUCTIVIST TEACHING IN ELEMENTARY SCHOOLS

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Introduction

This study took place within the context of the Science: Parents, Activities, and Literature (Science PALs) Project. Science PALs was a four-year systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and the Iowa City Community School District and funded by the National Science Foundation (NSF) and the Howard Hughes Medical Foundation. The overarching goal of the project was to move teachers towards an interactive-constructivist model of teaching and learning that assumes a middle-of-the-road interpretation of constructivism, where hands-on activities are used selectively and purposefully to challenge students' ideas, promote deep processing, and achieve conceptual change. This model differs from the extreme interpretations of social constructivism and radical constructivism. As many of the teachers in the project had little or no formal knowledge of interactive-constructivist principles, the project leaders sought to provide them with opportunities to examine these principles from the vantage points of learner and teacher.

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Problem

A central problem with documenting any educational innovation is selecting or developing instruments that fairly represent the theoretical innovation with valid and reliable measures. The Science PALs' version of interactive-constructivist science teaching and learning emphasized the shared roles of students, parents, and teachers regarding control, responsibilities, actions, and interactions. This perspective differs from traditional perspectives and other constructivist perspectives of science teaching and learning (Brooks & Brooks, 1993; Burry-Stock & Oxford, 1994; Yager, 1991). Traditional science instruction stresses absolute views of science, teacher control and structure, one-way communications and private mental activity, while many social constructivist perspectives stress post-modern views of science, group control and structure, two-way communications among the students directed at building consensus, and public mental activity. Therefore, it is necessary to use different documentation techniques and evaluation instruments (Searfoss & Enz, 1996). Common instruments may be used to document the basic features common among the perspectives, but additional instruments must be developed and used to document the unique features specific to any single perspective. Furthermore, it was decided that interactive-constructivist science instruction needed to be documented from a variety of perspectives of the stakeholders (teachers, students, parents, etc.) utilizing multiple methods and data sources (demographics, instructional artifacts, teacher self-reports, classroom teaching, student perceptions, parental comments, etc.). Within this problem space, the following research questions were addressed:

1. What are the internal consistencies and substantive, external, and structural validities of students' perceptions, teachers' self-reports, evaluations of videotaped classroom science teaching, and expert ratings?

2. Can students' perceptions and attitudes and teachers' self-reports be used as acceptable surrogate measures for videotaped interactive-constructivist science teaching?

Background

Science teaching, science learning, and science teacher education research has enjoyed increasing popularity in recent years with the publication of the National Research Council's *National Science Education Standards* (NRC, 1996), the *National Board for Professional Teaching Standards* (NBPTS, 1994), and the *Report of the National Commission on Teaching and America's Future* (Darling-Hammond, 1996). These documents reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on students' thinking, achievement, and science literacy. Furthermore, an analysis of the reform documents for language arts, mathematics, science, social studies, and technology revealed a common focus on "all" students, common learning outcomes of literacy and critical thinking, and common instructional intentions regarding constructivism and authentic assessment (Ford, Yore, & Anthony, 1997). Unfortunately, little attention has been given to developing concise, clear definitions of these innovations and how these desired reforms will be documented. This section attempts to clarify what interactive-constructivist science teaching involves, how it can be documented using established and new techniques, and how these new instruments can be verified.

Interactive-Constructivist Science Teaching in Elementary Schools

Constructivism, a historical view of learning that embraces much of the contemporary cognitive, sociocultural and linguistic theories, has provided a powerful foundation for addressing people's learning that behaviorism and cognitive development did not provide individually (Fosnot, 1996; Yager, 1991). Constructivism has encouraged educators to recognize the importance of ability, effort and prior performance, while also recognizing the potential influence of metacognitive awareness, self-regulation, misconceptions, sociocultural context, cultural beliefs, and interpretative frameworks. Unfortunately, the many interpretations of constructivism provide a "range of accounts of the processes by which knowledge construction takes place", but few insights into how teachers can facilitate such learning with compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). The individual interpretations have some common assumptions and important differences: world view, view of scientific knowledge, locus of mental activity, locus of structure/control, and discourse (Yore & Shymansky, 1997).

The interactive-constructivist model of learning utilizes an ecology metaphor to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence and privately integrated (assimilated or accommodated) into the person's knowledge network. Interactive-constructivist approaches differ from social constructivism (which utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are verified by social negotiations resulting in consensus and common understanding at the group level) and radical constructivism (which utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency). Interactive-constructivist science teaching promotes a hybrid view of the world in which science is people's attempt to search out, describe, and explain generalized patterns of events in the natural world and where these descriptions, explanations, and patterns are evaluated against evidence from nature. Constructing science understanding involves both public discussions to reveal and clarify alternatives and private reflections and reconciliation to integrate these new ideas into established knowledge networks. Interactive-constructivist science instruction utilizes shared control between the teacher and students and two-way communication among students and teachers. The interactive-constructivist approach has the following attributes:

- alignment among outcomes, instruction, resources, and assessment;
- outcomes of conceptual change, conceptual growth, metacognitive strategic learning;
- does not exclude just-in-time direct instruction embedded in a natural context of need;
- supports big ideas/unifying concepts and habits of mind needed to attain scientific literacy;
- requires students to gain ability to construct understanding, to think critically, to communicate their constructions, and to persuade others of their value or utility;
- encompasses guided inquiry, learning cycles, conceptual change, and generative approaches;
- and the teaching involves accessing, engaging, experiencing/exploring, justifying/rationalizing, consolidating/integrating old and new, and applying knowledge.

If constructivism, like inquiry in the 1960s science education reform, is not clearly defined and anchored to classroom practices, it will fail to enhance science teaching and learning. Realizing the need for a well-defined instructional model, Henriques (1997) defined a prototypical interactive-constructivist elementary science teacher as having:

> a working knowledge about inquiry, the nature of science, and science topics in elementary school science. This content knowledge is married with age-appropriate and topic-specific pedagogical knowledge (content-pedagogical knowledge) that informs instructional planning, classroom teaching, and

assessment. The interactive-constructivist teacher is spontaneous, flexible, and anticipates learners' interests, questions, and problems. This teacher is committed and reflective. The interactive-constructivist teacher teaches in a holistic, contextual manner with well-defined goals and cross-curricular connections. This teacher plans interactions with literature, activities, and prior experiences (includes misconceptions) in a supportive sociocultural context in which learners talk science, share alternative interpretations, and negotiate clarity. Children's ideas are assessed, valued, and utilized to plan, to modify, and to challenge concrete experiences; and the resulting new ideas are consolidated and integrated with prior knowledge structures and related to their daily lives. The interactive-constructivist teacher implements a variety of strategies to meaningfully involve parents in their children's science and in promoting science education. This teacher is a professional and leader responsible for professional development and an advocate for science in elementary schools.

Documentation of Interactive-Constructivist Science Teaching in Elementary Schools

Yager (1991) addressed the need for documenting constructivist science teaching by developing a self-check instrument consisting of 11 dipolar dimensions based on a science-technology-society (STS) grid. He identified a variety of sociocultural groupings and problem-based tasks, their anticipated responses and results, and the associated teaching strategies as the basis for his constructivist learning model. Yager stated the "extent to which a teacher allows students to construct their own meaning will vary for teachers, individual students, and particular classrooms" (p. 56). Close inspection of the self-check instrument revealed that the dipoles represented a traditional perspective and a social constructivist perspective consistent with a STS orientation. Brooks and Brooks (1993) provided a list of eight pedagogical features dealing with curriculum, learning, teaching, assessment, and instructional groupings to contrast traditional classrooms and constructivist classrooms. Their interpretation of constructivism also appears to emphasize a social constructivist perspective. Burry-Stock and Oxford (1994) developed a science teaching evaluation model utilizing an expert-novice approach based on "a constructivist, student-centered perspective" (p. 278). Inspection of the dimensions and exemplars suggested that the constructivist perspective favors slightly a post-modern interpretation of science instruction. Collectively, the review of the related practice and literature identified four potential ways of documenting science instruction in elementary schools: expert ratings, classroom observations, students' judgments, and teachers' self-reports.

Expert Ratings

Supervision of teachers and evaluation of teaching effectiveness have historically relied on the judgments of legally recognized experts, such as superintendents, principals, directors of instruction, and content area coordinators. They are required to provide judgments of a teacher's effectiveness based on their assessments of the teacher's planning, administrative responsibilities, classroom management, teaching strategies, assessment techniques, and other identified features believed related to effective instruction. The experts' judgments involve comparing their professional conceptions of teaching and their instructional expectations with actual classroom observations of the teacher's teaching, professional interactions with the teacher, and artifacts of the teacher's instruction. Occasionally, these judgments about science instruction were unreliable, and their validities were questioned because many of the legally identified experts lacked understanding of the desired teaching, the content area, the classroom context, and the associated types of evidence.

Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen, and Yore (1997) proposed the "professional development system" (PDS) to address these concerns about evaluating teaching effectiveness by identifying three important dimensions of instructional planning, classroom teaching, and leadership, and the associated points of evidence for each dimension. The PDS is based on the underlying assumptions of the interactive-constructivist perspective of science teaching, effective teaching (Dwyer, 1994; Shulman, 1986, 1990), and exemplary practices (Darling-Hammond, 1996). The PDS connects planning, science classroom practice, and leadership in elementary school to avoid the "tendency to ignore the substance of classroom life, the specific curriculum content and subject matter being studied" (Shulman, 1990, p. 53). Clearly judgments about elementary school science teaching effectiveness must reflect the culture of elementary schools, the context of the elementary classroom, and the unique features of the scientific enterprise.

In order to implement the PDS, definitions of quality within each dimension were developed in an iterative and collaborative manner — first relying largely on the literature. Second, conversations about proposed definitions of quality took place among the project staff, science advocates, and external consultants. The amended definitions resulting from these conversations were then re-evaluated against the research. Those definitions of quality that survived this process became the frame of reference for each performance standard. Based on experience and expertise in rating performance, confirmed by a growing literature in writing assessment in particular, the project staff elected to constrain each performance standard to four levels. The fourth, or highest level, is essentially the definition of quality for each dimension and collectively defines the desired prototype of an interactive-constructivist teacher (Henriques, 1997).

Classroom Observations

Classroom observation systems like interaction analysis, science classroom assessment procedures, and macroanalysis techniques have been used to systematically observe and code classroom actions and communications. Each of these early systems was based on specific assumptions about teaching, such as verbal interactions, inquiry learning, or emerging strategies. Furthermore, the limitations of systems were transparent when used to document teaching that did not agree with the underlying assumptions of the instrument, such as using interaction analysis techniques to document hands-on inquiry science teaching.

The Expert Science Teaching Educational Evaluation Model (ESTEEM) is based on student-centered learning and flexible classroom structures and is designed to assess expert science teaching within social constructivist classrooms (Burry-Stock & Oxford, 1994). The social constructivism perspective is somewhat implied by the fact that a high score is achieved when students interact with each other, discuss and test their own ideas, seek consensus, and share these ideas with the teacher and by its use to document STS teaching. Most examples of students' activity is public with little evidence of the private reflection required by an interactive-constructivist approach. The constructs that each learner makes are influenced by interactions with others and cannot be separated from the sociocultural context.

Burry-Stock's (1995) Science Classroom Observation Rubric for ESTEEM has four major categories related to teaching: (a) facilitating the learning process from a constructivist perspective, (b) content-specific pedagogy (pedagogy related to students' prior understanding and understanding of targeted concepts), (c) context-specific pedagogy (adjustments in strategies based on interactions with the students) and (d) content knowledge (knowledge of subject matter). Three to six dimensions inform each category. Each dimension has five levels of teacher performance ranging from novice (1) to expert (5) and are anchored in low inference performance standards, which increases reliability and informs validity. The rubrics contain exemplars about students' behaviors and actions in addition to the teacher's behaviors and actions. The maximum score that can be earned by a teacher on the Classroom Observation Rubric is 90.

The ESTEEM rubrics were reviewed by experts in the science education community. The external reviews supported the instrument's face validity. The rubrics' validity and reliability were explored using a group of expert teachers' science classes. Forty-six Grade 4-8 teachers from seven states were selected to participate in the study. Burry-Stock and Oxford (1994) reported that the median for this group was 61, while the 25th percentile was 50 and the 75th percentile was 66. The means, standard deviations, and reliabilities were reported for the total instrument (57.30, 16.69, 0.91), facilitating learning processes (15.33, 4.81, 0.84), content-specific pedagogy (19.15, 5.12, 0.89), contextual knowledge (9.28, 2.70, 0.87), and content knowledge (13.54, 3.72, 0.80) categories.

Analysis of the ESTEEM rubrics indicated that two categories (context-specific pedagogy and content knowledge) matched the interactive-constructivist model while the other two categories (facilitating the learning process from a constructivist perspective and content-specific pedagogy) differed slightly from the interactive-constructivist model. This alignment and the psychometrics for the ESTEEM rubrics justified its use in verifying the interactive-constructivist theory and related instruments.

Students as Judges of Teaching Effectiveness

The use of students' perceptions of the constructivist teaching/learning environment to measure effectiveness is not new. Fraser (1989) reviewed 60 studies of student perceptions of constructivist teaching environments. He argued that there were several advantages to using student perceptual measures rather than observational measures, including student perceptions are based on many lessons or classes, while peer/expert observations are based on limited numbers of observations; the information obtained is the pooled judgment of all the students as opposed to the single view of an observer; and the student perception is based on the teacher's real behavior and therefore more important than inferred behavior based on observer judgment. Wilkinson (1989, p. 123) suggested that analysis of "student ratings of their teachers appeared to be as reliable as those undertaken by more experienced raters". Wagenaar (1995, p. 68) argued that students "are best at detecting consumers' perspectives on those teaching behaviors most noticeable to students".

Much of the recent work on student perceptions has been at the secondary school level with elementary schooling being overlooked (Goh & Fraser, 1995). Instruments developed at the secondary level, such as the Constructivist Learning Environment Survey (Chen, Taylor, & Aldridge, 1997), have used such factors as personal relevance, uncertainty, student negotiation, shared control, and critical voice to determine the level of student perception of the constructivist environment. Such factors are centered on the students' beliefs that the teacher encourages them to negotiate meaning, they have some control of the learning, and the study of science is more than the authoritarian view put forward by the textbook (an absolutist view of science). Goh and Fraser's (1995) study of elementary school science classrooms used the factors of leadership, helping/friendliness, understanding, student responsibility/freedom, uncertainty, dissatisfied, admonishing, and strictness as the bases for students' perceptions of the learning environment. These factors focus on teacher behavior but not necessarily all appear to be reflective of a constructivist environment. When preservice elementary teachers were asked to judge the success of constructivist teaching approaches, they chose two primary factors: "students' learning and the children's attitudes toward science" (Stofflett & Stefanon, 1996, p. 15). This would indicate that instruments designed to measure elementary students' perceptions of their teacher's implementation of constructivist approaches should incorporate these factors.

<u>Self-Report of Teaching</u>

Self-report, self-check, and self-regulation are established goals of the reflective teacher. Self-evaluation — although a desired goal — has been questioned for its validity and reliability since it may emphasize intent rather than actual practice. Self-evaluation and self-report appear to provide better quality information when the instruments closely reflect the shared goals and understandings of the teachers reporting. Therefore, self-report instruments need to be custom designed to a specific task involving well-defined and commonly understood assumptions and should not be the single source of information for important decisions.

<u>Instrument Verification</u>

Instructional innovations require a close link between model verification and instrument verification. Therefore, constructivist teaching approaches must be assessed by instruments based on the same theoretical underpinnings, reflecting specific learning environments and disciplines, and not anchored to any single established reference (Geisinger, 1992; Royer, Cisero, & Carlo, 1993). Instrument validation (validity and reliability) is an accumulative inquiry process involving the theory, the prototype and the instrument (Anastasi, 1988; Geisinger, 1992; Messick, 1989).

Validity can be considered in components: substantive, external, and structural (Yore, Craig, & Maguire, 1998). Substantive validity (face and construct) can be explored by objective expert analysis of the theory, prototype, and assessment instrument and by comparison of results of instruments to a commonly accepted reference. External validity (convergent and discriminate) can be examined by testing predictions (differences in groups expected to be different and detect changes known to exist) based on the underlying assumptions of the theory. Structural validity begins by assuming that reliable, valid data collected from the perspectives of the theory will exhibit the underlying assumptions of the theory. Factor analysis techniques can be used to examine the adequate fit of data to the fundamental structure of the model (Embretson, 1983). The goodness of fit between model and data can be explored by predetermining the number and unifying structure of the principal components revealed by the factor analysis (Loehler, 1987). Principal components of data that closely approximate the underlying assumptions of the model are taken as supportive evidence of the model. Reliability is an integral part of structural validity and intimately connected to factor analysis approach.

Design

The research questions were addressed using a case study of the science advocates for each of the 16 elementary schools in the Iowa City Community School District. These science advocates were elementary school teachers willing to serve as science leaders in their schools and to participate in the Science PALs project. Multiple methods were used to collect data on the science advocates' implementation of the Science PALs' goals (expert ratings), their classroom teaching (ESTEEM), their self-perceptions (self-reports), and their impact on students (students' perceptions and attitudes). These data were collected during the 1995-96 school year. Complete data sets were developed for 14 science advocates since 2 science advocates left the school district and the project.

Instruments

Constructivist classrooms look different than their traditional counterparts. The students and teachers have different roles. As a result, traditional forms of teacher evaluation and measurement do not work well for constructivist classrooms (Searfoss & Enz, 1996). The first problem encountered in this study was to select and develop instruments that accurately reflected the interactive-constructivist theory. Techniques established to measure social constructivist practices will not fully document the interactive-constructivist perspective. As a result, something else had to be used, while attempting to anchor the new instruments to the established instruments. The Professional Development System (PDS) was collaboratively developed by the science advocates, project staff, and external consultants (Shymansky, et al., 1997). The PDS guided the selection and development of instruments since it represented the underlying assumptions of the interactive-constructivist approach and was commonly understood by the science advocates, experts, and project staff involved in this study.

Expert Ratings

The advocates' implementation of the Science PALs approach was globally assessed by four expert staff members who had been involved in the development and calibration of the PDS (Director of Professional Development, Science Coordinator, and two graduate student staff members). Each expert had strong science content background and considerable experience with elementary school teachers and science instruction. They were asked to rank order the 14 advocates remaining in the project at the end of year 2 (1996) on their overall implementation of the interactive-constructivist approach, use of children's ideas, use of children's literature, and knowledge of reforms and misconceptions. The raters based their ratings on work with the science advocates in professional development activities and in their classrooms. There was 75%

agreement (3 or more experts agreed within 1.5 positions in the rank order) among the four raters on the top 4 and bottom 4 advocates, while only 33% of the ratings of the middle 6 advocates reached this level of agreement (Henriques, 1997). Therefore, an average rating was calculated for the four ratings.

ESTEEM Ratings of Science Teaching

The ESTEEM rubric was used to evaluate two videotaped science lessons provided by each science advocate. The videotapes were scored by two of three independent experts (Henriques, 1997). One of these experts had significant experience with the ESTEEM rubric from another research project. This expert trained the other two science educators to use the ESTEEM rubric. Drastic differences in scoring (±5 points on the total score) of a videotape resulted in discussion between the experts and rescoring when consensus could not be reached. The higher total ESTEEM score for the two science lessons was used to represent the advocate's teaching for this analysis. The ESTEEM scores ranged from 39 to 85 with an average of 61.07.

Students' Perceptions of Science Teaching and Attitudes toward Science Learning

Students' perceptions of science teaching was composed of (a) view of constructivist approach, (b) parents' interest, (c) teacher's use of children's literature in science, and (d) relevance of science. Students' attitudes toward science learning was composed of (a) attitudes towards school science, (b) self confidence, (c) nature of science, and (d) science careers. These domains and subscales were assessed using Likert items to determine the students' agreement, lack of awareness, or disagreement with specific statements about each factor. The items were developed by the project staff and external consultants to reflect the established features of the science reform and the project. The subscales were established using factor analyses techniques. Original items were scored as disagree (1), do not know (2), and agree (3) and were assigned to factors using a varimax approach with minimum loading weights of 0.30. Items not meeting this condition were deleted, resulting in a final Grades 1-2 survey of 37 items, Grades 3-4 survey of 57 items, and Grades 5-6 survey of 72 items. Table 1 provides the number of items in each factor and the internal consistency based on data collected for Grades 1-2, 3-4, and 5-6 in the spring of 1996. Internal consistencies ranged from marginal (0.45-0.60) on 18 data sets to reasonable (0.61-0.88) on 42 data sets. Generally, the instruments have reasonable validities (substantive and structural) and reliabilities for exploratory research, but further verification will result from this study.

Teachers' Self Reports

The science advocates' perceptions of their science planning, teaching, and assessment were assessed by Likert items designed to assess strong disagreement (1), disagree (2), neutrality

Table 1
Internal Consistencies of and Number of Items in the Likert Item Factors used to Assess Students' Perceptions and Attitudes

Scale and Factors	Grade-Level Groupings 1-2	3-4	5-6
Perceptions of Science Teaching	0.83(20)	0.85(34)	0.88(35)
Constructivist Approach	0.67(8)	0.81(21)	0.85(17)
Parental Interest	0.70(6)	0.68(5)	0.72(7)
Use of Literature in Science	0.52(3)	0.49(3)	0.61(5)
Relevance of Science	0.50(3)	0.56(5)	0.74(6)
Attitudes toward Science Learning	0.71(17)	0.79(23)	0.84(37)
Attitude toward School Science	0.58(6)	0.74(5)	0.81(21)
Self-concept	0.54(3)	0.64(6)	0.63(6)
Nature of Science	0.60(4)	0.53(9)	0.51(7)
Careers in Science	0.68(4)	0.72(3)	0.79(4)

(1996 data: $N_t = 2552$, $N_{1-2} = 831$, $N_{3-4} = 722$, $N_{5-6} = 999$)

(3), agree (4), or strong agreement (5) with specific ideas on a 5-point scale. The items were developed by the project staff and external consultants to reflect the underlying assumption of the project. A factor analysis of these items revealed 32 items with reasonable factor loadings (0.30) and conceptual unity fit a 3-factor solution. The first factor consisted of 17 items related to using children's ideas in planning and teaching with an internal consistency of 0.88. The second factor consisted of 10 items related to the application of science to the children's daily lives with an internal consistency of 0.82. The third factor consisted of 5 items related to the use of print resources with an internal consistency of 0.73. These three self-report dimensions closely parallel the pedagogical emphasis of Science PALs — using children's ideas, relevance, and using children's literature. The instrument was judged to have reasonable validities (substantive and structural) and reliabilities for exploratory research.

Data Analyses and Results

The research focus of this study was to verify the use of students' perceptions and attitudes and teachers' self-report information as measures of interactive-constructivist science teaching in elementary schools. The analyses provide descriptive data, correlations, ANOVAs, and T-tests for 14 science advocates who have been involved in the Science PALs project. The correlations between these measures and established instruments (expert ratings and ESTEEM ratings) provide an indication of substantive validity (construct). Differences in ESTEEM scores, perceptions, attitudes, and self-report information for 3 groups of advocates based on the expert ratings were tested using Analyses of Variance (ANOVA) and T-tests as indications of external validity. Tables 2, 3, and 4 provide descriptive statistics, correlations, summary ANOVAs, and pair-wise T-tests for each measure.

The expert ratings were based on the judgments of the 4 well-informed science educators and on numerous encounters with the 14 science advocates' instructional planning, teaching, and leadership. There was 68% agreement (±1.5 positions in rank order for 3 of the 4 experts) among the science educators. The variability was expected since each expert viewed the science advocates' implementation from slightly different perspectives, but their collective judgment (average rating) was believed to be the best indicator of the science advocates' overall implementation of the interactive-constructivist approach.

The ESTEEM scores indicate that the science advocates do not fully reflect the social constructivist perspective implicit in the instrument. The average ESTEEM score for the advocates teaching (61.07) is slightly higher than the average ESTEEM score for the 46 expert science teachers (57.30) used to norm the instrument (Burry-Stock & Oxford, 1994). Only one advocate with a score of 85 appears to approximate the teaching strategies implied by the ESTEEM rubric. Most science advocates (12) have middle-of-the-road scores (55 to 75) that are characteristic of a shared-control but learner-focused teaching style implied by the prototypical interactive-constructivist teacher. The interactive-constructivist teaching approach has many common expectations with the ESTEEM model, but it is unlikely that an interactive-constructivist teacher would score in the 80-90 range on the ESTEEM rubric.

The students' perceptions of their teacher's teaching were slightly positive to positive (2.08-2.67), while students' attitudes toward science learning were somewhat more positive (2.19-2.63). Teachers self-reported use of students' ideas, applications of science to the children's world, and use of print resources were positive (3.63-4.07). Close inspection of Table 2 illustrates a general pattern among the science advocates identified by the experts' ratings as low-level implementors, middle-level implementors, and top-level implementors in

Table 2
Means of Science PALs Advocates for Specific Measures of Constructivist Teaching

Measure	Level of Implementation Low (N = 4)	Middle (N = 6)	Top (N = 4)
ESTEEM	55.00	61.83	71.00
Students' Perception of Science Teaching (SPST)	2.40	2.33	2.50
Students' View of Constructivism (SVC)	2.66	2.58	2.77
Parental Interest (SPI)	1.99	1.93	2.14
Use of Literature (SUL)	1.55	1.50	2.20
Relevance (SR)	2.71	2.68	2.41
Students' Attitude toward Science Learning (SASL)	2.46	2.41	2.42
Students' Attitude toward School Science (SASS)	2.20	2.19	2.64
Students' Self-concept (SSC)	2.66	2.67	2.53
Nature of Science (SNS)	2.84	2.73	2.06
Careers in Science (SCS)	2.08	2.08	2.47
Teachers using Children's Ideas (TUCI)	3.49	3.43	3.66
Teachers' Applications to Children's World (TACW)	3.81	3.83	3.73
Teachers using Print Resources (TUPR)	3.25	3.21	4.04

which the middle-level group frequently has lower student perceptions, student attitudes, and self-reports than do the low-level and top-level implementors. The top-level implementors have the highest values on 8 measures while the low-level implementors have the highest value on 5 measures.

The correlation between the ESTEEM scores and the expert ratings was significant ($p \leq 0.01$). The inter-measure correlations revealed disappointing relationships between ESTEEM and students' perceptions, students' attitudes, and teacher's self-report information.

Table 3
Inter-measure Correlation Matrix

	Expert Ratings	ESTEEM	SPST	SVC	SPI	SUL	SR	SASL	SASS	SSC	SNS	SCS	TUCI	TACW
ESTEEM	0.68**													
SPST	0.28	0.08												
SVC	0.30	-0.02	0.90***											
SPI	0.34	0.03	0.94***	0.83***										
SUL	0.58*	0.23	0.72**	0.67**	0.76**									
SR	-0.40	0.04	-0.04	-0.25	-0.21	-0.61								
SASL	-0.12	0.01	0.48	0.37	0.25	-0.03	0.66*							
SASS	0.66**	0.27	0.64**	0.59*	0.60*	0.81***	-0.31	0.26						
SSC	-0.37	-0.10	0.08	0.10	-0.08	-0.47	0.61*	0.61*	-0.38					
SNS	-0.63*	-0.13	-0.31	-0.38	-0.47	-0.80***	0.85***	0.50	-0.66**	0.69**				
SCS	0.62*	0.19	0.46	0.52	0.45	0.78***	-0.54*	0.08	0.86***	-0.50	-0.73**			
TUCI	0.26	-0.11	0.44	0.38	0.43	0.51	-0.22	0.36	0.44	-0.03	-0.18	0.42		
TACW	-0.08	-0.33	0.06	0.05	0.09	0.26	-0.29	0.09	0.06	-0.09	-0.09	0.30	0.73**	
TUPR	0.50	0.23	0.40	0.29	0.40	0.60*	-0.26	0.22	0.68**	-0.34	-0.39	0.56*	0.68**	0.21

* denotes $p \leq 0.05$
** denotes $p \leq 0.01$
*** denotes $p \leq 0.001$

Table 4
Summary ANOVAs and Pair-wise T-tests for Three Groups of Science Advocates
Based on their Perceived Implementation of Science PALs

	ANOVAs		Pair-wise Comparisons					
			Top vs. Low		Top vs. Middle		Middle vs. Low	
Measure	F-ratio	P-value	T-value	P-value	T-value	P-value	T-value	P-value
ESTEEM	440.20	0.001	29.22	0.001	11.62	0.001	22.32	0.001
SPST	2.47	0.134	1.14	0.279	2.22	0.051	-0.98	0.351
SVC	4.05	0.052	1.55	0.152	2.84	0.017	-1.15	0.277
SPI	2.30	0.151	1.37	0.120	2.14	0.050	-0.64	0.538
SUL	39.99	0.001	7.20	0.001	8.45	0.001	-0.55	0.596
SR	2.78	0.109	-2.11	0.061	-2.05	0.067	0.26	0.800
SASL	0.27	0.769	-0.52	0.617	0.15	0.881	-0.72	0.488
SASS	12.13	0.002	4.03	0.002	4.59	0.001	-0.16	0.875
SSC	1.67	0.236	-1.47	0.174	-1.72	0.146	0.11	0.911
SNS	9.11	0.006	-3.87	0.003	-3.66	0.004	-0.59	0.569
SCS	14.78	0.001	4.55	0.001	4.98	0.001	-0.01	0.996
TUCI	0.55	0.594	0.69	0.508	1.04	0.323	-0.29	0.776
TACW	0.18	0.840	-0.43	0.675	-0.58	0.573	0.11	0.914
TUPR	3.62	0.066	2.18	0.054	2.52	0.030	0.13	0.899

The relationships between expert ratings and the students' perceptions, students' attitudes, and teacher's self-report information is somewhat more promising. These results support the expectation that the ESTEEM instrument emphasized a slightly different perspective of constructivism than the interactive-constructivist approach. Furthermore, these results suggest that the students' perceptions and attitudes and the teacher's self-report instruments need fine-tuning to increase their substantive validities.

Significant ($p \leq 0.05$) main effects in the ANOVAs were found for ESTEEM, students' view of constructivist approach, students' perception of use of literature in science, students' attitude toward school science, students' attitude toward the nature of science, students' attitude toward careers in science, and teachers' report of using print resources. The pair-wise t-test comparisons for these significant main effects reveal that 7 differences between the top-level implementors and middle-level implementors account for most of the main effects. Most frequently, the difference favored the top-level implementors (except students' self-concept in science). Six differences between the top-level and low-level implementors were found significant. All but one difference (students' self-concept in science) favored the top-level implementors. The only significant difference between middle-level and low-level implementors was for the total ESTEEM scores.

Discussion

This study supported the anticipation that instruments based on social constructivism would not completely and accurately document science teaching based on interactive-constructivist assumptions. The correlations between experts' ratings and ESTEEM ($r = 0.68$) and the ANOVA and pair-wise t-tests of ESTEEM differences for groups specified by their expert ratings were significant, but sizable amounts of variance (54%) were not accounted for by the social constructivist-based instrument.

This study also revealed that some students' perceptions of science teaching (view of constructivism, parental interest, and using literature in science) and attitudes toward science learning (attitudes toward school science and careers in science) have reasonable validities and reliabilities to use as indicators of interactive-constructivist teaching. Teachers' self-reports of using children's ideas and use of print resources also have potential as indicators of interactive-constructivist teaching. Students' perceptions of relevance and self-concept, self-concept in science, and attitudes toward nature of science and teachers' self-report of applications of science to the children's daily lives appear to distract from the instruments' substantive and external validities. Eliminating or revising these dimensions should improve the overall utility of these instruments.

Analysis of each dimension (item) within the 4 categories of the ESTEEM rubric suggests that some items could be revised or the exemplars revised to more closely reflect an interactive-constructivist perspective of elementary school science teaching. Revisions would require new expert exemplars for student engagement in activities, novelty, textbook dependency, student relevance, and higher order thinking skills. Another solution might be to establish an ideal ESTEEM score for the prototypical interactive-constructivist teacher (i.e., 85) and to express ESTEEM scores as a positive or negative deviation score about the idealized ESTEEM score. This would allow changes in teaching to be defined as growth toward the ideal score.

This study of 14 science advocates' teaching, their students' perceptions and attitudes, and their self-reports indicates that students can detect some differences and some self-reported information matches external judgments. If the two instruments are revised, they can be efficient and effective surrogate measures of interactive-constructivist science teaching in elementary schools.

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TEACHING THROUGH INQUIRY: A NOVICE TEACHER'S AUTHORITY OF EXPERIENCE

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Inquiry-based instruction in which teachers engage students in scientific investigations and problem-solving surfaces as an important strategy advocated by recent science education reforms (AAAS, 1993; NRC, 1996). Knowledge of inquiry is also a key outcome for students as stated in the National Science Education Standards -- "the ability to conduct inquiry and develop an understanding about scientific inquiry" (NRC, 1996, p.105). State frameworks promote students' construction of scientific knowledge through processes such as developing questions, empirically testing hypotheses, and gathering and synthesizing information (e.g. State of Michigan Department of Education, 1993).

These reform-minded orientations to teaching inquiry build on a research base of constructivist views of learning (Brown, Collins, & Duguid, 1989; Cobb, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Newman, Griffin, & Cole 1989). The reforms explicitly ask teachers to change their teaching by shifting the emphasis from the textbook to exploring questions that are student-centered and can be answered empirically. Teaching Standard B of the Standards states that teachers "focus and support inquiries while interacting with students" and that "inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (NRC, 1996, p.32-33). In addition, the Standards advocate that teachers design investigations situated in real phenomena, in classrooms, outdoors, or in laboratory settings and that are demanding, yet feasible for students to carry out.

However, orchestrating this kind of instruction is not a simple endeavor. Inquiry-based instruction challenges the most expert of teachers (Gallagher, 1989; Krajcik et al., 1994; Marx et al, 1994; Tobin, et al., 1990). Challenges to create this kind of instruction escalate in the case of novice teachers who have the liability of inexperience in several domains of knowledge of teaching including pedagogy, pedagogical content knowledge, knowledge of students, and knowledge of classrooms (Shulman, 1986). This study is important because it helps fill the gap in understanding how the intended curriculum of the reforms links to classroom practice of beginning teachers. This study describes the background and beliefs of a preservice teacher who appears above average in her ability to create and carry out inquiry-based instruction. Further, this study explores the changes this preservice teacher undergoes in her thinking and teaching as she encounters obstacles throughout the course of a year. Finally, implications for teacher education programs are suggested including the need to engage preservice teachers in an ongoing endeavor to focus on inquiry in teaching. Using a case study approach (Yin, 1989), this research simultaneously examines a preservice teacher's planning and the reasons behind her planning, her interactions with her students, her reflections before and after lessons, and her reflections the year following her one year of field experience.

Visions of the kinds of learning environments set forth in reform documents portray the outcomes, but leave out details of day-to day-events in the real world of classroom life. Because this kind of teaching demands that teachers build on students' current states of knowledge, one might question the ability of preservice teachers to successfully carry out this kind of instruction. Given that preservice teachers have to deal with all the complexities of the classroom as novices, this study focused on the central question: *In what ways is it possible for a preservice teacher to successfully construct an inquiry-based learning environment?*

This study consisted of an in-depth collaborative study of one preservice teacher's endeavors to design and carry out two inquiry-based units over the course of her one year field experience. Questions relating directly to this preservice teacher's work included:

1) In what ways did this preservice teacher engage her students in inquiry?

2) What factors contributed to this preservice teacher's decision to design and carry out inquiry-driven instruction?

3) What were the supports and constraints to this preservice teacher using inquiry?

4) What implications do these findings have for other preservice teachers?

Theoretical Framework

Inquiry-based instruction involves students pursuing the answers to significant questions (Brown & Campione, 1990) in ways similar to those used by scientists (Brown et al., 1989). Inquiry should not be confused with merely providing students with a series of hands-on activities. Instead, teachers need to meld inquiry activities with constructivist-oriented discussions to facilitate students building on their current knowledge and revising their understandings (Driver, Asoko, Leach, Mortimer, & Scott, 1994). This study is influenced by social-constructivist theories in which students' understandings of science are actively built in a social setting through a process of debating and negotiating with others (Solomon, 1989; Vygotsky, 1978; Wood, Cobb, & Yackel, 1992). Interactions of the students and teacher are the foci of the tugging and pushing of ideas students bring to each lesson.

Having students solve problems and do "real" science stems from the writings of John Dewey. Dewey believed that children learn from activity, through a continuum of their own experiences, and from contemplating the writings of others (Dewey, 1938). A number of researchers have applied Deweyian ideas of experiential learning to classroom-based projects and long-term investigations that are student-centered and contextualized (Krajcik et al. 1994; Roth, 1994; Roup, 1993; Schwab, 1976; Tinker, 1991). Authentic problems that students solve collaboratively differ from traditional school science "experiments" that tend to be verification labs during which students seek the "right" answer. Instead of completing exercises from a chapter in the textbook, students construct their understandings by solving real-world problems (Tinker, 1991).

This study focuses on the feasibility of a preservice teacher to immerse students in the kind of experiential learning that includes both social-construction of knowledge and contexualized instruction. Preservice teachers in fifth-year programs typically enter with varied experiences and orientations to teaching and learning science. Likewise, teacher education programs vary in the extent to which ideas such as the nature of science and inquiry-orientations to pedagogy are explicitly addressed in methods courses. For example, one study of an elementary preservice science cohort found that challenges and difficulties associated with designing and carrying out instruction include linking concepts, assessing students' prior knowledge, and improvising during instruction (Starr, Zembal-Saul, & Krajcik, 1997). The ability to adapt and mold instruction in response to student-centered inquiry appears a likely stumbling block for novice teachers who have difficulty with improvisation during interactive teaching. Researchers point to the need for novices to develop an integrated understanding of pedagogical content knowledge that includes the ability to transform the essence of subject matter into an understandable form (Grossman, 1991; Shulman, 1986). In this study Inquiry is the subject matter to be transformed.

Background of the Preservice Teacher

The study of Denise, the preservice teacher in this study, evolved during the fall term of 1995. Denise, a pseudonym, was one of 22 cohort students in the twelve-month, fifth year Masters in Arts in Teaching (MAT) program at a northwestern university, 14 of whom majored in science education and the others in mathematics education. After beginning the MAT program in the summer, Denise was placed for her fall practicum field work. Her high school placement was in a small farming and logging town in the pacific northwest, nestled near the coastal mountains. During this practicum, it became apparent to the author, who was her university supervisor, that Denise was unique in her planning. Unlike the other MAT students' traditional units that centered on topics, Denise planned for her general biology students to study nutrient cycling through a collaborative, aquaculture/hydroponics project.

Prior to entering the MAT program, Denise had varied work experiences in horticulture research and as a volunteer teacher's aide. Denise worked for ten years in commercial and university labs, conducting studies such as screening for bacterial isolates and running experiments relating to weed control for local growers. As part of her job responsibilities she wrote proposals, designed and carried out a variety of experiments, and gave oral presentations. In order to strengthen her application for the MAT program, Denise volunteered to work with teachers in two different schools. Denise assisted Jake, a high school teacher regarded in the community as an excellent teacher who involved his students in community-based projects.

Denise also worked with Linda, who later became her mentor teacher. With the backdrop of her varied life experiences, Denise became an expert informant on the thinking of a beginning teacher.

School and Community

The small public high school of approximately 120 students was a center for activities in the small town, and the local community enthusiastically supported the football and basketball teams. The high school faculty shared course expectations and background information on students. Teachers had significant input in the development of the district curriculum, and had flexibility in designing instruction. Denise's mentor teacher had graduated from the MAT program five years before, and her activity-based classroom was stuffed with aquaria, books, lab materials, and student work.

Although the twenty students (14 boys and 6 girls) in the sophomore biology class were not culturally diverse, the students ranged greatly in academic success and ability. One student had certified learning disabilities, several students publicly contemplated dropping out of high school as soon as they turned sixteen, and another student was a young mother and frequently absent.

Overview of the Two Inquiry-based Units

Denise successfully designed and taught two inquiry-based units for the sophomore biology class: the first, she called Nutrient Cycling, included a collaborative project in which students worked in groups as they designed and conducted an experiment associated with a Aquaculture/Hydroponics system. The second unit, taught in the winter term, Denise called the Independent Research Project (IRP). Denise described the IRP as a more involved project in which each student chose an area of interest, developed a feasible research question, reviewed current literature, designed and conducted an empirical investigation, drew conclusions from the investigation, wrote a technical report, and made a formal presentation to the class. During the winter term, Denise designed a global warming unit for two eighth grade integrated math and science classes which was not part of this study. However, Denise's decision to plan this additional project-oriented unit provided further evidence for her orientation towards projects and inquiry-based teaching.

Method

The purpose of this study was to document Denise's field experience in order to characterize her planning and classroom teaching, and to determine the factors influencing her decisions.

Sources of Data

The case study of Denise's planning and instruction developed from multiple sources of data representing perspectives of the author (serving as fall supervisor), a second university supervisor (for the winter term), the mentor teacher, the students in Denise's class, and Denise. The research relied heavily on input from Denise, the teacher, and focused on understanding how Denise made sense of her teaching (Richardson, 1994). The main sources of data involved actual classroom observations to verify how Denise carried out her plans. Denise acknowledged the most important influence on her learning to teach was her field work, the student teaching experience. Records of Denise's teaching during the fall term included the author's written observations of lessons once a week During this time, the author's role was that of Denise's university supervisor, and the formal written observations included critiques of the lessons and suggestions. During the winter term a different university supervisor recorded observations of lessons once a week. The author continued to make weekly classroom visits throughout the winter term and compiled handwritten and videotaped records of each of Denise's lessons.

Another important source of data included audiotaped conversations between the author and Denise. Conversations took place throughout the fall and winter terms, during the following summer, and during the fall of Denise's first year of teaching. These conversations consisted of two kinds: 1) semi-structured interviews guided by protocol questions designed by the author lasting 30-45 minutes and centering on lesson planning issues, post-lesson debriefing, and the research questions; and 2) informal conversations occurring weekly during fall and winter and continuing into summer and fall of the second year, ranging from a few minutes to 30 minutes or longer. These informal conversations allowed Denise to talk freely about her thoughts centering on day to day events in the classroom, challenges she encountered, and revisions she made in planning. As a first year teacher, Denise described her new challenges and successes and reflected on lessons learned from her preservice teaching experience.

Additional data sources included a) written observations by the mentor teacher and a second university supervisor during the winter term; b) Denise's written lesson plans and formal written reflections; c) videotaped interviews of pairs of students in early April to determine student's perspectives of the second unit (Denise suggested that students be interviewed in pairs to create a more comfortable environment); d) students' final written reports for both units; and e) audiotaped conversations with the second university supervisor.

Analyses of the Data

Analysis of the videotaped lessons followed an interactive process described in previous studies of inquiry-based instruction (see Crawford, 1996 ; Krajcik, et al., 1994). This interactive process utilized a three part scheme consisting of data reduction, data display, and conclusion drawing and verification (Miles & Huberman, 1994.) Documents were produced by first writing summaries of each lesson segment--a segment consisting of a change in activity Evidence of students and teacher engaging in inquiry-related events or conversations were noted, and these sections were transcribed. Commentary was then written following each segment, noting teacher and student interactions. Finally, hypotheses were written guided by the research questions. This process produced a narrative document for each videotaped lesson.

These narrative documents along with documents from the other data sources described below were placed in chronological order and formed the base for finding patterns in Denise's teaching and beliefs. Placing the documents in chronological order served to highlight changes in Denise's planning and instruction. Each of the data sources were used to either corroborate or refute developing patterns and themes as these emerged from the analysis of the data.

Analyses of the supervisors' and mentor teacher's written critiques of Denise's lessons focused on the summaries of the lessons, descriptions of Denise's strategies, and notations of student responses. After reading through the supervision critiques several times, the author added commentary related to the presence or absence of inquiry-related events. These commentaries were then added to the chronological collection of analyses documents..

Transcriptions were produced of the audiotaped conversations between the author and Denise and the videotaped interviews of pairs of students at the end of the second term. These transcriptions were combined with student reports and students' written responses to a questionnaire given towards the end of the second unit. These documents, combined with Denise's lesson plans, Denise's written reflections after teaching each lesson, and Denise's written philosophy and analysis of her own teaching were used to determine Denise's perspectives on her planning and teaching. The author read and reread each of these data sources and underlined sections related to the research questions. All documents were folded into the chronological collection. Throughout the data analysis the author constructed the case study by writing hypotheses in the form of narratives and then supported or refuted these hypotheses by using each data source (Yin, 1989).

Results

The findings of this study will be organized around the research questions beginning with a discussion of Denise's beliefs about science and her stated goals for teaching.

Denise's Beliefs about Science and Goals for Teaching

In the beginning of Denise's practicum experience Denise utilized language that resembled the kinds of traditional jargon found in documents advocating inquiry. But, by the end of April, Denise had modified her goals to embody a more mature view of teaching inquiry. In the fall Denise viewed science as "a study of inquiry and the natural world...it is important I believe that we teach science as an ever growing and expanding field of study; where creative new ideas and interpretations may lead to new knowledge; where ideas are open to consideration and scrutiny; where new theories continually redefine how we view the world, and ourselves" (from her written Philosophy of Education, crafted during fall coursework).

Denise's initial goals for teaching centered on getting students to think, communicate, and take responsibility. One of Denise's primary goals for teaching was for her students to learn to think independently and to critically evaluate information given them. Denise viewed her role as a facilitator and "the role of education is to guide students through this development and encourage problem-solving skills, effective communication, critical and creative thinking, focus, and a sense of local and global community ownership" (from her written Philosophy of Education, revised Feb. 1996). By the end of February, Denise attributed her success in student teaching to instruction "centered around student projects (both independent and cooperative) that involved a variety of applications in math, communications, and discussion of social issues."

By the end of April Denise had modified her goals to include aspects of student performance based on the realities of classroom experience. This modification resulted from Denise's reflection on students' work during the fall Nutrient Cycling unit and the winter IRP unit. Denise experienced frustration in the fall when some of the students failed to contribute to the group investigations. Denise noted that in almost every group, all the work was done by one or two students. In the winter, Denise changed from cooperative group work to individual research reports. By the end of the winter term , a few students still failed to complete a final written report. Thus, a goal that emerged for Denise based on her fall and winter experiences targeted students acquiring the values of self-motivation, challenge and success. In the year following her preservice field work Denise continued to express her goal that students take initiative and develop ownership in their learning.

In interviews over the year of her preservice experience, Denise restated her concern with clarity and relevancy as illustrated by her responses to questions about her teaching. When asked what she thought was important in her <u>teaching</u>, Denise responded, "That's a wide open question.." When pressed to continue her response, she identified "Clarity.. relevance. (pause)...

sincerity.. honesty." When asked to identify what was important in learning, Denise responded, "Relevance, I suppose. That's the top of my list." She later added that communication was extremely hard for her. "It is a real learning process. It is so straightforward, and yet being able to understand, the knowledge base, a basic conceptualization.. some of the kids.. it seems linear, like putting variables into equations. I'm not sure. Again, there's just a big communication problem." Although Denise articulated some fairly clear goals such as making instruction relevant to students, other ideas appeared to be still in a formative stage of development. Denise appeared to struggle with the process of communicating her goals to her students.

In What Ways Did this Preservice Teacher Engage Her Students in Inquiry?

Denise designed inquiry-based experiences beyond that of a typical MAT student during both the fall and winter terms. The fall unit engaged students in designing and carrying out experiments relevant to people living in an agricultural community. In the winter Denise's students selected questions that related to their own interests and conducted independent investigations. Denise excelled when working with small groups or one-on-one with students on independent investigations. Yet, Denise struggled when carrying on whole class discussions focused on students developing their understandings of science concepts. Thus, Denise's instruction was characterized as dichotomous-- often she began her lesson with a teacher-directed lecture targeting terminology, and ended her lesson using an inductive, inquiry-based approach as students worked on aspects of investigations.

Design and Teaching the Fall Unit-- Nutrient Cycling

Features of Denise's teaching during the fall unit included: 1) teacher facilitated, question-driven investigations related to nutrient cycling; 2) effective mentoring of students in small groups and individually; 3) struggling with motivating all students to contribute to group work; 4) dichotomous lessons using two contrasting methods; 5) lecture parts of lessons targeting terminology.

The MAT program required students to design and teach a three week unit during the fall practicum experience which represented for most of the preservice teachers their first extended teaching experience. The formal write-up of this unit called a Work Sample, included the Rationale, Unit Goals and Objectives, Lesson Objectives and Detailed Plans, Written Reflections, Student Data Analysis of Learning, and Analysis of Teaching. The work sample consisted of a hefty document composed of numerous topic papers, revised lesson plans, calendar of lessons, examples of student work, tests, and additional resources. Although most of the MAT students developed units around traditional topics found in the biology textbook such as cells, classification, and genetics, Denise created an original project-driven unit. In this project students designed and carried out aquaculture/hydroponics experiments while learning about the role biotic factors play in the balance of cycling. Denise wrote in Work Sample #1 that "the first goal is to initiate students to the concept of nutrient cycling by drawing on familiar knowledge of oxygen and carbon dioxide exchange in photosynthesis and respiration. An additional goal of this unit is to give students an opportunity to design their own experiments and explore the parameters involved in a scientific inquiry." Denise planned and taught the Nutrient Cycling unit in eight sequential, 85 minute lessons from mid-October to mid-November.

As an example of innovative instruction during the fall, Denise developed an inquiry-based lab of her own creation that involved students testing nitrogen levels in horse manure and barn shavings. During part of the investigation students followed procedures for extracting nitrogen from both aged and fresh manure, carefully recorded data, drew conclusions, and discussed sources of error. The inquiry was contextualized and afforded students opportunity to collaborate about problems related to the real-world of a farming community. For example, the homework question asked, "Do your results give you indications as to why fresh manure might injure plants?"

During the lab work time Deb moved easily from one student to the next, interacting by asking questions and answering questions with thoughtful responses. All the students actively conducted tests on the two manure samples, and collaborated about their observations. During the debriefing Denise emphasized the critical components of an experimental design including development of an hypothesis, identifying independent and dependent variables, and the importance of constants. Denise later reflected on Lesson #2 in her writing:

> Introducing nitrogen into the lesson went well but would (in re-teaching) require modifications for better clarity and focus. The responses to the nitrogen questions asked in class discussion were great. Many of the students knew that fresh manure causes plant injury (smelled significantly stronger of ammonia than aged manure) and that kitchen compost was not as good of a nitrogen source as manure for garden plants. Additionally there were some interesting questions from students about mushroom growth and mature relationships, effects of burying manure, and how manure differed with different animals.
>
> (Lesson Reflection, 10/19/95)

Denise continued to engage her students in inquiry as she introduced the centerpiece of the Nutrient Cycling unit: "Think of a question that would be interesting to test that utilizes an Aquaculture/Hydroponics system". Student ideas brought to the next class session sparked a good discussion about possible experiments. Denise assigned students to small groups, and gave roles to different students. Denise guided her students in designing their experiments by teaching them the 4-Question-Step Process (Cothron, et al., 1989). This process created a framework for her students relating to selecting materials, treatments, and measuring responses.

Denise's assessment rubric gave the highest points to students who clearly identified the independent and dependent variables, were able to write a clear support for the hypothesis, developed treatment that exhibited a good understanding for nutrient cycles, sampled carefully throughout the experiment, clearly presented the results of the project, and worked well in their group.

For their investigations, groups set up one gallon jars and varied numbers of fish or amounts of plants to see the effect on other parts of the system. For example, one group wrote:

"Our group wanted to find out the effect of plant density on plant growth. We thought that the more plants in a tank there were, the more fish would be needed to balance the pH, nitrite, nitrate, and ammonia. The hypothesis stated: The density of cutting will affect the rate of rooting of Wandering Jew."

During group inquires Denise perceived her students to be motivated and that "overall I felt the Ss enjoyed this lesson, most were actively engaged throughout" (Lesson Reflection Day 5). Minor challenges included supporting students in data collection and refocusing a few students who strayed off-task during open work times.

Major challenges that influenced Denise's design of her second inquiry-based unit included missing an opportunity to integrate more writing into the final product, and the imbalance of effort by different members of the groups. Denise wrote, "What happened in several groups, only 1 or 2 people worked really hard to complete the comprehensive report, while their group members did literally none of the final report or presentation work." (Lesson Reflection Day 6).

Although Denise created inquiry-based opportunities for her students beyond the typical MAT student, many of Denise's lessons were dichotomous as described earlier; half of the lesson consisted of information-dispensing segments and the other half, were inquiry-based centering on innovative activities. During the first half of these lessons Denise focused primarily on presenting information: carbon dioxide and oxygen cycling, flow of forms of nitrogen through an ecosystem, description of Aquaculture and Hydroponics systems, and how to design and set up a controlled experiment. Underlying these teacher-directed parts of her instruction was Denise's concern with *clarity*, a theme that emerged over the course of the year.

Denise's concern with clarity may have related to her focus on terminology. Denise's lecture-style parts of lessons targeted terminology, and had limited success in engaging students in grappling with conceptual understandings. During these lesson segments, Denise usually stood at the front of the room using the overhead projector to define terms or show complex diagrams such as nutrient cycling.

One lesson in mid-October illustrates how segments within the same lesson could differ greatly in the opportunity for inquiry, student input, and knowledge construction. During the first part of the lesson Denise disseminated information relating to a lab on manure (Lesson #2, 10/19/95). Denise wrote the formula, N (triple bond) N on the overhead while saying the word, "nitrogen", followed by giving the quantity of N in the atmosphere. One boy asked about the triple bond, but Denise responded that would take her a week to explain. As Denise began to fill the overhead with chemical formulas and explained the role of bacteria in the nitrogen cycle, the students watched passively without asking further questions. During the second half of the lesson, Denise engaged her students in testing nitrogen levels in horse manure and barn shavings manure in a lab described above.

In her written reflection, Denise recognized that she needed to modify the lesson to introduce the nitrogen molecules a little more simply. In addition she needed to cut down the presentation of the entire nitrogen cycling to information pertinent to that lesson. Denise recognized that the molecular chemistry part of the lecture confused her students, and decided she needed to introduce concepts on a "as-needed" basis.

Denise's final reflections on the entire Nutrient Cycling unit highlighted her ownership of the unit and enthusiasm for revising and re-teaching it. In addition she noted that her students had gained ownership of their own experiments. "The projects were the most motivating part of the unit for almost all the students, even those that often remain relatively uninvolved." (Summative Evaluation of Student Teaching, Dec., 1995). In interviews, Denise articulated two concerns. First, Denise struggled with <u>clarity.</u> Denise recognized that she had confused students with vocabulary to which they did not relate. Second, Denise identified the <u>poor dynamics between some group members.</u> Denise identified that this lack of cooperation hindered group members' full potential.

<u>Design and Teaching the Winter Unit- The Independent Research Project (IRP)</u>

During the winter Denise continued to build on her success using inquiry-based instruction, and incorporated modifications in the design of her instruction based on her reflections on the fall. Denise envisioned her students choosing a question based on their own interests, using the literature as a base on which to build, designing an original, controlled experiment, and finally writing up a formal report. For their final IRP product Denise expected her students to produce a five to six page biology research including an impact statement to connect the results to issues relevant to the world.

One big change from the fall unit to the winter unit, was that Denise taught the IRP "wedged in between" lessons on cell biology and bacteria and viruses. After reading the author's draft of her own case study Denise crossed out the words "integrated in her subject matter lessons". As a correction, Denise wrote in the margin, "IRP- concurrent with regular subject matter required in general biology." In other words, the IRP was a discrete unit from the cell biology unit, although they ran parallel to each other. The IRP lessons spanned from January 18 to the final student presentations in late March, the week that followed the school spring break. Denise's calendar of events portrayed an initial lesson on the nature of science followed by an introduction to the project. Later lessons alternated discussions of cell organelles and bacteria with lessons directly related to the IRP such as experimental design, use of spreadsheets, and how to create a bibliography.

This second inquiry-based unit presented new challenges for Denise. The first challenge involved Denise' difficulties in guiding students in choosing a topic. The fall Nutrient Cycling project offered fairly limited choices to her students. However, Denise designed the IRP to be more open-ended and emphasized technical writing. During an interview in mid-February Denise told the story of one interaction: "One kid, he was very obstinate. He.. he wouldn't come up with a topic. ah. And.. well there were a few of them that weren't able to come up with a topic and I was able to guide them in their interests. I would say, what do you think of the world? And there was this one boy. And he finally came up with a topic.of feeding studies of alligators.(laughing) but I wasn't sure how he could get an alligator. I asked if he had snakes at home. No. he doesn't have any .. so. that is where it's at right now."

Once her students selected a topic of interest, Denise guided her students toward selecting a question to investigate and in designing a study using the same 4-Question-Step Process used in the Nutrient Cycling unit. A few students developed experiments related to the fall Nutrient Cycling project. Most of the students investigated completely new topics. Examples of students' questions included: Will small quantities of cotton remove large quantities of oil from the sea? What do teenagers think and understand about abortion? When do Labrador Retrievers begin to experience symptoms of Hip Dysplasia? Which color of light is most important for radish growth? Do mushrooms grow better on cedar or straw substrate? Do bass and trout act differently in different temperatures. Many of the questions explored by students closely matched their own interests, such as breeding Labrador Retrievers.

Denise's lessons continued to follow the dichotomous pattern of the fall lessons, alternating lecture-style segments with inquiry-oriented segments. In early March, Denise lectured on bacteria while students listened passively, asking few questions:

T: Eubacteria. Archeobacteria. I'm not quite sure how you say that.
Does anybody know "holophile"?

Denise, without waiting, proceeded to give the meanings of the two parts of the word.. halo-salt and phile means liking, answering her own question while writing words on the overhead.

T: What is the difference between eukaryotic and prokayotic?

One student responded and Denise completed the student's answer.

T: A nuclear membrane.

On the one hand these lecture-style segments remained teacher-directed and focused on content.. As her winter supervisor stated, "lecture was reduced to terminology." One of her students wrote on a student response sheet that "you used some words and explained things without relating to what we would understand." On the other hand, Denise's interactions with students during project work time exemplified constructivist approaches in her pressing students in thinking about their experimental designs. For example, during project work time in mid-March, students worked in different areas of the room. Denise moved from one student to the next, offering advice or asking questions as illustrated in this lesson vignette:

> One boy working at the back of the room on an aquaculture/hydroponics experiment lamented that his goldfish had died. Denise asked him if he wanted to modify the experiment.
>
> D: Did they die before? Maybe you should use your experiment to test <u>why</u> the fish died.
>
> Denise suggested that he take some ammonia and nitrite readings right then. Meanwhile, another boy arranged samples of radish plants taken from light boxes on a piece of paper. He planned to photograph the slender young plants.. Denise suggested he use colored paper for better contrast. A third boy testing the effect of pasteurizing straw on growing oyster mushrooms wondered about cutting the plastic bags once the mushrooms got large enough. Later, the boy testing the dead fish water, walked over to Denise who was working with another boy using a spreadsheet.
>
> S: "That's a bummer, the nitrite level was high". Look at this concentration of nitrite!"
>
> D: Ah! Now we know what is happening.
>
> Denise explained to the boy how the nitrogen cycle tied in.
>
> D: You could do a nice write-up of your experiment and tell what has happened. That is totally acceptable.
>
> (Lesson 3/16/96)

During project work-time, Denise viewed her role as facilitator and guide. Although the frequent flow of visitors into and out of the room sometimes distracted students (for example, taking pizza orders for lunch) , Denise managed to stay focused on each student as she worked with him or her. Denise's shift from a teacher-centered lecture mode to a more student-centered inquiry mode fit with Denise's recognition of the importance of open-inquiry: "Using their questions as a starting base for research topics was fun, and I feel that it allowed them to feel more ownership over the project."

Students viewed these project times as productive as evidenced by these representative responses to a written survey

Q: What were your favorite parts of this class?

A: When we had work time to work on our projects and experiments.

Q: In what ways did I (the teacher) help you learn?

A: Told me some stuff I didn't already know. Gave me ideas for new projects. Helped learn to recognize some deficiencies.

You tried to answer all the questions we had; you showed me better ways to show and interpret data and go about experimenting.

Q: What were your least favorite parts?

A: The worksheets, and there wasn't enough conversation; long lectures about scientific things I'm not interested in.

Student interviews corroborated the students' positive written responses about project work. "She just helped me if I didn't , like sometimes, I'd just get stuck and didn't know what to do and she'd help me figure out what to do next." Most of the students valued the IRP. "It was something that you really wanted to do. It's not the same if someone else comes up with the question because they're not, you know, it's basically not the same, like what people will answer -- if it's not your question... It's your choice (in the IRP), your answer. "

In addition to students exhibiting positive attitudes towards the project work and their teacher, students learned about the importance of variables in designing experiments. When asked to identify some of the problems in doing the experiment, this was a typical response: "I'd have more treatments, and I'd make sure when I boiled the substrates, that they both got to the same temperature, and I boiled them the same amount of time, so it would be the same."

Summary of the two units. Denise engaged her biology students in a variety of inquiry-based experiences. Although not always successful in orchestrating whole-class discussions centered on conceptual understandings, Denise was effective in engaging her students in creative, open-ended, relevant investigations and successfully worked with students in small group settings. Denise wrote in a reflection: "The most powerful lesson for both the students and myself was the recognition of the value of challenging students to take initiative, ownership, and responsibility for an independent project." Ownership taken by Denise's students during the two projects parallels reports of experienced teachers designing long-term, student-centered project-based instruction (Crawford, 1996; Roth, 1995; Roup et al. 1993; Scott, 1994; Warren, Rosebery, & Conant, 1989). During her field work experience, Denise's planning and instruction correlated with the Standards call for teachers to fashion investigations that are demanding for students, but within their capabilities.

What Factors Contributed to this Preservice Teacher's Decision to Design and Carry out Inquiry-driven Instruction?

Denise's decision to design two inquiry-driven units appeared to stem primarily from her earlier work experiences in labs and field work. This finding is consistent with previous studies that demonstrate the influence of preservice teachers' prior work on the development of their science schema and extending this to their teaching (Palmquist & Finley, 1997.) Secondary influences appeared to be Denise's mentor teacher's reception to her ideas and Denise's experience as a teacher's aide in a project-oriented classroom prior to entering the MAT program.

During a conversation a year after her student teaching, the author asked Denise directly what was the main reason she tried these projects. She quickly said, "Oh, that's easy. My 10 years as a research technician." Denise went on to say that she had been good at designing these kinds of experiments, and had wanted to involve her students in these same kinds of experiences. In a later interview she revealed that the idea for the Aquaculture/Hydroponics experiment resulted from information from a journal as she prepared a "resource card' for one of her summer MAT courses. Contributing to Denise's final decision to develop both the Nutrient Cycling unit and the IRP was her mentor teacher's support and willingness to allow her to try out new things.. "I asked her (my mentor teacher) what she thought about nutrient cycling, and she thought that would be great. So I thought that would be a good way to go about nutrient cycling, and to do an independent research project. So that was an opportunity to try out cooperative group work. I am certain that I got the idea for cooperative group work from the fall (methods) course; that I would not have thought up on my own."

Denise's decision to design the Independent Research Project during the second term appeared to originate from herself and resulted from confidence gained from completing her first project in the fall. When Denise realized that the school curriculum required sophomores to prepare a research paper, Denise quickly saw an opportunity to combine her goals for involving her students both in inquiry and in the writing of a technical paper. Denise stated. "I had that in my head before I even went into teaching..that I would have kids do independent research projects or a group research project. It seems like a natural thing."

Denise's initiative to design and carry out this complex form of instruction resulted from her expertise and confidence in conducting controlled experiments. In addition, Denise had a model of how she could translate her professional experience into her classroom constructed from her volunteer experience with Jake, a project-oriented teacher. Denise acknowledged that "Jake is dynamic, and I would like to spend more time with him in his classroom."

What Were the Supports and Constraints to this Preservice Teacher's Teaching Using Inquiry?

Supports

Once Denise decided to design the inquiry-directed units, several factors influenced her success. From triangulating the data gathered from supervisors, the mentor teacher, and the preservice teacher, six key factors appeared to support Denise in her efforts to sustain an inquiry-based environment. These factors included: 1) prior research experience; 2) volunteering in project-oriented classrooms; 3) extensive planning and having a clear vision of her unit goals; 4) developing a trust relationship with her mentor teacher; 5) collaboration with experts outside the classroom, and 6) consistent and thoughtful reflection on practice.

The first two of these influences on Denise's vision of inquiry-based teaching related to her experiences prior to entering the MAT program. These influences included her experience as a research technician as described earlier, and her experience as a teacher's aide working with project-oriented teachers. The teaching practices of successful inquiry-based teachers emerged as a model for Denise. "the two people I spent the most time with were Jake and Linda (later, to become her mentor teacher), and they are both project oriented people. ah....and I think it is easier. It is more comfortable and it is easier. (Conversation, 10/19/96)

Third, Denise had a clear understanding of the goals and objectives for both her units and visualized the outcomes she hoped her students would attain. Denise carefully planned both the Nutrient Cycling group project and the more ambitious IRP that included a formal, technical research paper. Although Denise encountered struggles with her students in the journey towards these outcomes, she maintained a clear vision of the final destination. Denise invested substantial time in preparing lessons and materials needed for the unit. Denise's own enthusiasm for the units carried her through days during the second unit when some students resisted, parents challenged her expectations of her students, floods ravaged the valley, and almost the entire school took a week off for a high school basketball tournament.

A fourth factor that sustained Denise was her close working relationship with her mentor teacher. Her winter supervisor stated that "she feels comfortable with calling her mentor teacher....Her relationship with Linda has a sense of trust." The mentor teacher took a maternity leave for part of the winter term. Since the mentor teacher lived in town and Denise felt comfortable with her, Denise would often drop in to talk with her. Due to this established trust between the mentor teacher and Denise, this preservice teacher was given flexibility in choosing the unit to develop in the fall, as well as the winter. Denise described this freedom as being able to "do anything I wanted." Support from her mentor teacher, flexibility in her choice of units, and encouragement by her university supervisor appeared to be critical to both her initiation and carrying out of the two inquiry-based units.

A fifth factor in supporting Denise was the help she obtained from experts outside the classroom. Setting up the elaborate aquaculture/hydroponics system of aeration required after school time and week-end work. Denise sought out and relied on the expertise of her mentor teacher's husband, who was an aquarist and fisheries biologist. Other resource people important in acquiring materials for her project included a local pet store owner.

A sixth factor that contributed to Denise's resolve to engage her students in challenging inquiry-directed instruction was her thoughtful reflection on her developing practice. For example, when the author first proposed the idea of developing a case study of her teaching, Denise expressed a real interest in looking more in-depth into her own teaching. Her winter supervisor described Denise as "honest with herself and good at reflection."

Constraints

Although Denise experienced success in engaging most of her students in inquiry, Denise also experienced frustration. During the fall inquiry-based unit, Denise was generally concerned with disproportionate work done by students in groups. She felt that one or two students in each group "carried" the other students. Her other concerns related to her clarity in giving information.

Denise encountered new challenges in designing and teaching her second inquiry-based unit in the winter. The first challenge involved the reality of supporting students in choosing their own topics, designing various open-ended investigations, and carrying these out in the classroom. Although Denise had a vision of the project, all her students did not share this same vision. Her winter supervisor ascertained that "she made the assumption early that because they are 10th graders, they will want to do it. She can talk about environmental issues, and it doesn't excite them all. She's finding that her excitement doesn't translate into their excitement." During a phone conversation, Denise acknowledged that "a lot of kids are having a hard time collecting data, and they don't know what to do with it... they are dragging their feet...they need more time and more guidance."(Phone conversation 3/11/96). Denise noted "that one boy still had an experiment, although his fish had all died. But it was like pulling teeth, because he has no real intention of passing." Once her students finally decided on a topic, and set up the investigations, Denise encountered the reality of trying to manage a number of students working on different projects. "I felt like I was a person who couldn't be in 16 different places at a time." During project work times Denise's role changed every few minutes. During one period of thirty minutes Denise responded to one student's questions, gathered materials for another student, offered advice to a third, participated in another student's survey, and tutored yet another student in using computer software.

The second challenge related to the technical writing portion of the project. Denise admitted that she entirely overestimated her students' abilities to envision a final report, and to write this to her specifications. One student described this as ""well, she started off by giving us a lot, a lot of work, just like right off, quick. She wouldn't slow down. She just kept going and going. And then once we got to our research it kind of slowed up. We knew what to expect." During one part of the unit, Denise stated that "she has taken some heat for what she is doing." At one point two parents requested a meeting with her and the vice-principal to discuss their concerns with the timelines and scope of the written reports. Denise realized that technical writing was something her students had not done.

The third challenge related to numerous interruptions to the flow of the instruction due to natural disasters, such as flooding and ice storms, and school-based events, such as the high school basketball tournament. During these times, classes did not meet for a week at a time.

Denise identified several changes in her two units that she would make if re-teaching them another year. First, she acknowledged the limiting factor of time. After several lessons, Denise commented that she needed to give students more time to work on projects in class. A second change concerned communication with parents. Denise stated that at the beginning of the project, she would send home information on the scope of the project, including all deadlines. A third change would involve increased communication with her students. "In terms of my communication with students, I feel that I probably expected too much from them at the beginning of the unit and in retrospect, I wish I would have begun slower with the materials and homework assignments." Also, Denise would modify lecture-discussions of science content. "There were definitely times when I confused them, and a number of times when I used vocabulary (not science related) that they were unfamiliar with." (from Summative Evaluation of Teaching, 2/96) A fourth change would be to collaborate with a language arts teacher in the school, in order to strengthen her students' support in writing, making the IRP an interdisciplinary project across departments.

Discussion

Denise, like many preservice teachers, had to deal with the demands of planning new units with limited knowledge of curriculum, school context, and overall awareness of abilities and personalities of different students. Considering that inquiry-based teaching is complex and classrooms in which students engage in Standards-based inquiry are rare (Gallagher, 1989), the ability of this pre-service teacher to plan and carry out two successful inquiry-based units is remarkable. Prior to this study, it was the author's belief that creating and carrying out complex inquiry-based instructional units may realistically be beyond a preservice teacher's capabilities. This belief was built from the author's own experience in designing and carrying out projects in secondary classrooms (Crawford, 1996) and from researching inservice teachers' attempts to change their instructional orientations (Marx, et al., 1994). One conclusion we might draw from this one case study is that preservice teachers, given certain caveats and adequate support, can feasibly create inquiry-based environments similar to those advocated in the Standards.

Denise's success in creating aspects of an inquiry-based environment raises as many questions as it provides answers. Why, in fact, did Denise stand out as an anomaly? Denise remained unique in her planning and teaching--one of twenty two students in a substantive teacher education program built on a theoretical knowledge-base promoting thoughtful student-centered opportunities to construct understandings and engage in inquiry (Shulman, 1986). Why did not more cohort teachers attempt to design and carry out similar kinds of inquiry-based units? What can we do to support preservice teachers and guide them in planning inquiry-based instruction? How successful will Denise be in her first year of teaching -- in a different context and with the added teaching load of a first year teacher --in sustaining her inquiry-based orientation to instruction?

If we accept the conclusion that novice teachers can potentially design and carry out inquiry-based instruction, the important question then becomes: what are the key steps in guiding novice teachers, who may be typical in their ability, in creating these reform-based environments? By looking at the combination of factors that influenced Denise, teacher educators may be able to apply these findings to preservice programs as well as professional development programs for inservice teachers.

First, the data suggests that Denise's view of science as "a study of inquiry and the natural world" contributed to her engaging her students in inquiry. We know that teachers' beliefs impact their learning and teaching (Pajares, 1992), although we should be cautious in assuming that "having beliefs" necessarily translates into teaching practice (Haney, Czerniak, & Lumpe,1996.) The knowledge and beliefs of students entering teacher education programs exert powerful influences on what they learn about teaching (Borko & Putnam, 1994). Exploring preservice teachers' beliefs about teaching and about science appears an important first step in getting them to think about the meaning of inquiry-based learning environments. More research is needed in exploring how these beliefs translate into practice.

Second, Denise's clear vision of her overall goals and flow of lessons in both units enabled her to connect the teaching of process-oriented skills such as hypothesizing, designing experiments, collecting data, and drawing conclusions to the needs of her students and to the overall goals of her question-driven units. Planning extended projects requires careful attention to the sequencing of lessons. Lessons linked to solving a particular question move students toward drawing conclusions and constructing new knowledge. During the fall unit, Denise attempted to weave in ecological concepts of nutrient cycling and energy flow using the project as the framework. Research on expert and novice teachers suggests the importance of encouraging novice teachers to plan lessons using an overview of the curriculum, rather than simply focusing on objectives of the specific lesson at hand (Westerman, 1991). This suggests the importance of preservice teachers planning long term units that relate to important questions --not simply stringing together discrete lessons related by topic. Greater emphasis on unit goals as preservice teachers plan individual lessons followed by attention to the links and cross links of individual lessons may move preservice teachers to gain an important "big picture" view of their teaching.

A third implication of this study relates to Denise's knowledge of inquiry from her 10 years of professional lab experience. If indeed Denise's experience was critical to involving her students in inquiry, how can we provide authentic kinds of experiences for all preservice teachers . We need to explore alternative ways for preservice teachers to gain knowledge of inquiry through similar kinds of experiences. One possibility is to change undergraduate science courses to include long-term investigations. Other possibilities include providing authentic inquiry experiences within science methods courses.

The fourth implication relates to opportunity. Denise had opportunity to design and carry out inquiry-based instruction. In contrast to high school teachers who design innovative units, but then fail to move them into the classroom (Lynch, 1997), Denise risked trying out a novel unit in her first field experience. With the support and encouragement from her mentor teacher and aided by her knowledge from working in inquiry-oriented classrooms, Denise worked toward translating her beliefs in engaging students in investigations to the reality of the classroom. The importance of a supportive environment is noted in other studies (e.g. Loughran, 1997). It seems intuitive that the field placement greatly influences the kinds of instruction eventually adopted by preservice teachers. Careful selection of mentor teachers who model inquiry-based approaches appears critical Alternative ways to provide models of inquiry-based environments may include video-based case studies of what this instruction might look like. Research into constraints encountered by first year teachers that might deflect a preservice teacher such as Denise appears necessary for preservice teachers to sustain the gains made in their understanding of how to craft inquiry-based instruction.

The fifth implication points to the importance of reflection on teaching. Much has been written about teacher reflection (e.g. Munby & Russell, 1992; Schon, 1983). Denise's daily reflection focused her thinking on her students' understandings and motivated her to revise upcoming lesson plans. In this way, Denise constantly reconstructed her own understandings of learning and teaching. Denise operated in a planning, teaching, and reflective loop in which she selected teaching strategies to enhance students' understandings versus maintaining student interest (Loughran, 1994). Throughout her planning and teaching, Denise collaborated with colleagues (mentor teacher, university supervisor, fisheries expert). In some ways, Denise engaged in practical inquiry (Richardson, 1994) as she sought guidance through collaboration with her mentor and supervisor Denise remained thoughtful about how she could improve in areas she identified, e.g. "clarity", and hoped to resolve her dilemma of needing to cover content while engaging her students in time-consuming investigations.

Conclusion and Implications

At the risk of generalizing from one preservice teacher to all and recognizing the limitations of a single case study, Denise's case study provides a positive view of what can happen in a preservice teacher's classroom. The advantage of an indepth study of one preservice teacher rests in the richness of the details of the events of the year--from planning issues to implementation issues. This case study points to giving attention to the authority of experience of the preservice teacher (Munby & Russell, 1994). Denise listened to her previous experiences as she worked towards understanding inquiry in her classroom. In order to lessen the gap between what is happening in classrooms and what needs to happen, it is teachers themselves who must make "real" the visions of the reforms. As in this study, researchers must learn from teachers' work.

Denise's case study suggests a combination of conditions necessary to enable novice teachers to create desirable kinds of inquiry-based learning environments. These conditions translate to the following implications for preservice teacher educators:

1. *Explore novice teachers' beliefs about science and about teaching science* as an important first step in getting them to think about the characteristics of inquiry-based learning environments.

2. Involve novice teachers in opportunities to *undertake authentic investigations.*

3. Scaffold novice teachers in *planning long term units that relate to important questions* and link to important content.

4. *Model inquiry-based approaches* in the field and/or through videotaped cases.

5. Engage novice teachers in *collaborative inquiry of their own teaching*.

Because this study focused on only one year of Denise's teaching, this study points to the need for longitudinal studies of preservice teachers who appear promising in their development as science teachers as they continue their journey through the treacherous first few years of full-time teaching.

The results of this study suggest that it is realistic to expect preservice teachers to design and carry out aspects of inquiry-based instruction. Expecting emergent teachers to engage in inquiry-based instruction seems especially critical in fifth-year programs that end in a terminal degree. This final year of preparation to teach presents a critical chance to promote thoughtful, innovative, Standards-based, inquiry instruction. Otherwise, we risk contributing more teachers who are complacent and comfortable with instruction based on the belief that teaching is telling. Teacher education programs need to require minimum competencies that indicate a teaching candidate utilizes developmentally appropriate inquiry-based teaching strategies as stated in the draft Certification and Accreditation in Science Education (CASE) Standards (NSTA, 1997). It seems imperative that as teacher educators, we expect similar orientations to learning and teaching from our preservice teachers as national standards advocate for inservice teachers of K-12 grade students-- through the creation of meaningful-complex tasks that foster learning through explorations of authentic questions.

Notes

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LESS TALK, MORE ACTION, FOR MULTICULTURAL SCIENCE

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The numbers indicate that science teachers are not reaching ethnic minority students as effectively as they could. The research literature is rife with recommendations for remediation. But many of these "cures" do more to sustain a style of science education that perpetuates cultural bias than they do to help all students achieve. As multiculturalists and as science teachers who wish to maintain fidelity to our discipline, we all want students to appreciate the scope and limitations of science, the cultural influences that have and will color it, the societal manifestations of it, and the opportunities inherent within it. But we should not abandon learning theory to "deliver" these notions when student inquiry will better provide for the construction of these meanings for each individual.

The Historical Context

Consider the four sample questions below– they're part of a forty-question battery called the Army Alpha Test 8: Information instrument that was administered to soldiers during World War I.

1. The Knight engine is used in the:
   a. Packard b. Lozier c. Stearns d. Pierce Arrow

2. Isaac Pitman was most famous in:
   a. physics b. shorthand c. railroading d. electricity

3. The stanchion is used in:
   a. fishing b. hunting c. farming d. motoring

4. Cheviöt is the name of a:
   a. fabric b. drink c. dance d. food

A high score was a virtual guarantee of stellar opportunities in the armed services. Missing half was the equivalent to a scarlet letter classification of mental inferiority which followed the infantryman for life. The test had been developed by the American Psychological

Association as a means for determining who was intellectually fit for advancement, and who was to be classified as "feebleminded" (Paul, 1995). How do you rank?

Nearly two million soldiers took this proto–I.Q. test. When the results were released after the war, it was revealed that "the lowest scores were registered by Blacks and members of newer immigrant groups" (Paul, 1995); 47.3 percent of them had been declared feebleminded based upon the test. The outcome resonated throughout American society, and spawned more such tests to be administered to school children and workers, all used for promulgating a vision of supremacy among the white middle and upper classes who ranked highest on these misguided intelligence measures (Paul,1995).

Viewing the test and its implications through the corrective lens of hindsight, one can fully recognize the inherent bias associated with it. A select population of test-takers were favored—specifically those belonging to the same cultural, socioeconomic, and even geographic population as the test's authors. How obviously naive a design and intent, we might think. Who among America's poor (disproportionately minorities and recent immigrants) would stand a chance when simply owning a motorcar was a luxury far beyond reach, let alone a Stearns with its Knight engine?

Yet here we are eighty years later using antiquated notions of learning and assessing our progress with one-size-fits-all standardized tests to determine such modern rites of passage as college entrance and professional certification. And by all indications, biases persist. The 1993 assessment report of the American College Testing service revealed that every minority group in America scored lower mean composite scores than did Caucasian American/White examinees (Walton, 1993). Moreover, Hispanic students consistently achieve at a lower level than their Anglo peers in school (Rakow and Bermudez, 1993) and it has been conservatively estimated that 18 percent of Black males drop out of high school (Wright, 1992).

There is now no question that the relationship between educational attainment and ethnicity points toward underachievement for the children of America's ethnic minorities (Hodson, 1993).

This disparity is particularly pronounced in school science coursework at the secondary and tertiary levels (Hodson,1993), accounting, no doubt, for the dramatic underrepresentation of minorities in scientific careers (Blake, 1993). In light of this prevailing condition, it is not surprising that minority students have been found to hold less confident attitudes about their own capabilities and the future pursuit of science as a career (White and Richardson, 1993).

The question of culpability, and a search for remediation therefore become issues of great national import. It cannot bode well for a nation where only 2.9 percent of all practicing scientists and engineers are black despite a national population percentage of 11.9 percent. And likewise among Hispanic Americans— comprising over 9 percent of the population and growing more rapidly than any other ethnic minority group-- to whom only 1.3 percent of bachelor degrees in the sciences are awarded (Rakow, 1985, Atwater,1994, Foundations, 1997). Something is clearly turning the children of minority ethnic cultures off to science. The numbers portend a gloomy picture for the profession as well as for society as a whole: in the twenty years it will take for today's students to hit full stride in the workforce, half of America's population will be comprised of people of color (Banks, 1992), and we can ill afford to have half our population disenfranchised from scientific careers. All of tomorrow's adults will live in a rapidly changing technological environment, and their attitudes toward that change will influence their ability to cope with it in emotional as well as material ways (Mordi, 1993).

Thus it is in all of our best interests to examine the process by which students learn about, and develop attitudes regarding, science. The evidence supports the presence of cultural bias in the process. Within our culture, it is schools specifically that must carry the burden of ameliorating such bias, as the science classroom has been shown to have the single greatest influence upon attitudes and career outlooks for adolescents toward science (White and Richardson, 1993).

A Contrast in Viewpoints

Something is amiss in the way that science is too often taught. Many science teachers are not reaching all of their clientele with equal efficacy. This begs the ultimate question to be explored here: should the ethnic and cultural make-up of our clientele influence the way we teach science? Those who believe the answer is "yes" have proposed an eclectic array of strategies and techniques for shoring up the confidence and subsequent performance of underrepresented minorities in science class.

These strategies include altering the "language of science education," "taking more account of the religious beliefs and customs" of our students, highlighting the "contributions of non-Western and pre-Renaissance scientists" (Hodson,1993), the incorporation of "ethnoscience" (Rakow and Bermudez, 1993), providing role models of students' own ethnicity in the form of teachers and mentors (Wright, 1992), the promotion of culture as the center of the educational process (Holt, 1992), the "introduction of concepts via materials and examples from both the dominant culture and the specific ethnic culture of the students" (Allen and Seumptewa, 1993), and the segregation of students along ethnic lines in a tactic termed "ethnic streaming" (Wright, 1992; Loving,1993).

Answering "no" to the focal question of this discussion is not to be construed as a denial of the existence of pervasive bias in science education. Rather, this view holds that cultural bias can be overcome more equitably and more pedagogically soundly by implementing an inquiry approach to science education, with themes built around science/technology/society, and employing strategies that have been empirically derived to be successful and which form the basis for the National Science Education Standards.

A thesis for the argument put forth herein is that the only truly multicultural science classroom is one that accords students the opportunity to identify problems and issues of a relevant nature, to explore these issues collaboratively through every avenue the school setting can bring to bear, and to derive meaning from those experiences such that each student can gain a clearer understanding of the natural world and their place in it.

Science For All

General consensus exists regarding the goals of science education. Conscientious science teachers hope that their students find science to be "fun and interesting" and that each student develop the attitude that he or she "can do science" (Penick, 1997). Stated formally through the National Science Education Standards, our goals are to educate students who are able to:

- experience the richness and excitement of knowing about and understanding the natural world
- use appropriate scientific processes and principles in making personal decisions
- engage intelligently in public discourse and debate about matters of scientific and technological concern
- increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers (National Research Council, 1996)

These goals are congruent with an inquiry approach to the teaching and learning of science. Inquiry science is characterized by a classroom atmosphere in which students "engage in the description of objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others" (NRC,1996). In short, inquiry science is an active process, where "learning science is something that students do, not something that is done to them" (NRC,1996).

Multiculturalism: Sound Motives, Suspect Strategies

The intervention strategies advocated in much of the multiculturalist literature depart from the general principles of inquiry science. The recommendations are geared toward traditional science settings where lecture and student passivity prevail. For example, science teachers are urged to utilize "more photographic slides and visual aids" when lecturing to the "highly visual and low verbal-expressive" Western Teton Sioux students (Atwater, 1994).

Moreover, augmenting a traditional lecture with "story situations that include food, places and events" have been found to benefit Native American students (Atwater, 1994). Multiculturalism advocates implore teachers to "use examples and content from a variety of cultures, groups, and their own personal experience" to help make science more exciting (Atwater, Crockett and Kilpatrick, 1996). Teachers are urged to cite the scientific "contributions of females and scientists of color" in their curriculum (Atwater, Crockett and Kilpatrick,1996), and to charge students with conducting "racism checks" of course materials (Williams,1994). Should laboratory time arise amidst the stories,vignettes, and readings, one multiculturalism advocate cites the danger of using "complex and expensive equipment that may implicitly promote the view that science is the preserve of the rich, industrialized nations" (Hodson, 1993).

When coupled with the intervention strategies briefly mentioned earlier, the premise under which many multiculturalism advocates operate becomes clear: that "the priorities of schools with high ethnic minority populations will be significantly different from those in schools in which the student population is drawn largely from the dominant culture" (Hodson, 1993). Educational equity is a reachable goal, but it will come through the widespread adoption of inquiry science practices rather than as a series of contrivances that aid and abet a pedagogical status quo. Multiculturalists' noble intent notwithstanding, the energy expended to promote this particular collection of remedies is miss-spent for three reasons: 1) multicultural interventions themselves assume monocultures of minorities in classrooms; 2) the multicultural literature speaks of all members of particular ethnicities as if cut from the same mold; and 3) the foundations for an ethnically inclusive science education strategy are already at hand.

The typical teacher in a Fresno, Miami or Chicago classroom may have as many ethnic cultures represented as there are students in the classroom (Loving,1995). The task of validating each student's culture through citations of significant contributors to the current body of knowledge becomes a futile and patronizing practice (Williams,1994). Inevitable marginalization would be the end result in a class where every topic discussed must be presented from the perspectives of the different cultures represented in the room (Good, 1995). It may be argued that

these are isolated pockets of ethnic heterogeneity; that in reality, ethnically homogeneous student groupings prevail where multiculturalist interventions are warranted. The assumption now becomes one of student uniformity of vision.

Research on learning styles according to ethnicity has resulted in the delineation of broad categories of learners—labeled as field dependent or

independent (Oakes, 1990; Baptiste, 1993), of western or non-western world view (Anderson, 1988), and various subcategorizations on these themes regarding visual and perceptive classes of learners (Atwater, 1994). Sweeping generalizations of students have been made to support the adoption of different teaching strategies

dependent upon the ethnic make-up of the classroom. One multiculturalist contends that students with non-western world views, namely "African Americans, Chinese Americans, Mexican Americans, Native Americans, and many European American females, value group achievement, think holistically, embrace religion, accept world views of others, and are socially oriented" (Atwater, 1994), whereas those with a western world view, namely European American males, "emphasize individual competition, believe that people must conquer and dominate nature" and "think that their world views are better" (Atwater, 1994).

Another proponent of this line of thinking demarcates groups based upon field sensitivity (or dependence). Accordingly, the "cultural experiences of Blacks, females, Hispanics, and Native Americans tend to promote a field- sensitive orientation" (Baptiste, 1993), which accounts for their desire that "science concepts be presented in a humanized story format", and their "desire to work with others and to assist others" and a characteristic "high motivation when working individually with teachers" (Atwater, Crockett, Kilpatrick,1996). Conversely, field independent learners (comprised of ethnic groups not included in the field-dependent) are said to typically prefer "individual recognition, more formal interaction with the teacher, finish first and pursue nonsocial rewards," and prefer that "the details of science concepts be emphasized" (Atwater, Crockett and Kilpatrick,1996).

If we are to operate on the premise of Science For All, a task early on must be to dismantle such prejudicial groupings at the outset, while recognizing and being sensitive to the great diversity that exists among individual students within as well as across ethnic and cultural boundaries. But the categorization of students, or of any individual, "by a single microculture membership and the expectation of certain behaviors in turn are inappropriate and often prove incorrect anyway" (Gollnick, 1992). Kids who fare poorly in science, be they White or Black, male or female, do so "because of systematic inequities in the pedagogical approach to the the teaching of science" (Garibaldi, 1992). Therefore the pedagogical style of science teachers must be reformed to a model of inquiry that suits individual learning styles of all children, regardless of ethnicity or cultural experience.

Equity through Inquiry

The foundations for an ethnically inclusive science education strategy are already at hand. When teachers present science through inquiry, they "plan for meeting the particular interests, knowledge and skills of each student and build on their questions and ideas" (NRC,1996). Authentic questions that are generated from students' own experiences are central to inquiry, where "the focus is predominantly on real world phenomena" (NRC,1996). Thus, all children, "regardless of age, gender, cultural or ethnic background, disabilities, interest or motivation in science" can develop the knowledge and skills to be valued contributors to a scientific and technological society (NRC,1996). Equity and systemic reform in science education have a reciprocal relationship: "Educators cannot successfully attain or accomplish one without the other" (Foundations, 1997). Leaders in the movement for multicultural curricular inclusion in science would do more good for a greater number of American children by urging on the widespread dissemination and utilization of reform programs that outline the inquiry approach, such as the National Science Education Standards. Some of the benefits of inquiry science are:

- Students are actively engaged in doing science, rather than hearing about how it is done
- The real world is brought into the classroom and into students' lives
- Teamwork and collaboration in solving problems and addressing issues are central
- Diverse learning styles are accommodated through various strategies of pursuit– hands-on, research, dialogue, reflection
- Topics lead to connections with other school disciplines
- The thought processes of students are revealed by, and guide the course of, inquiry science (NRC, 1997)

Making a case for inquiry science is to make a case for multicultural science. "Teaching science this way creates classrooms in which all students, not just a select few, can learn science" (Foundations,1997). The only tenable justification for continuing to push for overt multiculturalist techniques would be a failure to universally adopt inquiry science. A traditional classroom—dependent upon textbook and lecture methods of content delivery, emphasizing what we know more than what we do in science, and where a teacher delivers more than receives—will inevitably be riddled with cultural bias. The question would then be whose bias.

As multiculturalists and as science teachers who wish to maintain fidelity to our discipline, we all want students to appreciate the scope and limitations of science, the cultural influences that have and will color it, the societal manifestations of it, and the opportunities inherent within it. But we should not abandon learning theory to "deliver" these notions when student inquiry will better provide for the construction of these meanings for each individual.

Disparity in performance between ethnic populations when it comes to science boils down to attitudes crafted during the science education of the learner (Debaz, 1994). Research on ethnically heterogeneous classrooms supports the value of inquiry science as a means for bolstering the confidence, and subsequently the performance, of students of all ethnic and cultural backgrounds (Yong, 1993; White and Richardson, 1993; Mordi, 1993; Atwater, Wiggins and Gardner, 1995; Catsambis, 1995).

Conclusion

Attitudes among Blacks and immigrants regarding the Army and their prospects in it were surely dim indeed after failing the Alpha 8: Information Test. They were forced to reckon with the notion that perhaps they were ill-suited for military service based upon this measure. Today conscientious people cringe at this gross mismeasure using a tool with no applicable basis for drawing such conclusions. We would demand that at the very least, a form of measure be employed that authentically assesses military service itself before we cast judgment on a soldier's potential. Traditional science pedagogy is a metaphorical Alpha Test. It resembles nothing of the authentic discipline, and convinces worthy members of the population that science is not for them. Rather than take a multicultural tactic against our own version of the Alpha Test by simply amending it to be more inclusive, science education reform advocates, true multiculturalists, want the test thrown out, so that the venture of *doing* science can speak for itself.

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Integrating Field Experience and Classroom Discussions: Vignettes as Vehicles for Reflection

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Abstract

Through an action research perspective (Elliott, 1991), this study tells the story of the reform of a large enrollment introductory secondary education course over a two year period and the subsequent development of the vignette assignment as a vehicle for reflection. The reform began with a search for a strategy that would facilitate the integration of the field experience with the campus-based discussions. However, what had started as a search for a quick-fix strategy resulted in an ongoing introspective examination of philosophical perspective and professional identity (Volkmann & Anderson, *In-press*). The vignette assignment was developed as a problem-posing exercise (Friere, 1970, Giroux, 1987), to help students reflect-on-action (Schon, 1987). Vignettes consist of brief written descriptions of discrepant events observed by practicum students. Through the vignette exercises, students learn that classroom problems are managed rather than solved (Berlak & Berlak, 1983), and teaching decisions are moral in nature (Jackson, Boostrom, & Hansen, 1993). Ethical issues associated with the use of vignettes are discussed (AERA, 1992). Implications for teacher education and life-long learning are described.

Introduction to Education (EDCI 204B) is the first course students take in the teacher preparation program at Purdue University. It was created in 1978 to provide an opportunity for students to experience teaching early in their teacher education program. The course consisted of two parts: a field-based and a campus-based component. The field-based component consisted of ten observations of a local teacher's classroom over the course of a semester, where the student assisted and participated as a teacher. The campus-based component dealt with the theoretical aspects of learning to teach. Activities included discussions of reading and writing assignments; videos of teaching; and guest speakers on educational issues.

Historically, the practical field-based component was dissociated from the theoretical campus-based component. The practical lessons encountered in the privacy of local classrooms were difficult to incorporate into the public space of the campus-based discussion. The practical quality of the field experience juxtaposed against the theoretical quality of the campus discussion resulted in poor student evaluations indicating that the theoretical discussions lacked relevance.

In 1992, as a new visiting assistant professor, I was offered the opportunity to coordinate Introduction to Education (EDCI 204B). I accepted the challenge on the condition that I would have the freedom and the support to re-create a course that bridged the theory/practice gap. I realized from my own experience as an undergraduate in teacher education that students value experience in classrooms above all other forms of teacher education instruction (Russell and Munby, 1994). My goal was to integrate the meaningfulness of the field experience into the campus based sessions through reflection on those experiences.

My desire to create an introductory education class that was both useful and meaningful turned out to be far more difficult than I anticipated. On the surface, the problem was simple to solve: develop and implement a new curriculum that contained opportunities for discussion and reflection about field experiences. Beneath the surface lurked the problems associated with privacy, confidentiality, ego, and my own approach to teaching others to teach. My initial attempts to re-define the course focused on the surface changes of re-defining curriculum. After trying and failing over three iterations of the course, I began to suspect what Pogo has now made infamous, "I have met the enemy and the enemy is me."

My story of reform is self revealing. Through it I describe the mistakes I made and my recognition of a possible solution. In the next section I describe my action research approach as I investigated new strategies and my own values and beliefs about teaching and learning to teach.

Action Research Methodology

Initially, I chose action research because I wanted to implement new teaching and learning strategies within my own classroom. Action research provided tools I could use to document the success of my efforts. As my understanding of the complexity of my endeavor deepened, I continued to use action research because it assisted my introspective effort to examine my own attitudes and beliefs about learning to teach. My overarching goal was to awaken students to their own attitudes, values, and beliefs about teaching to enable them to act upon them. Hiding within that goal I discovered a lesson: do not expect your students to do what you are unwilling to do. In retrospect, I see that my research proceeded in two phases: (A) an extrospective phase that focused on finding the right strategy to stimulate my students' thinking about their values, attitudes, and beliefs about teaching; and (B) an introspective phase that focused on my own values, attitudes, and beliefs about teaching. In both phases (extrospective and introspective), my efforts were directed toward addressing four questions posed by Elliott (1991):

1. What is the initial idea?
2. What changes should be made?
3. What do I hope to achieve? (The plan)
4. What counts as evidence of success?

My approach agreed with Elliott (1991) when he said, "theories are not validated independently and then applied to practice. They are validated through practice" (p. 69). What I learned through practice and about practice is shared below.

What is the Initial Idea?

Prior to my coordination of the course, students had no opportunity to share their field experience with their peers or their section instructor. Furthermore, no attempt was made to connect campus-based discussion topics with the problems, concerns, or successes students experienced in the field. Reading assignments were un-connected to the observation experience; journal entries were rarely shared with other students; and writing assignments were one-way communications to the instructor. There are two problems associated with the compartmentalization of the two course components. First, compartmentalization resulted in a missed opportunity to examine, reflect, and learn from the practice of teaching through campus-based social interactions. Second, compartmentalization re-enforces the code of silence that protects the teaching profession self-criticism and reform.

What Should be Changed? -- A History of Reform

What I hoped to accomplish was the integration of field experiences into the campus-based sessions. From my reading of the observational journals I knew the students' field experiences provided entrance to a variety of issues and problems. The difficulty was that the students experienced these issues and problems in the context of their individual field experience. That is, because no two students attended the same field experience, i.e. issues and problems were experienced privately. For this reason, the journal served as the perfect vehicle for discussion of events: it retained the private quality of the experience, but because that experience was written, it was possible to transport the experience to class for later discussion. I hoped the classroom discussion could provide students with ways to resist the professional isolation experienced by classroom teachers. I hoped to find ways to talk about teaching actions without students feelings vulnerable and exposed or feeling like they were divulging inequities experienced in their field observation.

The journal required students to write descriptions of what happened during each school visit and to reflect on those observations as they placed themselves in the role of teacher. The students wrote about a variety of topics such as: student mis-behavior, the teacher's sense of humor, the classroom atmosphere, monitoring makeup tests, tutoring students, the difficulty of explaining information, and how their teacher represented the role of the teacher. The journal writing also provided a private link between the student and their campus-based instructor. The journal was a good place for students to privately air their judgements about teaching, learning, the teacher's competence, and students' abilities. My first revision focused on the journal writing.

Semester I

I decided one way to transport what was meaningful in the field experience into the campus-based discussions was to use the journal writing exercises as a focus for the class discussions. I hoped the private link between instructor and student could continue, but I also hoped to make the individual experiences available to the larger class-sized audience. Out of respect for our school-based colleagues, I asked the students not to use the name of the students, teachers, or school in their writing or in our discussions.

I encountered two problems. First, the intimacy/vulnerability of the private journal was diminished by making it part of a public forum. Students no longer felt free to air their questions or vent their frustrations. When the audience changed, so did the nature of their writing. As a result, students did not feel safe when they were asked to write for this new audience. Second, each student's experience was so varied that I was unable to isolate common themes for discussion. Some students focused on technical problems, some on practical problems, and others on emancipatory problems (McIntyre, Byrd, & Foxx, 1993). I felt overwhelmed by the diversity of the observations and unable to focus class discussion in a way that included everyone.

Semester II

In the next semester, I decided to continue to use the journal for class discussions. I strongly believed that the journal was the best vehicle to integrate the two course components. Unfortunately, the strength of my belief blinded me to the students' need for private conversation. In order to focus class discussions I provided a structure to guide student writings in terms of similar field-based events. The writing guides consisted of weekly themes that directed students to reflect and write on special education, multicultural education, classroom atmosphere, and assessment. I hoped this structure would provide a thematic strand I could link to assigned readings. I especially hoped the themes would focus class discussions on student experience.

The first problem I encountered was that the themes were rarely coincident with the students' experiences. For example, on days when students were to observe events associated with special education, nothing significant would happen involving special education. The second problem I encountered was dull writing. I believe that my requirement to write about a particular topic and to publicly share the writing caused students to filter what they shared with the entire class. The observation journals became little more than daily logs (Thomas, 1995). Finally, I realized that public sharing and structured themes had damaged one of the most successful assignments of the course.

What I learned from these two semesters of attempted change was that transporting classroom observations into campus-based discussion was extremely difficult. I confirmed that teaching is a private and personal endeavor that is difficult to share. As I planned for the third semester of reform, I vowed to dispense with the thematic writing guides and to return the journal to its former private status. This decision left me in doubt about what vehicle I could use to transport field experience into the class discussions.

Semester III

For the third revision I decided to focus on educational case studies (Shulman, 1992; McAninch, 1993). I toyed with the idea of assigning students to write their own case studies, however, Shulman's (1992) description of the difficulties she experienced in teaching teachers how to write cases convinced me that it was beyond the scope of the course. Instead, I selected a variety of cases from Silverman & Lyon (1991) that were consistent with the themes I had previously chosen to guide the journal writing. I felt that case studies would provide a set of common experiences that could serve as the central focus for classroom discussion. In an effort to re-capture the positive aspects of the field experience and make them part of the campus based discussion, I instituted a fifteen minute period of informal small group conversations about field experiences each week. In effect, this gave the students time to swap stories and to confirm their experience with one another. However, these discussions seldom resulted in prolonged reflection, discussion, or journal writing. At best, these sessions helped students confirm what they thought, rarely were they pushed to reconsider their beliefs.

There were a number of problems with this third revision. First, my decision to use case studies to focus class discussions dispensed with my original goal to integrate the field-based experiences into the campus-based discussions. Reading about the field experiences of others dismissed the relevancy of the students' own field experiences. Second, when students compared what they read to what they experienced, they came away feeling the case studies were flat and contrived. Third, oral sharing of field experience was an important activity because it gave students an opportunity to validate their own experience without feeling judged. However, because these experiences were only shared in small groups, there was little opportunity to use these experiences to guide reflection and to question initial beliefs.

What do I hope to achieve? (The plan)

I felt discouraged and unable to come to grips with how to achieve my goal to integrate personal experience with group discussion and reflection. The difficulty students expressed was that they did not want to publicly compromise their relationship with their supervising teacher or their field-based students, and they did not want to publicly divulge their own fears, frustrations, concerns, and questions. The students' feelings matched my own. It seemed to me that the journal provided my only access to students' field-based experiences. Realizing the folly in making journals public, I opted for an antiseptic approach by using case studies. The problem I faced with case studies was that by using them I ignored the students' real experiences.

My goal to integrate the relevancy and meaningfulness of the field experience into the classroom discussions had failed. I was caught in a Catch-22. My efforts were focused on teaching students through their social construction of meaning from field experience. This effort was in direct conflict with the widely held belief that teaching is a private and personal act. My social constructionist approach pitted the public nature of learning against the private nature of teaching.

Until now, all of my attention was directed toward the curriculum--I had not considered my own role or the roles I scripted for my students. My awakening to this concern was initiated by reading of Paolo Friere's Pedagogy of the Oppressed (1970). It helped me to focus on my own values, attitudes, and beliefs about teaching by introducing me to the banking concept and the problem-centered concept of teaching.

The banking concept was a metaphor Friere (1970) used to describe traditional pedagogy. Under this concept the teacher holds all the wealth of knowledge and distributes it to the impoverished students. Friere described the banker teacher as the one who "chooses the program content, and the students (who were not consulted) adapt to it" (p. 54). By maintaining a tight grip over the curriculum, I had ignored the most powerful teaching idea at my disposal--posing relevant problems. Unknowingly, I had supported what I abhorred--the banking concept of education. Problem-posing placed the student in the central position of deciding what questions they wished to address. According to Friere's view, "the teacher is no longer merely the-one-who-teaches, but [the] one who is himself taught in dialogue with the students, who in turn while being taught also teach (p. 61)."

Friere's words helped me reconceptualization my dual role as teacher/student. Embracing a problem-posing approach meant replacing my teacher-centeredness with student concerns. This approach replaced professor knowledge (as the stuff to learn) with student knowledge (as the stuff to analyze and inform practice). Placing student concerns over instructor choice meant re-evaluating my role in the class. This was a slow process because it meant my own professional identity was at stake (Volkmann & Anderson, In Press). By giving up my teacher-centered expertise, I also gave up my security of knowing the answers to all the questions. I exchanged that security for casting myself in the position of reflective practitioner who struggled along with the students to find the best solutions to pedagogical problems. It meant giving up contrived problems for real-world problems. I realized that if I wanted the class to change, then I had to change: My beliefs about teaching and learning and my role as professional educator had to change (Cohen & Ball, 1990). As I challenged my own thinking about my role as teacher, I challenged my students' thinking about their role as student.

Based on this new perspective, I decided on three new directions for the course: change the purpose of the course; involve students in the selection of readings; and conceptualize a new field-based assignment that embodied my reconceptualization: the vignette. My hope was to help students develop reflection as a habit of mind that could result in changed thinking and doing.

Fourth Revision: Implementing of a Problem-Centered Pedagogy

The old purpose of the course was to give students an opportunity to experience teaching in order to help them make an informed decision about becoming a teacher. I realized early in my work that the vast majority of students believed they could be successful at teaching. Few students changed their minds as a result of the course. If a student had a good experience with their supervising teacher, then they had no reason to change their minds. If they had a poor experience with their supervising teacher, then they used this experience as an example of what not to do as a future teacher.

I recognized that the power of the field experience was its potential for teaching students about themselves and about teaching. Simply experiencing the field experience did not teach the students about themselves. Unless students examined their field experiences critically as a problem-posing experience, then the introspective, educational value of that experience would be lost. This new purpose recognized and respected the field experience as a paradoxical event: one that was experienced privately by everyone in the class. What I needed to do was to create an atmosphere within the classroom where students could share what was personally trouble-some without feeling personally vulnerable or at risk.

The power of the field experience was its potential for teaching students about themselves and about teaching. Simply experiencing the field experience did not help students understand themselves or challenge their thinking. Unless students examined their field experiences critically as a problem-posing experience, then the introspective, educational value of that experience would be lost. This new purpose recognized and respected the field experience as a paradoxical event: one that was experienced privately by everyone in the class. What I needed to do was to create an atmosphere within the classroom where students could share what was personally trouble-some without feeling personally vulnerable or at risk.

What Ethical Issues are Associated With the Use of Vignettes?

The ethical issues are complex. They involve a variety of beliefs about the teacher's right to privacy, professional respect, the sanctity of the classroom, and feeling valued. Discussing vignettes of local classroom events in university classrooms is potentially dangerous. However, if done with care, the risks of creating ethical dilemmas is reduced.

Teachers value their classroom privacy. The history of this privacy has been well documented (Jackson, 1968; Lortie, 1975; Waller, 1932/1961). Liebermann and Miller (1992) found that teachers enjoyed working in private because their mistakes remain hidden. The teachers who volunteer for the field experience program know in advance that practicum students will be discussing classroom events. The nature of these discussions is communicated to these teachers. The purpose of the written assignments and follow-up discussions is to help students develop and maintain a reflective attitude about teaching. I describe the vignette assignment to participating teachers and I assure them that the names of teachers, students, and schools are not used in the writing or in the discussions. Furthermore, I assure them that the primary focus is on events rather than on the teacher. In the three semesters I have used vignette assignments, I have experienced no negative reaction from any of the 100 teachers who host our students.

Implications For the Use of Vignettes in A Problem-Centered Approach to Teacher Education

The vignette assignment in concert with a problem-centered approach to teacher education may be illustrated more clearly if compared to a teacher centered/traditional approach to teacher education. Traditional teacher education programs do not help students examine their underlying assumptions about teaching. These implicit (hidden) assumptions are what make students feel they already know how to teach. Unless these assumptions are challenged, students' implicit beliefs remain hidden and students enter teaching feeling their role as student is similar to their role as teacher.

The traditional model of teacher education implies that teacher educators know their students' implicit beliefs. The problem-centered approach places the task of finding solutions in the hands of future teachers. By expecting these future teachers to reflect on their experience, to question naive conceptions of teaching, to provide expert analysis, and to develop personal theories they are learning a life-long habit of reflection (Connelly, & Clandinin, 1985).

The purposes of traditional reform are for the improvement of institutional practices--curriculum, management, communications, testing, writing behavioral objectives, etc. The purposes of reform in problem-centered teacher education is for teachers to develop theoretical attitudes that address teaching dilemmas and search for personal/professional solutions. Furthermore, teachers and students are looked on as equals in the pursuit of rational practice, and teaching and learning are treated as interchangeable terms.

The traditional research program is objective in nature, working toward certain generalizable procedures that can be adopted whole-scale through institutional reform. The problem-centered research program is individual and subjective. It works toward the education of individuals who are not only interested in solving immediate problems, but are interested in learning more about self and addressing moral problems. The research is personal in nature and is focused on real-time problems. This research is cyclical, never-ending, and product-less (hermeneutic).

Traditional assessment of future teachers consists of checklists of expertise and descriptions of skills all teachers must possess. Problem-centered assessment explores the future teacher's practice of reflection and seeks ways to embed assessment into the learning activities.

Traditional teacher education programs look upon field placements as damaging and undoing all the habits and attitudes central to the campus-based work. Problem-centered teacher education hopes to involve host teachers in the same discussions of problem identification and resolution by inviting teachers to reflect on the problems they identify.

Characteristic	Traditional	Problem-Posing
Beliefs	The teacher educator disregards student beliefs and tells students what to know and believe.	The student identifies his/her beliefs about teaching and reflects on them.
Reform	Work to improve institutionalized practices.	Address teaching dilemmas and search for personal and professional solutions.
Research	Work toward generalizable procedures that can be adopted whole-scale through institutional reform.	Work is personal in nature and is focused on real-time problems.

Assessment	Traditional assessment of future teachers consists of checklists of expertise and descriptions of skills all teachers must possess.	Problem-centered assessment explores the future teacher's practice of reflection and seeks ways to embed assessment into the learning activities.
Field Experience	Field placement is damaging and undoes all the habits and attitudes central to the campus-based work.	Field placement invites host teachers to reflect on the problems identified by practicum students.

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Example #1: Staying On Task

I was observing in a class in a relatively large school. The students in the class are mostly freshmen. The class is first year biology and many of the students are obviously not paying attention to the class lesson. Mr. Q is a student teacher in the class and the students are supposed to be doing a lesson using a computers. One particular student was messing around with the computer and distracting the students around him. He was not doing the lesson as he should have been. The student teacher asked him twice to stay "on task" and to finish the lesson. The teacher explained that the questions at the end of the lesson would be on the exam. The student looked at the student teacher and laughed and said that biology is not important and neither was the lesson they were doing. The teacher sat down next to the student and gave him a quiet reprimand and explained to him the importance of the computer lesson. As soon as the teacher left the student was again fooling around and hitting the keys. He looked at me to see if I was watching. The teacher again sat next to the student and did not leave until the student had completed one part of the lesson. The student did not do well on the quiz at the end of the lesson. It turned out that the student simply did not understand the material and that is why he did not want to do the lesson.

Question: How can a teacher tell if a student is acting up because he does not understand the lesson or if there is another reason involved?

The Problem: A student is banging on the computer keys. His actions disrupt other students, disrupt the teacher, and show disregard for school property. Some teachers might respond to the behavior without looking for the cause. The trouble-maker is acting out because he does not understand the computer lesson. Unfortunately, he has chosen to demonstrate his need for help through his negative actions. I believe that students should never be punished for learning problems. Punishment will not help him learn. On the other hand, this kind of disruptive behavior should not go unaddressed.

My response: (Approaching the student privately and speaking quietly) "You are disturbing other students and you have disturbed my attention to their needs. Do not bang on the computer keys. If you need help, raise your hand. Now, since I am here, I will help you get started."

Example #2: Right Or Wrong

After Mrs. H had passed out the exam that the class had taken a few days earlier, one student asked for her to clarify something on her paper. As Mrs. H. looked at the paper, the student pointed out that a correct answer was marked wrong. (When Mrs. H. grades papers, she marks through the incorrect answer and puts the correct one next to it.) Since it was close to the end of the period, Mrs. H. agreed to look at it later. When I came in during her prep period, she showed the paper to me and asked for my opinion. I could not tell whether the pencil marks were on top of the red ink or visa versa, Since it was hard for both of us to tell with the naked eye, Mrs. H. decided to look at it through a magnifying glass. In our minds, however, we both doubted that the student had the correct answer before because why would a teacher mark out an answer and put the same one next to it. After inspecting the answer under the magnifying glass, Mrs. H. knew that the pencil marks were on top of the red ink so the answer was in fact wrong. The student was a little upset that she did not get away with cheating, but she will probably think twice before doing that again.

Question: To what extent should a teacher go to determine whether or not a student has changed an answer after a paper has been graded? What would you have done?

Example #3: A Stroll in the Classroom

Mrs. A was giving a leaf identification test, The best way she felt to give the test was to pass the specimens around the room, giving the students approximately a minute to answer the coordinating question. This method works if the students are willing to follow directions and listen to the teacher. It is common knowledge that during a test students should not get out of their seats and walk around the classroom, Student X did that very thing. He got out of his seat during the test and strolled around the classroom until Mrs. A saw him. She told him to pass in his paper and return to his seat because it was apparent that he was finished with his test. He told her he would sit down. The test paper wasn't handed in, and no other action was taken to punish him for not following basic testing procedures.

Question: Do students learn to follow directions when no action is taken if they don't? Is anything learned from hollow threats?

DEVELOPING AND ACTING UPON ONE'S CONCEPTION OF THE NATURE OF SCIENCE: A FOLLOW-UP STUDY

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Introduction

Science educators and major science education organizations are increasingly advocating the preparation of scientifically literate students (e.g., American Association for the Advancement of Science [AAAS], 1990, 1993; National Research Council [NRC], 1996). An adequate understanding of the nature of science (NOS) is a central component of scientific literacy (Klopfer, 1969; National Science Teachers Association [NSTA], 1982). Indeed, helping students develop adequate conceptions of the NOS is a perennial goal of science education and can be traced back to the turn of the century (Central Association of Science and Mathematics Teachers, 1907). However, despite the longevity of this goal and the efforts undertaken to enhance learners' views of the NOS, research has consistently shown that students and teachers are generally not able to articulate the meaning of the phrase "nature of science," and to delineate the associated characteristics of science (Duschl, 1990; Lederman, 1992, among others).

The present study is a follow-up of an earlier investigation (Abd-El-Khalick, Bell, & Lederman, in press). Both studies highlight the central role of science teachers in helping K-12 students develop adequate conceptions of the NOS by focusing on the relationship between teachers' conceptions of the scientific enterprise and their classroom practice. And while both studies share several commonalties in terms of focus, rationale, and methodology, the present study features a somewhat different intervention that was based on the results of the previous study. Before proceeding, we turn to explicate our definition of the NOS and highlight the assumptions that have guided research related to the relationship between teachers' conceptions and their classroom practice.

The NOS

The NOS typically has been used to refer 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. We believe, however, that most of the disagreements about the definition of the NOS are irrelevant to K-12 instruction. These disagreements are generally far too abstract for K-12 students to understand and far too esoteric to be of immediate consequence to their daily lives. For example, the notion of whether there is an objective reality or only mental constructions is, perhaps, only of importance to the graduate student in philosophy. There is, however, an acceptable level of generality regarding the NOS that is accessible to K-12 students. Moreover, at this level of generality, clear connections can be mapped between students' knowledge about science and necessary everyday life decisions regarding scientific claims (Lederman & Abd-El-Khalick, in press).

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.

In this regard, it is important to note that the NOS is often conflated with science processes. And even though science processes and NOS overlap and interact in significant ways, it is nevertheless important to distinguish the two. Scientific processes are activities related to the collection and interpretation of data, and the derivation of conclusions (AAAS, 1990, 1993; NRC, 1996). For example, observing and inferring are scientific processes. On the other hand, the NOS refers to the epistemological commitments underlying the activities of science. Consequently, an understanding that observations are constrained by our perceptual apparatus and are inherently theory-laden is part of an understanding of the NOS.

Assumptions Guiding Previous Research

In the context of the efforts undertaken to enhance students' conceptions of the NOS, recent research has focused on helping science teachers develop the desired understandings of the NOS (Aguirere, Haggerty, & Linder, 1990; Brickhouse, 1989, 1990; Brickhouse & Bodner, 1992; Bloom, 1989; Briscoe, 1991; Gallagher, 1991; King, 1991; Koulaidis & Ogborn, 1989). These efforts were guided by two assumptions. The first was that teachers' conceptions were significantly related to their students' conceptions. The second assumption was that teachers' conceptions directly and necessarily translate into their classroom practice (e.g., Cotham & Smith, 1981; Nott & Wellington, 1996).

The assumption that teachers' conceptions directly translate into their teaching practices, while intuitive, has not been validated by empirical research (Mellado, 1997; Tobin & McRobbie, 1997). Research studies have been consistent in indicating that the relationship between teachers' conceptions of the NOS and their classroom practice is more complex than originally assumed (Lederman & Druger, 1985; Lederman & Zeidler, 1987). Several factors have been shown to mediate and constrain the translation of conceptions of the NOS into practice.

instruction (i.e., teaching about the NOS before teaching how to teach the NOS) provided by our Master of Arts in Teaching (MAT) program on preservice teachers' pedagogical preferences for teaching the NOS and the translation of those teachers' conceptions of the NOS into instructional practice.

The Contexts of the Studies and the Intervention

The contexts within which the present and previous investigations were conducted are pivotal to understanding the nature and the logic of the current intervention and useful for interpreting the ensuing findings. Thus, prior to describing the intervention, a discussion of the MAT program and its courses, as experienced in the previous study, is provided.

The Context of the Previous Study

Preservice teachers proceeded through the MAT program as a cohort. The program began during Summer term with courses in educational psychology, foundations of education, legal and mutli-cultural issues in education, instructional technology, science methods (part I), and science pedagogy. It is during the first science methods course and the science pedagogy course that students were initially exposed to the NOS.

As far as the NOS is concerned and as was the practice for the past few years, during the pedagogy and science methods (part I) courses, the NOS, its central role in the reform efforts, and its implications for teaching science in the classroom were emphasized. Using activities that can be employed with secondary level students, preservice teachers were explicitly taught several aspects of the NOS. These aspects are identical to those delineated at the beginning of this report. Preservice teachers directly experienced or discussed approximately 15 different NOS activities (see Lederman & Abd-El-Khalick, in press).

The fact that the aforementioned NOS activities are appropriate for use with secondary school students was intended to bridge what was done in the science methods course with what the preservice teachers were expected to do in the secondary science classroom setting. Thus, it was reasoned that while the preservice teachers were learning about the NOS, they were also experiencing a model for its classroom implementation. As such, for the preservice teachers enrolled in the program, there was a simultaneous and constant interplay between learning about specific aspects of the NOS and learning how to teach those aspects to secondary school students.

During Fall term, preservice teachers completed a part-time, field-based internship (20 hours per week). In the first few weeks of the internship, the preservice teachers were involved in a variety of professional activities. This involvement was intended to acquaint them with the multi-faceted nature of school life and the variety of roles that teachers play within this intricate social fabric. As such, preservice teachers attended the Fall faculty inservice, and science department, school faculty, teacher/parent, and school board meetings. They were also involved in alternative faculty assignments, such as curriculum and committee work, and additional assignments, such as hall duty, bus duty, cafeteria duty, etc. Preservice teachers also conducted in-depth interviews with specialized school personnel about classroom management, plans of assistance, discipline policies, instructional resources, etc. In addition, preservice teachers performed a variety of classroom and instructional activities, including making seating charts, keeping track of attendance, correcting exams, conducting homework discussion and review sessions, and teaching a few mini-lessons (10-15 minutes). During these weeks, preservice teachers planned a science unit complete with objectives, instructional activities, and assessment and evaluation strategies. Next, preservice teachers assumed full instructional responsibility (under the close supervision of their mentors) for two weeks during which they taught their planned unit. Overall, during the Fall internship, preservice teachers were exposed to almost all the aspects related to high school science teaching.

During Fall term, in addition to the internship, preservice teachers completed coursework in teaching and learning, science methods (part II), microteaching, and science subject matter. Within the second science methods course, the NOS was revisited. Again, heavy emphasis was placed on the various aspects of the NOS and how to teach them. It should be stressed that the MAT program emphasized an explicit approach to teaching the NOS. In this regard, it is noteworthy that most of the earlier efforts undertaken to enhance students' views of the NOS shared an underlying assumption. This assumption, largely intuitive and not supported by empirical findings, was that students learn about the NOS "implicitly" through participation in science-based inquiry activities. Most of the curricular reform efforts of the 1960s and 70s emphasized hands-on, inquiry activities on the premise that through "doing science" students would also come to understand the NOS. However, research studies that focused on the effectiveness of the 1960s and 70s curricula have not lent support to this assumption (Durkee, 1974; Tamir, 1972; Trent, 1965; Troxel, 1968).

During Winter term, preservice teachers completed a full-time internship. They assumed full instructional responsibility for 12 weeks during which they taught at least two different science courses. This internship was associated with a weekly campus-based seminar. Finally, during Spring term, preservice teachers completed courses in counseling, curriculum, assessment and evaluation, and two subject matter courses.

The Context of the Current Study and Intervention

The intervention in the present study was informed by the results of the previous study. Particular among those results was that preservice teachers in the previous cohort claimed to have taught the NOS through a variety of instructional approaches that contradicted the message promoted by the MAT program (an explicit, activity-based approach). Specifically, these instructional approaches often conflated the NOS with science processes, were restricted to hands-on activities that lacked explicit connections to the NOS, and ignored the NOS as a cognitive outcome.

The participants in the previous study clearly possessed the overriding view that students would learn the NOS implicitly by engaging in science related activities or, put simply, by "doing science." This view appeared to have been the result of, or alternatively resulted in, an intricate interaction between participants' perspectives on the NOS, pedagogy, and instructional outcomes. A number of preservice teachers in the previous cohort appeared to confuse the NOS with the processes of science. As far as pedagogy was concerned, the participants expressed a preference for the use of manipulative activities. For many of them, a demonstration or historical episode followed by an in-depth discussion related to the NOS was less valued than activities that directly involved students in manipulating materials. Finally, participants did not seem to recognize learning about the NOS to be a cognitive outcome. The interaction among these aspects seemed to have equipped participants with a strong pedagogical conception whereby they conflated a process or inquiry oriented teaching approach with an attempt to teach the NOS "implicitly."

The researchers argued that within the context of the MAT program, as outlined in the earlier section, preservice teachers were learning two lessons related to the NOS simultaneously (Abd-El-Khalick et al., in press). Preservice teachers were learning abstract subject matter that was novel for most of them (i.e., the NOS), and at the same time expected to learn how to address it instructionally in a future setting (i.e., secondary classrooms), the components of which they had little or no concrete functional knowledge. Therefore, it was quite possible that the simultaneity of learning about the NOS and how to teach it, and the different contexts within which the preservice teachers learned about the NOS (i.e., science methods courses) and in which they were expected to apply their knowledge (i.e., secondary classrooms), were two factors that contributed to compromising their ability to transfer their conceptions of the NOS into their instructional practice.

The researchers reasoned that a possible approach to mitigate this concern would be to temporally separate developing preservice teachers' conceptions of the NOS and learning to teach these conceptions to their students. Such a separation would not only allow time for preservice teachers to elucidate and articulate their understandings of the NOS, but would situate any attempts to promote their abilities to teach the NOS in the realistic context of the secondary classroom. Thus, the intervention in the present investigation was concerned with the sequence of the NOS-related activities in the MAT program rather than with the kind or quality of these activities.

During the first science methods course (Summer term), the preservice teachers in the present investigation were introduced to the NOS using the aforementioned activities. The course instructor (the second researcher) made a concerted effort to exclude or postpone any discussion related to teaching the emphasized aspects of the NOS to secondary students. Next, during the second science methods course and following the conclusion of the Fall part-time internship (and prior to the Winter full-time internship), the NOS was revisited. Participants' understandings of the various aspects of the NOS were elicited, discussed, and clarified. Then, a concerted effort was made to clarify the distinction between science process skills and aspects of the NOS.

A thorough discussion about teaching the NOS followed. First, the rationale behind and the significance of teaching the NOS, initially discussed in the Summer pedagogy course, was reemphasized. Second, a concerted effort was made to help the participants realize that it is highly unlikely that their students would learn about the NOS implicitly through participation in science activities. The importance of giving explicit attention to the NOS was underscored. An explicit, reflective, activity-based approach was emphasized. Participants were made aware that the same kind of activities that were used in the program to help them learn about the NOS can be used to teach their secondary school students about the various aspects of the NOS. Finally, the participants were encouraged to think about the NOS as a cognitive instructional outcome. The implications of this consideration for planning and classroom instruction were highlighted.

Thus, the experiences of the present cohort with NOS instruction provided in the MAT program differed in two major ways from the experiences of the previous cohort. First, participants in the present study had more time (approximately two months) to come to terms with what were to most of them new notions about the scientific endeavor. Second, discussions related to teaching aspects of the NOS to secondary school students, including the distinction between science processes and NOS and the importance of according explicit attention to the NOS, followed the participants' initial firsthand experience with teaching secondary school science and were situated and related to this more concrete context.

It should be emphasized that the aforementioned modification of sequence was the sole difference between NOS-related instruction provided in the MAT program to participants in the present and the previous studies. As such, to the extent to which participants in these two studies were comparable and their experiences in the program were similar, any differences between the two cohorts' NOS instructional practices can be plausibly attributed to the intervention. In this regard, it should be noted that the program has fairly strict and consistent admission criteria and that the NOS instruction received by both preservice teacher cohorts was provided by the same instructor (the second researcher).

The purpose of this study was to elucidate the relationship of preservice teachers' conceptions of the NOS with their planning and student teaching. Additionally, the study assessed the influence of temporally separating teaching preservice teachers about the NOS and teaching them how to address it instructionally in their classrooms. The main questions of the present investigation were:

1. What are preservice science teachers' conceptions of the NOS prior to student teaching?
2. Do preservice teachers emphasize the NOS in their planning and/or teaching?
3. What are the factors that explain preservice teachers' emphasis on the NOS in their teaching?
4. What is the influence, if any, of temporally separating teaching preservice teachers about the NOS and teaching them how to address it instructionally on preservice teachers' pedagogical preferences for teaching the NOS and the translation of those teachers' views of the NOS into teaching practices?

Method

Participants

Thirteen preservice secondary science teachers, eight male and five female, all Caucasian, participated in the study. Participants were enrolled in a fifth-year, MAT teacher preparation program in a rural, mid-sized state university. Their ages ranged from 23 to 33 years with an average of 27 years. Two of the participants, a male and a female, did not complete the program and the various phases of the investigation and were thus excluded from the study. All of the 11 remaining participants had earned BS degrees (seven in biology, two in physics, one in geology, and one in general science) and three had earned MS degrees (two in biology and one in geology) prior to joining the program.

Procedures

Data collection spanned most of the calendar year in which participants were enrolled in the program. Numerous data sources were used to answer the questions of interest. At the end of Fall term and prior to the Winter student teaching internship, the preservice teachers were administered an open-ended questionnaire to assess their conceptions of the NOS. The questionnaire comprised seven items that were intended to assess preservice teachers' 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 (see Appendix). Later, follow-up interviews were conducted to validate participants' responses to the questionnaire (Lederman & O'Malley, 1990). The questionnaires were not analyzed until the end of the data collection process. Thus, the researchers were not aware of the participants' views of the NOS prior to completing the analysis of other data sources. This approach was undertaken to insure the validity of any inferences made regarding the relationship between participants' conceptions and their instructional practice.

Other data sources included copies of participants' daily lesson plans for the Winter 12-week internship, as well as classroom videotapes, and supervisors' weekly clinical observation notes. Each participant's portfolio, a requirement for the completion of the MAT program, was also used as a data source. Portfolios consisted of two full units (12 to 16 days each) of instruction, including rationales, goals, objectives, lesson plans, assessment instruments, and videotapes of classroom instruction. These data sources were analyzed to document whether the preservice teachers planned to teach or taught the NOS explicitly.

During Spring term, following student teaching and the completion of the analysis of portfolio and instructional materials data, participants were interviewed. The interviews were semi-structured and aimed to validate responses to the NOS questionnaire and generate in-depth profiles of the participants' views. The interviews also aimed to corroborate the previous analysis of other data sources, to elucidate the factors that explain preservice teachers' instructional emphasis on the NOS, and to explicate the participants' pedagogical preferences for teaching the NOS. A core set of questions guided the interviews. These questions, with the exception of item 8, were similar to those used in the interviews conducted in the previous study:

1. What do you think are the most important things to emphasize in your teaching? Why?
2. What in your opinion is the NOS? What makes science different from other disciplines of inquiry (religion, philosophy, etc.)?
3. (At this point interviewees were provided with their questionnaires, were asked to familiarize themselves with their earlier responses and to comment on and clarify these responses.) What did you mean by your response to question number (1-7)?
4. Do you think that teaching the NOS is important? Why? (or Why not?)
5. Did you teach the NOS? If yes, how? Why did you teach the NOS in that particular way? (If not, why?)
6. Did you do enough? Can you elaborate?
7. Did your students learn the NOS? How do you know? Did you assess your students' understanding of the NOS? How did you do that?
8. What, in your view, is the best way to teach the NOS to your students?
9. How will you deal with the NOS when you have your own class?

The interviews typically lasted for one hour. Digressions were common, and the participants' lines of thought were followed and probed in depth. All interviews were audiotaped and transcribed for analysis.

Data Analysis

The first and third researchers and a doctoral student analyzed the data. Given that the second researcher provided all instruction related to the NOS, it was a concern that this individual would consider data as partially evaluative. Consequently, a doctoral student in science education replaced the second researcher for the analysis of data.

Prior to analyzing the entire data set, three identical, randomly selected samples of each of the data sources were independently analyzed. These data were searched for evidence that the preservice teachers planned to teach and/or taught the aforementioned aspects of the NOS during their student teaching. The specific explicit instances in which participants addressed the NOS in their planning and/or teaching were documented. Instructional objectives and/or activities that overtly addressed one or more aspects of the NOS were taken to be explicit instances. Implicit instances of planning to teach and/or teaching the NOS were disregarded. This decision was based on the lack of empirical support for the effectiveness of an implicit approach for enhancing students' conceptions of the NOS (Durkee, 1974; Tamir, 1972; Trent, 1965; Troxel, 1968). Implicit instances included isolated statements inserted into an instructional sequence and activities that were consistent with a particular view of science, but did not explicitly focus students' attention on the NOS. For example, engaging students in a laboratory investigation was not considered an explicit instance of teaching the NOS unless the activity was followed with a discussion that emphasized one or more aspects of the NOS.

Results of these analyses were compared in order to establish inter-rater agreement on identifying explicit instances of planning to teach and/or teaching the NOS. Better than 90% agreement among the three researchers was achieved. Finally, the remaining collected documents and videotapes were distributed among the three researchers and analyzed for explicit instances of planning to teach and/or teaching the NOS.

The interview transcripts were analyzed by all three researchers. The analysis aimed to validate participants' responses to the NOS questionnaire, generate in-depth profiles of the participants' views, corroborate the previous analyses of the other data sources, elucidate the factors that explain preservice teachers' instructional emphases on the NOS, and to ascertain the participants' pedagogical preferences for teaching the NOS. In this analysis, each participant was treated as a separate case. Data from each interview was used to generate a summary of the participant's views on, and conceptions of the aforementioned issues. This process was repeated for all the interviews. 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.

Results

The results are reported in two separate sections. The first focuses on the participants' conceptions of the NOS. The second section elucidates the participants' instructional practices related to the NOS.

Conceptions of the NOS

Analysis of responses to the open-ended questionnaire, as validated in the interviews, indicated that participants' views of the NOS were, in general, consistent with the contemporary conceptions of the scientific enterprise emphasized in the MAT program. Most of the preservice teachers demonstrated adequate understandings of the empirical and tentative nature of science, the distinction between observation and inference, differences between scientific theory and law, and the role of subjectivity and creativity in science. A few were able to explicate a role for social and cultural factors in the construction of scientific knowledge. These conclusions are elucidated and supported with quotations in the sections that follow.

The Empirical Basis and Tentativeness of Science

Like the preservice teacher cohort in the previous study, the majority of the participants expressed the belief that science is empirically based. The following are representative of the preservice teachers' comments:

> What makes science different is that there is evidence and the use of actual, physical phenomena in the derivation of, and development of explanations. It is not solely based on things that we think of, it is based on things that actually occur. Potentially there is some manipulation of something in the physical realm in order to derive knowledge. (T #10)

> Science is a different way of knowing . . . because the ideas in science are supposed to be either observable or consistent with observations that can be made relating to the idea that you have. (T #7)

Furthermore, many participants emphasized that this empirical nature sets science apart from other ways of knowing, such as art and religion:

> Scientists use their imagination to think of hypotheses to explain how the world works. They would then look for data to confirm their hypotheses. Artists, on the other hand, use their imagination to create structures that don't need to be exhibited in the real world. (T #7)

> Art, like mathematics, is under no obligation to conform to the "real" universe we observe. Science is. (T #3)

The tentativeness of scientific theories was explicated by all participants. Fewer explicitly described the tentativeness of scientific laws, but it was clear from their responses that participants viewed scientific knowledge as tentative:

> Scientific ideas . . . have to be flexible so that they can be altered or changed in the future. (T #7)

> Theories definitely change. But we teach them because they tend to be the dominant paradigm of the time and are reflective of where scientific thought is currently going. Both [theories and laws] are tentative. (T#10)

As with the cohort in the previous investigation, many participants associated the tentativeness of science with its empirical nature. Thus, the accumulation of new evidence was the principal explanation stated for theory change:

> Theories are based on evidence and sound, logical thinking. Students can be helped to realize when more evidence is found that doesn't fit the original theory, then it must be changed and that is acceptable. (T #8)

> I think that science is a changing body of knowledge, as new evidence becomes available things are discarded or modified. Science today isn't what it was a hundred years ago. (T #4)

Some participants also noted that theories may change as scientists recognize new ideas and relationships:

> Theories can be modified, expanded, or discarded based on new observations/ideas. (T #3)

> Yes, theories can change as scientists revise their explanations for mechanisms of the world. Theories change as scientists discover relationships they had not noticed before. (T #7)

<u>Creativity and Subjectivity in Science</u>

Most participants acknowledged the role of creativity in the construction of scientific ideas. They believed creativity and imagination to be integral to scientific investigation:

> Sure. Scientists, by nature of the design of experiments, use creativity for choice in selecting what data to collect. Then they select how to collect it. A second area of creativity is data analysis. Choice of analysis method is an art form. Depending on what the scientist wants to do with the data, she can choose from an array of statistical tests. The last area of creativity is interpreting results. Once numbers have been crunched, the scientist attempts to use them to explain what went on in the investigation. Creativity abounds. (T #8)

> Scientists use creativity and imagination to draw bigger conclusions and ideas from what they have experimented with. Leaps of intuition require both creativity

and imagination. (T #4)

> Breakthroughs in both science and art have often been accomplished by people who were capable of mentally stepping outside of the current ways of seeing and thinking about things. (T#3)

Participants differed somewhat on the specific roles they ascribed to creativity during scientific investigations. Many noted that creativity plays a significant role during the interpretation of data:

> Scientists use their creativity and imagination during their analysis of the data . . . in the interpretation and application of their data. (T #5)

> Yes, for example, in the Feynman video [British Broadcasting Corporation, 1981], he has to create the math to interpret his observations. (T #2)

> I think that this is just a part of science--you have data and there is where imagination and creativity come into play. The answer is not going to jump at you from the data, you have to work the data and see what it means. (T #10)

Other preservice teachers, however, did not limit creative thinking in scientific investigations to data interpretation. They also ascribed roles for creativity in experimental design, data collection, and data analysis:

> Plans and designs may be altered during data collection based on "what ifs"... creative thoughts. Afterward? Certainly. Creativity and imagination allow us to perceive patterns and ask questions. (T #3)

> During data collection, one might be imaginative in seeing new/unexpected direction for the research as data comes in. After data is collected, one must be creative in seeing how the data can be interpreted within a rational cognitive framework. (T #6)

Participants also advanced subjectivity as a factor contributing to the tentative nature of science. They dismissed the view that science is a completely objective and rational activity. Subjectivity, including the individuality of scientists, their backgrounds, and their beliefs, was thought to play a major role in the development of scientific ideas:

> Yes, scientists are human. Humans hold natural biases. Therefore, scientists have different opinions . . . Differences in opinion or training can lead to different

interpretations of the data.
(T #8)

> The truly revolutionary ideas have sprung in those moments of pure intuition and dogged pursuit, and foolish good luck where a deeply personal relationship to your task at hand is required. (T #1)

> Some scientists believe one thing and as more information becomes available, new ideas come into vogue. However, other scientists can't as easily give up old ideas. (T #10)

Theoretical Constructs in Science

One of the items on the open-ended questionnaire was concerned with the model of the atom, how certain are scientists about that model, and what kinds of evidence they use to support it (see Appendix, Question #2). This question focused on the difference between observation and inference. Most participants demonstrated a clear understanding of this difference:

> I don't know what an atom looks like. But, I know that what it supposedly looks like has been inferred from a lot of data over the years. So, the inference that I've been taught is that an atom consists of a small, very dense nucleus that contains charged particles, and that there are negatively charged electrons in orbit around the nucleus in certain configurations. (T #6)

> I think that in terms of the actual size and shape of the particles and those things are just for the use of the model and they are a teaching device rather than an actual perception of the atom. (T #10)

In contrast to the previous cohort, all of the preservice teachers in the present study were able to clearly elucidate the distinction between theories and laws. Their responses clearly demonstrated that they understood that laws are statements or descriptions of discernible patterns in observable phenomena and that theories are inferred explanations for those phenomena:

> A law describes relationships between observed phenomena. For example, Boyle's law says that a gas's pressure is inversely proportional to its volume. The law describes what we see. A theory infers from observations to explain what is occurring and why. So, the kinetic theory says we see this relationship because matter is made up of particles. It infers this explanation of *why* we see the Boyle relationship. (T #6)

> Law is a statement of understanding that reflects directly observable phenomenon and patterns in that phenomenon. It pertains to the observation itself and not an explanation of how it happens, e.g., the law of gravity. Theory is an explanation of why law occurs, e.g., a theory of gravity might explain how gravity occurs--why do objects attract. (T #10)

> A theory is a big idea from a rather small but growing base of evidence, an inference that may never be proven precisely and beyond a shadow of doubt. A law is a prediction of future events based on a wealth of direct evidence readily available and accessible to almost everyone. (T #1)

Moreover, unlike many of the participants in the previous study, the preservice teachers in the present study did not believe in a hierarchical relationship between theories and laws. This misconception that stems from the failure to recognize that theories and laws are different kinds of scientific knowledge, is exemplified in the belief that theories become laws once enough evidence has been accumulated in their favor. Only 1 of the 11 participants in the present cohort expressed such a belief: "Laws are merely theories that have been scrutinized to the point that very few or zero flaws/exceptions have been found" (T #4).

<u>The Social and Cultural Embeddedness of Science</u>

The effects of the social and cultural contexts in which scientific investigations are embedded were mostly overlooked by the participants in the previous study. In fact, only one participant of that cohort mentioned that culture influences scientific practice. The preservice teachers in the present investigation referred more frequently to this aspect of the NOS. In particular, they described two types of cultural influences. The first involved the influences of the larger society upon the scientific enterprise:

> Both [science and art] gain and lose acceptance according to current social trends. (T #4)

> There are different societal views . . . religion might come into play . . . People are different and think in different ways and are going to interpret data in different

ways. (T #9)

> There are lots of changes over time in what we call politics, religion, and economics. The role of religion, the role of economics, all of these things have changed. And so, the way we go about accumulating our knowledge is going to change. Even our goal, is going to change considerably over time, because it changes how we view ourselves and the natural world, our political role with each other, our economic role with each other, as well as theology. These things have a bearing on the intent to do science, the intent, really, to do anything, but science is in there, too. (T #1)

The second way in which cultural influences were described had to do with the culture of the scientific enterprise itself. Many participants described how this "micro-culture" determines what counts as science:

> I think that within science you have peer review, you have to publish things or you have to present things. Here others have a chance to refute it if they don't believe it. There is a system through which knowledge seems to travel before it becomes accepted. (T #11)

> Scientific production and creativity are held within peer imposed bounds. In other words, experiments and results and theories stemming from them are expected to use logical and defensible reasoning. If not, peers are likely to reject the work, not due to individual like or dislike of the product, but due to it being "unscientific." (T #8)

In summary, although each of the 11 participants had not mastered all seven aspects of the NOS emphasized by the MAT program, the majority was able to demonstrate adequate understandings of these concepts. In particular, the preservice teachers demonstrated elaborate understandings of the empirical basis of science, tentativeness, the distinction between observation and inference, differences between scientific theories and laws, and the role of subjectivity and creativity in science. A few referred to the social and cultural embeddedness of the scientific endeavor. This represents an improvement over the cohort of the previous year, who were less able to distinguish between scientific theories and laws and who scarcely mentioned social and cultural influences.

Planning for and Teaching the NOS

Not only did the participants in the present study attain more complete understandings of the targeted aspects of the NOS than those in the previous study, more of them considered the NOS an important instructional goal and attempted to teach it purposively. This view was reflected in their responses to interview questions, their lesson plans, and their classroom instruction.

When asked what they would emphasize most in their teaching, the preservice teachers, like the participants in the previous study, offered a variety of instructional outcomes. All of the respondents stressed science content as an important component of science instruction. Additionally, the processes of science and critical thinking figured prominently in the responses. Many ascribed importance to engaging students in interesting and relevant material. Other requisite goals of instruction included helping students develop an appreciation for science, teaching them to work cooperatively in groups, and teaching appropriate classroom behavior.

More importantly for the purposes of the present study, the NOS was frequently mentioned as an important instructional goal. Several respondents stressed teaching science content with less emphasis on rote learning of factual knowledge and more emphasis on unifying themes, including the NOS, science processes, and the impact of technology on science and society. Additionally, two of the participants emphasized teaching for scientific literacy that, according to their descriptions, included an understanding of the NOS. Overall, 5 of the 11 preservice teachers included the NOS or aspects of the NOS among their primary teaching goals. This compares to 3 out of 14 preservice teachers in the previous study who mentioned the NOS when asked what was important to emphasize in their teaching. It should be noted that this question was asked first before it became evident to the participants that the NOS was the focus of the interview. This lessened the possibility that participants' responses would be biased by their recognition that the NOS was the topic of subsequent questions. Thus, even in the absence of directive questions or cues, the NOS was notable in the preservice teachers' list of important instructional outcomes.

Later in the interview, the participants were asked directly whether they thought that teaching the NOS was important. All 11 answered affirmatively and justified their views. Several thought that the NOS makes learning science more interesting. Others posited that the NOS provides the background necessary for critical thinking and problem solving. Still others discussed how teaching the NOS provides a more authentic context for understanding scientific knowledge and its progression. Finally, some students justified teaching the NOS by linking it to scientific literacy and the need for citizens to make informed decisions in a highly technological society. As one participant put it, "students will be consumers of science, so they ought to be educated consumers" (T #3). The preservice teachers' rationales for teaching the NOS were similar to those offered by the previous cohort.

It should be noted that, just as with the previous cohort, the preservice teachers in this study may have perceived the question on the importance of teaching the NOS as "loaded." The three researchers had served as instructors in several of the preservice teachers' science education courses. In some of these courses, the second research provided explicit instruction on the NOS and how to teach this construct to K-12 students. Additionally, during their student teaching experience, many of the participants had been supervised by at least one of the researchers. Thus, they were likely aware of the researchers' interest in the NOS. Finally, as previously mentioned, this question was asked late in the interview, giving the participants the opportunity to ascertain the researchers' focus and respond accordingly. Therefore, it was important to consider their actual planning and classroom instruction along with their responses.

The NOS in Classroom Instruction

In order to characterize the participants' classroom instruction about the NOS, participants were specifically asked during the interviews whether they taught the NOS during their student teaching experience, what aspects of the NOS they emphasized, and how they had taught it. In response to these questions, 9 of the 11 participants indicated that they had, indeed, addressed the NOS in their instruction. Subsequent analysis of the participants' lesson plans, portfolios, and supervisors' field notes substantiated the preservice teachers' descriptions of NOS instruction. Explicit references (as previously defined) to most of the activities and NOS concepts the participants had described were recorded in their lesson plans and/or supervisors' field notes. This represents a substantial improvement over the previous cohort, where similar analyses of collected materials revealed that only 3 of the 14 participants' lesson plans contained explicit references to the NOS.

Aspects of the NOS that the participants described having taught were tentativeness, creativity, subjectivity, the use of indirect evidence in the construction of scientific models, and observation and inference. One participant described a lesson where she taught the tentativeness of scientific explanations by using a "black box" demonstration. In this lesson, the preservice teacher emphasized that her students needed to modify their inferred explanations when new data became available and then related this to the tentative nature of scientific theories. Another student described how he used a cat toy as a prop to teach about creativity in science:

> Oh, there was another thing I did once. I had this cat toy that is a sphere that rolls around on its own and when it hits something it spins around and heads the other way. I had my physics students draw what they thought was inside and theorize about it. I related it to indirect observations and that science is a creative enterprise. So yeah, that was a real explicit mention of the nature of science. (T #3)

A third student used an overhead transparency of a perceptual Gestalt (it appeared to be the duck/rabbit picture) to teach about creativity in the interpretation of data:

> We did do some explicit activities to get at subjectivity . . . . I put up pictures on the overhead, for example, where they were looking at the same picture, and somebody might see a duck and somebody might see a rabbit . . . . I made explicit reference to [the concept that] different explanations from the same set of observations is an integral part of science. And I actually had them say that before I did. So, I asked them, "Well, what does this have to do with science?" And a couple of students were able to recognize that we're looking at the same thing, but we're seeing different things. This is not a question of right or wrong, it's a question of different points of view. (T #1)

A couple of participants described how they used "black box" activities to teach about the use of indirect evidence in the construction of scientific models and knowledge:

> I did some lessons that were directly related to the nature of science, such as the toilet roll thing. I did that with them and talked about the use of modeling about what we know and what we think we know--how to figure out what is there inside the roll even though we cannot see it. And that is what science is, trying to find explanations for things that we cannot see; that we don't necessarily have direct evidence for. And then I tried to weave this into different lessons in which I talked about models. (T #10)

> Yes, I did [teach the NOS]. In some cases it was explicit. I used some of [the professor's] activities, such as the tracks and the tube and the cans. Not all at once, but over time . . . . With the tubes and the cans it was basically an idea of here is the data, make up something that fits the data . . . . If we can't look inside how can we tell who is right? (T #11)

<u>Pedagogical Preferences for Teaching the NOS</u>

It is interesting to note how often the terms "explicit" and "directly related" were used by the participants to describe how the NOS was addressed in these examples of classroom instruction. This clearly differs from the responses of the previous cohort, who generally did not describe explicit teaching of the NOS, but actually claimed that the NOS could best be taught implicitly through doing science. It appears that many of the participants in the present study had internalized the importance of teaching the NOS explicitly:

> I think that most of the [aspects of the NOS] we are talking about are fairly abstract . . . and I don't think that students were making those connections and I think therefore that if this was something that you mean to teach then you need to make it explicit and let the students know. (T #10)

References to the necessity of explicit NOS instruction were evident even in the case of those preservice teachers who indicated that they did not adequately address the NOS:

> [Whether I taught the NOS] is debatable. I intended to teach something about the nature of science. When I intended to do it, the activity was structured so that it would be a sort of a nature of science activity, and at the end I didn't do enough of the discussion and questioning to really kind of build it up, so that students can make the correlations. (T #4)

> I don't think that I did very much. I think that I verged on the nature of science, but in order to do it I have to make things more explicit. (T #7)

Despite these preservice teachers' apparent belief that the NOS should be taught explicitly, there was at least one NOS topic that the majority addressed in an implicit manner. By far, most of the NOS lessons described by the participants focused on contrasting observations and inferences. These lessons generally involved students in making observations from pictures and demonstrations, then inferring explanations from what they observed:

> I did a couple of demonstrations that were nature of science demos, like the siphon, where the students were talking about observation and inference and talking about what those are. (T #8)

> I did some observations and inference stuff . . . . I would ask them to do some observations and then asked them to draw some inferences. (T #4)

Analysis of the relevant lesson plans and supervisor field notes showed that some of the preservice teachers failed to debrief these observation/inference activities in regard to the NOS. Either these preservice teachers believed that the scientific processes of observing and inferring were in themselves aspects of the NOS, or they were simply emphasizing processes rather than NOS. The latter interpretation seems to be more plausible given that some participants emphasized developing students' science process skills as a primary goal for their teaching. Moreover, participants did not seem to conflate teaching science process skills with teaching aspects of the NOS.

Indeed, the evidence suggests that the majority of the participants in the present study did not confuse teaching science processes with teaching the NOS. This represents a major difference from participants in the previous study who clearly held the view that students would learn the NOS implicitly through instruction in science process skills. By contrast, several participants in the present study explicated a clear understanding of the distinction between NOS and science process skills:

> I tried to touch on just very general [aspects of the NOS], where it was, you know, appropriate. But I think I was more concerned with process . . . you know, nature of science does not equal process . . . . I think that's what I was doing more. (T #2)

Besides the observation/inference lessons, which may or may not have been the result of such confusion, there was only one clear example in which a participant described teaching science process when asked how he taught the NOS:

> I [taught the NOS] a little bit. I did a pendulum lab. I showed them what a pendulum was . . . . Then I had them design an experiment to see what affected the period . . . In my physical science class, there were times I discussed experimental design and kind of what scientists do . . . . I didn't have the physical science class come up with any [experiments]. (T #9)

NOS Objectives and Assessment

One particularly revealing characteristic of the participants' lesson plans was the lack of explicit instructional objectives related to the NOS. While a few NOS-related objectives were found in the collected lesson plans, most of these were considered inadequate for one of two reasons. The first reason concerned objectives that dealt with observation and inference. Like the lessons on observation and inference previously described, these objectives were aligned more closely with science process than NOS. The objectives focused on the definition and application of these terms with no reference to how they related to the generation of scientific knowledge. The objective: "Students will be able to make observations and draw inferences based on these observations" (T #6) was a case in point. The second reason was that many of the NOS objectives lacked clarity. For example, it was difficult to see how the objective: "The student will be able to grasp some of the NOS through discussion and conclusion of observed phenomena" (T #10) could effectively guide NOS instruction and assessment. Given these qualifications, analysis of the participants' lesson plans revealed only three objectives that clearly and explicitly related to the NOS.

Lack of explicit NOS objectives was likely to impact other aspects of instruction. This was evident in the case of assessment. The MAT program emphasized the use of specific instructional objectives in constructing valid assessments of student learning. With specific NOS objectives absent from their lesson plans, the participants' failed to assess student understanding of those aspects of the NOS that were emphasized. Only one of the participants described assessing aspects of the NOS when asked how she knew whether her students learned about the NOS. In her case, the participant asked students to respond to open-ended questions dealing with subjectivity in classification:

> In the taxonomy unit I [assessed an aspect of the NOS]. I had questions in student assignments and exams, why do classification systems change? Why would two scientists come up with different classification systems? (T #8)

None of the other participants described assessing the NOS, despite their earlier assertions of the importance of teaching the construct and the fact that many had taught lessons about the NOS. Follow-up questioning revealed several reasons for this omission. Some said that they simply did not consider the NOS when constructing their tests. Others cited the fact that they had spent too little time addressing the NOS in class to include it in their assessments. Still others expressed confusion about how the NOS could be assessed. Both the most common and revealing response, however, related to the lack of NOS objectives in the participants' lesson plans:

> I did not do an effective job of actually writing nature of science knowledge level objectives and assessing them as nature of science . . . . And the test always followed pretty close to the written objectives, rather than hidden objectives. (T #3)

> I didn't assess it because I didn't have it as an objective . . . . And when I did teach the nature of science I saw it as a kind of a break from the regular rhythm of teaching science. Because here was something different from what the students had experienced in learning about science before. (T #10)

> I taught it. I didn't teach it rigorously . . . and I didn't assess it . . . . It was just basically because I was down in the groove of this unit and it wasn't in my objectives. I mean, I had these objectives for the whole unit and I was like, "OK, this lesson will fit in this way." Then I started writing the lesson and I thought, "Oh, this would be a good place to talk about[the NOS]." I didn't start with those objectives, but then as I started planning it, I added it. So, not having it in the objectives was one factor in making me forget to assess it. (T #6)

Constraints to Teaching the NOS

The participants were asked if they thought that they had adequately addressed the NOS during their student teaching. None of the 11 preservice teachers thought that they had. The participants elucidated several constraints to explain why they thought the instructional emphasis they accorded the NOS was not congruent with their beliefs.

Though fewer in number, these constraints were comparable to those offered by the previous cohort. The most common of these had to do with the participants' perception of conflict between teaching the NOS and teaching other aspects of science such as content and science process skills. Some of the participants believed that they were pressured to cover these latter aspects:

> We have a lot of content to cover in biology and to take time to do anything else

would take a lot of time from content. (T #11)

> The nature of science does not necessarily increase one's ability to do science, and in doing the nature of science you are certainly taking time away from teaching students how to do science as a vocation. The conflict is between what the teacher wants to do and what businesses or society wants students to be able to do . . . . The company might say, I don't really care what you know about how science is created or how scientific discoveries are embedded in the culture--it may be interesting, but I don't care. (T #1)

A related obstacle was the issue of time. Participants believed that teaching the NOS required substantial time and that this prevented them from keeping up with other teachers:

> I think to do nature of science activities that are meaningful, it takes a lot of time. You have to let students go through things, discrepant events and things like that. (T #5)

> I don't think I did enough . . . . I had to cram the whole year of physical science class into one semester. I was further behind than most of the teachers. So I was playing catch up most of the time. (T #9)

Participants also described a lack of confidence in their own understandings of the NOS. Many noted that they themselves were still in the process of articulating their conceptions of various aspects of the NOS:

> Well, first I think that I didn't have a good understanding of [the NOS]. Throughout the past year I have come to develop a better understanding of it . . . If I'm given more time to process it I can include it. (T #7)

> I think I am more comfortable teaching the content than I am the nature of science because I understand the content better. I'm getting more understanding of the nature of science, so I could do a better job now. I think that was part of it. (T #9)

> Fear, pretty much, is what [prevented me from teaching the NOS]. I mean, it's hard to go. Well, I'm just going to teach something that I don't really have a handle on, but I'm going to give it a shot, OK? It's not what this program taught. This program taught if you want to teach something, you need objectives, you need a plan, you need and an assessment strategy. You can't do that with something you don't, like, totally understand. (T #1)

Another important factor was the nature of the student teaching experience. Participants explained that they had to keep up with their mentor teachers while covering similar content. They felt they were given little choice in deciding what their students should learn:

> I felt a bit pressured by my mentor to cover certain content and I found little time to work in the nature of science. I thought that I had to move along to cover a certain amount of specific content. (T #10)

> When I was out in the school as an intern, I tried to keep pretty close to what my mentor was doing. I didn't stray a lot from that. In the future I will have more say as to what my curricular objectives are going to be, as opposed to being plopped into the middle of an existing curriculum and trying to incorporate what I do into it. (T #3)

Finally, several of the participants described being so overwhelmed by the student teaching experience in general that they failed to focus on what they considered important to teach:

> I don't think that I did [the NOS] very much. I was kind of trying to keep my head above the water, not being able to think about the things that I would like to do . . . I definitely think that I have room for improvement. (T #7)

> You know, I was student teaching. I was focusing a lot on what I needed to do. What's the content? What's the logistics? How can I do this so that it's engaging to my students? How can I manage this? You know, survival day by day . . . . It was very hard to pull my focus away from just getting through it. When you're new, you're putting so much into just making the thing run. I mean, you want the enterprise to run and everything to be managed well enough to be engaging to the students. And you're being told that this content has to come through. I guess I lost sight of bigger objectives in the over-all planning . . . There was a definite disconnection between how I was planning and what my philosophy is. (T #6)

In summary, the participants in the present study demonstrated a more thorough understanding of how to teach the NOS than those in the previous study, both in terms of richer discourse, pedagogical preference for an explicit activity-based approach, and in terms of explicit instruction. Fewer confused teaching the NOS with teaching science process, and almost all did not hold the view that the NOS should be taught implicitly. On the other hand, the participants were unwilling or unable to include explicit NOS objectives in their lessons, which in turn, appeared to negatively impact their ability to include the NOS in their assessment strategies.

Constraints to teaching the NOS were comparable to those described by the previous cohort. The participants focused on perceived pressure to cover content and keep up with mentor teachers, lack of time, lack of confidence in their understandings and ability to teach the NOS, and their feelings of being overwhelmed by the student teaching experience.

Discussion and Implications

As with our previous investigation, participants appeared to have developed accurate conceptions of the tentativeness and empirical nature of science, the role of subjectivity and creativity in science, and the distinction between observation and inference. Additionally, the participants in the present study demonstrated adequate understandings of the distinction and relationships between scientific theories and laws, and, to a lesser degree, the social and cultural embeddedness of science. Consequently, we are convinced that the activities we have developed and used coupled with explicit debriefing can effectively promote understandings of the NOS consistent with national reforms.

Perhaps, the most important finding of this investigation is related to the particular intervention derived from our previous investigation. Research has clearly shown that teachers' conceptions of the NOS did not necessarily translate into classroom practice (Brickhouse, 1990; Duschl & Wright, 1989; Hodson, 1993; Lederman, 1992; Lederman & Zeidler, 1987). The same was true for the participants of our previous investigation. Consequently, one of the primary purposes of this investigation was to pursue ways in which we can make this translation more likely. Participants in the previous investigation confused science processes with aspects of the NOS and believed that students can learn the NOS through implicit teaching approaches, that is, through "doing science." We felt these problems were related to a general conflation of cognition and pedagogy. It appeared that this confusion was a direct result of the format and structure of the NOS instruction provided in the MAT program. In particular, preservice teachers were asked to learn about the NOS (i.e., a cognitive goal) as well as how to teach the NOS (i.e., a pedagogical goal) simultaneously. Understanding the NOS and learning how to teach the NOS are both abstract and their abstractness was further exacerbated by the lack of context within which the preservice teachers of the previous study had to work. It seemed reasonable that a focus on learning *about* certain aspects of the NOS should occupy the activities at the beginning of the program. Delaying attention to the teaching of the NOS to secondary students until the end of the Fall term provided more time for the preservice teachers to assimilate their knowledge of the NOS and, because it followed firsthand experience with teaching secondary students, provided a more concrete context for learning *how to teach* the NOS.

The results of the present study seem to clearly indicate that this temporal separation was successful. In general, the preservice teachers no longer confused scientific processes with aspects of the NOS. In addition, they clearly understood, with few exceptions, the importance of explicit instruction if one is attempting to help students develop an understanding of the NOS. Indeed, most of the participants in this investigation fared better than those in our previous investigation in terms of teaching the NOS explicitly. Furthermore, participants who did not teach the NOS were aware of the situation and emphasized the importance of using explicit techniques when teaching the NOS.

However, much work is left to be done. Although the participants of this investigation taught the NOS explicitly more frequently, they failed, as preservice teachers in the previous investigation, to make any attempts to assess student understandings. The preservice teachers frequently noted that they did not assess student understandings because they did not include NOS objectives among their unit or daily lesson objectives. In a sense, although the NOS was addressed, it was not formally planned (if written objectives is an indication of formal planning) as part of instruction. This situation appeared to have compromised any attempts toward assessment. This is not surprising given that the MAT program consistently and continuously emphasizes the critical role of clearly stated objectives in the development of assessment tasks. As such, more effort needs to be placed upon having preservice teachers include NOS among their primary instructional objectives.

Prior research has shown that teachers' intentions are related to classroom practice (Lederman, 1995). At this point, we do not have convincing evidence that our participants have internalized the importance of teaching the NOS. They certainly verbalized that teaching the NOS is important and we have been successful at getting them to include the NOS in instruction. However, it seems that if an individual has strongly internalized the importance of teaching a certain outcome, such an outcome would necessarily become part of that individual's instructional objectives and assessment practices. As a start, efforts should be made to assign preservice teachers the task of including NOS objectives and assessment strategies in written plans, to include these plans as part of their required work samples, and to implement their plans during student teaching experiences. It is through such an approach, assuming that the preservice teachers are successful, that we may begin to make progress in having preservice teachers sincerely internalize the values inherent to teaching the NOS as articulated in the national reforms.

Finally, it is important to consider that preservice teachers may not be the most productive sample to accomplish the goals of the reforms including those concerning the NOS. The concerns and constraints (whether real or perceived) of beginning teachers has been well documented (Hollingsworth, 1989) and continue to be problematic. Such concerns, including pressure to cover content and keep up with mentor teachers, lack of time, lack of confidence in understandings and ability to teach the NOS, and feelings of being overwhelmed by the student teaching experience were explicated once again by our participants. The NOS continues to be one of the most difficult constructs to teach to K-12 students. Expecting novice teachers whose primary concerns are necessarily classroom management, rapport with students, instructional organization, etc., to effectively internalize the primacy of the NOS and to consistently address it as a curricular theme is an expectation that is likely developmentally inappropriate.

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Appendix

Nature of Science Questionnaire

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 scientific theories. Defend your answer with examples.

   (This question aims to assess understandings of the tentative nature of scientific claims, why these claims change--students mostly attribute such change solely to the accumulation of new facts, and the role that scientific theories play in science.)

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 what an atom looks like?

   (This question aims to assess understandings of the role of human inference and creativity in science, the role of models in science, and the notion that scientific models are not copies of reality.)

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

   (This question aims to get at a common misconception about the relationship between the products of science. Most students believe in a hierarchical relationship between the two whereby theories become laws if and when enough evidence has been accumulated in their favor. Moreover, many ideas are usually expressed by students as they attempt to delineate the difference between theories and laws.)

4. How are science and art similar? How are they different?

   (This question aims to assess understandings of the role of creativity and imagination in science, the necessity of empirical evidence in generating scientific knowledge, and the cultural and social embeddedness of science.)

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.

   (This question aims to assess understandings of the role of human creativity and imagination in science and the phases at which students believe that these play a role. For instance, students often note that creativity plays a role in designing experiments. Creativity in this sense turns out to be "resourcefulness" or "skillfulness." Students rarely say that creativity is used in data analysis in the sense that scientists are, for instance, "creating" patterns rather than "discovering" them.)

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

   (This question aims to assess understandings of the role of empirical evidence in generating scientific knowledge.)

7. Some astronomers believe that the universe is expanding while others believe that 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?

(By posing a scientific controversy and stressing the fact that scientists are using the same data and yet coming up with differing explanations, students are invited to think about the factors that affect scientists' work. The question aims to assess students beliefs about such factors which might range from personal preferences and bias to differing theoretical commitments to social and cultural factors.)

THE IMPACT OF TRAINING AND INDUCTION ACTIVITIES UPON MENTORS AS INDICATED THROUGH MEASUREMENT OF MENTOR SELF-EFFICACY

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Induction programs are being developed and implemented in response to state policy, like that of California, which calls for support and assessment of new teachers. This is in response to the alarmingly high attrition rate of teachers. For California, the need for induction is made more complex by legislation which encourages decreased class size, thereby increasing the demand for teachers. In fact, it is predicted that in order to meet the demand for teachers, 20,000 new teachers are necessary. This is far beyond the annually credentialed 5,000 teachers.

Trends like that in California make induction a critical component of new teacher development. While a typically prepared new teacher benefits from support through the induction years, those new teachers who have circumvented the traditional preservice program in states' efforts to staff classrooms may be in more desperate need of support.

To address the need for induction, often times the mentor teacher is turned to as the support provider. Teachers seen as experts within the classroom are often selected to serve as mentors to new teachers at their own or other school sites. However, expertise within one's own classroom does not guarantee the ability to support others in their professional growth. Thus, mentor preparation programs are needed to develop mentoring abilities for the purpose of induction.

Developing mentor support can become a major financial investment for a school district. Inservice programs must be implemented to develop the mentors themselves. Additionally, in order to serve new teachers, the mentors must be released from their classroom duties through the use of substitute teachers or full time replacements.

To protect the investment of district funds and mentor time, mentor preparation programs must be able to develop effective mentors. The ultimate benefit of mentor effectiveness will be more effective for beginning teachers--which has long term payoff for districts and their students.

While much attention focuses on retention of teachers as a measure of induction success, mentor teachers and their abilities have received little investigation. There appears to be no research which studies the impact of mentor preparation programs on specific mentoring abilities. Those developing mentor preparation programs in addition to those districts utilizing them have a need for additional measures of program effectiveness. This paper reports on the impact of induction on mentors as indicated through the measurement of mentor efficacy beliefs.

The Mentor Efficacy Scale (Riggs, 1997) was utilized within this study to measure the self-efficacy and outcome expectancy beliefs of mentor teachers. Investigation of teacher beliefs is vital to a more complete understanding of teacher behavior. Koballa and Krawley (1985) defined belief as "information that a person accepts to be true" (p.223). This is differentiated from attitude which is a general positive or negative feeling toward something. Attitudes may be formed on the basis of beliefs, and both attitudes and beliefs relate to behavior.

An example based upon Koballa and Crawley's (1985) description, can be made to demonstrate the relationship between beliefs, attitudes, and behavior with regard to the mentor teacher context. A mentor teacher judges his/her ability to be lacking in regard to new teacher support (belief) and consequently develops a dislike for interacting with assigned new teachers (attitude). The result is a teacher who avoids the mentoring process if at all possible (behavior). In other words, mentors with the highest mentor self-efficacy would predictably devote more time and attention to their mentoring responsibilities. This strong interrelationship of beliefs, attitudes, and behavior dictates the inclusion of belief measurement within mentor teacher research.

Theoretical Framework

Beliefs have been closely linked to behavior with respect to phobics and self-efficacy (Bandura, 1977). Bandura suggested that people develop a generalized expectancy about action-outcome contingencies based upon life experiences. Additionally, they develop specific beliefs concerning their own coping abilities. Bandura called this self-efficacy. Behavior, for Bandura, is based upon both factors. Behavior is enacted when people not only expect certain behaviors to produce desirable outcomes (outcome expectancy), but they also believe in their own ability to perform the behaviors (self-efficacy).

Behavior might be predicted by investigating both types of expectancy determinants. Bandura (1977) hypothesized that people high on both outcome expectancy and self-efficacy would act in an assured, decided manner. Low outcome expectancy paired with high self-efficacy might cause individuals to temporarily intensify their efforts, but will eventually lead to frustration. Persons low on both variables would give up more readily if the desired outcomes were not reached immediately.

Related Research

When applied to the study of mentor teacher effectiveness, Bandura's theory might cause one to predict that mentors who believe new teachers can be positively influenced by effective mentoring (outcome expectancy beliefs) and who also believe in their own mentoring abilities (self-efficacy beliefs) should invest more time and effort with their new teachers than mentors who have lower expectations regarding their ability to influence new teacher growth (Gibson & Dembo, 1984). These beliefs are defined herein as mentor teacher efficacy beliefs and refer to the extent to which mentor teachers believe they have the capability to positively affect new teachers' professional growth.

These definitions have origins within the teacher efficacy belief literature. Within these works, two dimensions of teacher self-efficacy, that of Teaching Efficacy (Outcome Expectancy) and Personal Teaching Efficacy (Self-Efficacy) have been defined and utilized in subsequent studies. Several studies suggest that these teacher efficacy beliefs may account for individual differences in teacher effectiveness (Armor, Conroy-Osequera, Cox, King, McDonnel, Pascal, Pauley, & Zellman, 1976; Berman & McLaughlin, 1977; Brookover, Schweitzer, Schneider, Beady, Flood, & Wisenbaker, 1978; Brophy & Evertson, 1981). Student achievement has also been shown to be significantly related to teacher efficacy belief (Ashton & Webb, 1982).

In previous studies, the dimension of "Personal Teaching Efficacy" has been used to predict teacher behavior with most accuracy (Ashton, Webb, & Doda, 1983). Yet, the dimension of Personal Teaching Efficacy as defined within the teacher efficacy belief literature differs from Bandura's original description of self-efficacy and outcome expectancy as distinct variables. Researchers have defined this dimension as a combination of both self-efficacy and subsequent contingencies between performance and outcomes (outcome expectancy). Some items inadvertently contained a combination of both dimensions. This confused the analysis, and resulted in a heterogeneous scale. If teachers score low on such a scale, the reason might be due to their belief that they cannot teach or their belief that students can not learn even given effective teaching or a combination of the two.

While teacher efficacy may be helpful when investigating teachers' beliefs about their abilities to influence student learning, a mentor specific instrument would be more informative when studying teachers with regard to mentoring. A specific measure of mentor teacher efficacy beliefs should be a more accurate predictor of mentoring behavior and thus more beneficial to the change process necessary to improve the induction process. It is also consistent with Bandura's (1981) definition of self-efficacy as a situation specific construct.

Purpose

The purpose of this study was to analyze the impact of a mentor training program on mentors involved within a state-funded teacher induction program.

Method

Mentors involved within the Inland Empire Beginning Teacher Support and Assessment Program (IE-BTSA) were a major part of the sample assessed (N= 95). These mentors completed a year-long intensive program to better support their induction of new teachers. Additional mentors, not involved in IE-BTSA, were also assessed (N=127). Although these mentors might have taken extensive mentor training from their own district, they had not received any of the IE-BTSA training at the time their assessment.

The Mentor Efficacy Scale (MES) a self-report measure of 30 items was utilized to assess mentors' beliefs in regard to mentoring. The MES (see figure 1) consists of 2 subscales which measure both the outcome expectancy and the self-efficacy of mentors with regard to mentoring. Both scales demonstrate an adequate reliability: Self-Efficacy Subscale alpha= 0.87 while the Outcome Expectancy Scale alpha=0.77.

The MES asks mentors to reflect upon their mentoring abilities in 4 skill areas: personal, instructional, professional, and assessment. The first 3 of these areas are derived from current literature on mentoring (Field, 1994; Enz, 1992). Personal behaviors are defined as those which the mentor used to develop a trusting relationship and offer emotional support to the new teacher. Instructional behaviors refer to the mentor's ability to plan and implement instruction

Figure 1.

The Mentor Efficacy Scale

1.	If a new teacher is struggling, it is most often related to lack of effective mentoring.	SA A UN D SD
2.	I have problems facilitating my beginning teachers' understanding of their responsibilities as new teachers.	SA A UN D SD
3.	I can easily articulate the beliefs which underlie my teaching practices when I talk with beginning teachers.	SA A UN D SD
4.	The inadequacy of a new teacher's instructional program can be improved through good mentoring.	SA A UN D SD
5.	I'm not sure how to work with beginning teachers to identify a starting point for their professional growth.	SA A UN D SD
6.	I can connect my beginning teachers with ample educational resources.	SA A UN D SD
7.	When conferencing, I am able to promote the beginning teachers' own problem solving through good use of questioning.	SA A UN D SD
8.	When my beginning teachers have district-related concerns, I am able to facilitate their understanding and problem solving.	SA A UN D SD
9.	I wonder if I have the necessary skills to be an effective mentor.	SA A UN D SD
10.	The inadequacy of a beginning teacher's management system can generally be addressed through good mentoring.	SA A UN D SD
11.	I am able to use assessment to assist beginning teachers in observing their own professional growth.	SA A UN D SD
12.	I can use my knowledge of the development nature of teaching in my support of beginning teachers.	SA A UN D SD
13.	I am continually finding better ways to be a mentor to my beginning teachers.	SA A UN D SD

14. When conferencing with beginning teachers, I usually welcome their questions. SA A UN D SD

15. When I observe a beginning teacher's lesson, I find it it difficult to analyze what is happening. SA A UN D SD

16. When beginning teachers talk with me, I use good listening skills. SA A UN D SD

17. New teachers' instructional effectiveness is directly related to their mentors' coaching abilities. SA A UN D SD

18. I don't know how to use assessments to facilitate beginning teachers'own reflection for growth. SA A UN D SD

19. Mentors are generally responsible for the professional growth of their new teachers. SA A UN D SD

20. I am not very effective in monitoring my beginning teachers' professional growth. SA A UN D SD

21. If a principal comments that the new teacher is well-acquainted with school policies an procedures, it would probably be due to the performance of the teacher's mentor. SA A UN D SD

22. I struggle when I try to acknowledge the accomplishments of my beginning teachers. SA A UN D SD

23. When conferencing with my beginning teachers, I can communicate how our consultations have promoted my own professional growth. SA A UN D SD

24. I have difficulty managing my time so that I am available to my beginning teachers. SA A UN D SD

25. When a beginning teacher does better than usual in lesson planning, it is often because the mentor exerted a little extra effort. SA A UN D SD

26. Effective mentoring can help beginning teachers make developmental progress. SA A UN D SD

27. A new teacher's understanding of school policy can be developed through good mentoring. SA A UN D SD

28. Every new teacher can make incremental steps toward being a professional, given effective mentoring. SA A UN D SD

29. If new teachers are unaware of their accomplishments, it may be due to inadequate mentoring. SA A UN D SD

30. Mentors haven't done their job if their assigned new teachers have little understanding of school procedures. SA A UN D SD

Riggs, May, 1997.

while also being able to reflectively analyze instruction and promote these same abilities in others. Professional abilities refer to the mentor's ability to promote understanding of teachers' responsibilities, especially as they relate to policies and procedures.

The final skill area included was that of assessment, which refers to the mentor's ability to effectively assess the new teacher's strengths and weaknesses through a variety of means. The mentor then shares the information garnered with the novice teacher in a manner which promotes his/her own reflection and goal setting. Related dialogue should result in a professional goal and specific action plans for both the mentor and the new teacher. The assessment area was included since funded BTSA projects are expected to train and support mentors in their use of assessment to promote growth of new teachers.

Response Format and Scoring

The MES utilizes a Likert scale format. The response categories are "strongly agree", "agree", "uncertain", "disagree", and "strongly disagree". Scoring was accomplished by assigning a score of five to positively phrased items receiving a "strongly agree" response, a score of four to "agree" and so on throughout the response categories. Negatively worded items were scored in the opposite direction with "strongly agree" receiving a score of one. Item scores of each dimension were summed to calculate two separate scale scores for each respondent.

Results

IE-BTSA trained teachers were significantly more likely to have high self-efficacy with regard to their own ability to mentor (mean=77.32; t=5.50; $p < .00$) than were those teachers who had not participated in the training (mean=71.57). The outcome expectancy of these teachers did not differ.

When attention is focused on only those items which deal with assessment as a mentor skill, the difference between IE-BTSA mentors and mentors who have completed other trainings is quite evident. The following item results demonstrate a marked difference:

- Item: I am able to use assessment to assist beginning teachers in observing their own professional growth.

	Mean	t value	p value
IE-BTSA mentors	4.32	7.97	< .00
Non-IE-BTSA mentors	3.50		

- Item: I don't know how to use assessments to facilitate beginning teachers' own reflection for growth.

	Mean	t value	p value
IE-BTSA mentors	4.27	8.97	< .00
Non-IE-BTSA mentors	3.22		

- Item: I'm not sure how to work with beginning teachers to identify a starting point for their professional growth.

	Mean	t value	p value
IE-BTSA mentors	4.36	5.57	< .00
Non-IE-BTSA mentors	3.67		

- Item: When I observe a beginning teacher's lesson, I find it difficult to analyze what is happening.

	Mean	t value	p value
IE-BTSA mentors	4.31	3.50	< .00
Non-IE-BTSA mentors	3.98		

Conclusions

Results in this study indicate that a mentor trained within the IE-BTSA program is more likely to have higher self-efficacy with regard to their own ability to mentor new teachers. This is especially true with regard to their belief in their ability to use assessment as a means to promote new teachers' professional growth.

This outcome should cause others who are responsible for induction programs to seriously consider their own monitoring of their mentors' beliefs. Past research efforts in the area of self-efficacy have demonstrated this construct's relationship to performance. Within this study, we might predict that those mentors with the highest mentor self-efficacy would be most likely to spend time and effort on mentoring responsibilities, with more successful results.

Additionally, those who implement training programs for mentors or support providers could utilize the Mentor Efficacy Scale as one indicator of their program's effectiveness. One would hope that mentors completing a training program would have higher or at least comparable mentor self-efficacy to that with which they began the program.

The lack of difference in outcome expectancy beliefs of IE-BTSA and non IE-BTSA mentors is not alarming at this point. Other research efforts have also reported difficulties in impacting this construct through training efforts. While the self-efficacy sub-scale appears to be the most useful at this point in time, researchers are encouraged to continue assessment of mentor outcome expectancies. The result may be increased understanding of this belief area and its impact on mentor teacher behavior.

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MES Scoring Instructions

Step 1. Item Scoring: Score items as follows: Strongly Agree = 5; Agree = 4; Uncertain = 3; Disagree = 2; and Strongly Disagree = 1.

Step 2. The items listed below must be scored in reverse. Reverse scoring of the following items will result in high scores for those high in self efficacy and outcome expectancy beliefs and low scores for those low in self efficacy and outcome expectancy beliefs.

Item 2	Item 18
Item 5	Item 20
Item 9	Item 22
Item 15	Item 24

Step 3. Items for self-efficacy and outcome expectancy beliefs are randomly scattered throughout the MES. The following items are designed to measure beliefs of self efficacy:

Item 2	Item 13
Item 3	Item 14
Item 5	Item 15
Item 6	Item 16
Item 7	Item 18
Item 8	Item 20
Item 9	Item 22
Item 11	Item 23
Item 12	Item 24

The following items are designed to measure beliefs of outcome expectancy:

Item 1	Item 25
Item 4	Item 26
Item 10	Item 27
Item 17	Item 28
Item 19	Item 29
Item 21	Item 30

MEASURING THE SELF-EFFICACY OF UPPER ELEMENTARY AND MIDDLE SCHOOL TEACHERS: IMPLICATIONS FOR OUTREACH [1]

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For the past 20 years many initiatives involving science teachers at the pre-college level have focused upon professional development opportunities provided by organizations or universities during the summer months. Commonly, science teachers apply for summer institutes which may be held close to home or at great distances from their home school districts. Such summer institutes often include the following: stipends, funds for classroom supplies, college credit, travel costs, and a requirement to provide outreach in home districts. The design of institutes can, of course, be quite varied. Structure clearly can be dependent upon time, expertise of those overseeing the institute, requirements of funding organizations, or school schedules, as well as local/state/national standards. Increasingly the issue of state proficiency tests appears to be factored into the curriculum of many institutes. In the last five years, many groups appear to newly emphasize, or continue emphasizing, two added issues: (a) professional development sustained over time, and (b) the need for summer institute attendees to share their knowledge with peers (e.g., Ohio's State Systemic Initiative, Purdue University's Epicenter program, the Woodrow Wilson Fellowship Foundation).

In an effort to (a) investigate the mechanism by which "master" teachers instruct peers, and (b) explore ways to optimize professional development sustained over time, the National Aquarium in Baltimore conducted an extensive data collection. "Local" teachers who attended

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outreach programs provided by master teachers were surveyed during outreach and approximately one year later. The outreach was presented in districts throughout the United States. Data involving local teachers' self-efficacy, outcome expectancy, and ethnicity were collected, as well as the teachers' estimations of their students' economic status and ethnicity. By collecting such data, important information was revealed that can be used 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 the structuring of outreach which emphasizes local outreach using master teachers.

The Summer Institute

A recent National Science Foundation grant to the National Aquarium in Baltimore provided funding for multi-week summer institutes over a three-year period. Each summer institute was structured to prepare a national pool of teachers in the use of a Grades 5-7 curriculum entitled *Living in Water* (LIW). This curriculum has been developed, piloted, and revised over the past 10 years. The hands-on laboratory activities require a variety of supplies and are of varied durations. One of the activities, for example, involves the creation of an animal that will sink most slowly in the water once it is submerged. This lab requires a container that will hold water and other supplies that can be used to construct an animal (e.g., 35 mm film canister, aluminum foil, paper, nails, Styrofoam). All of the LIW labs can be conducted within a school's classroom, and students must not necessarily have access to lakes, rivers, or oceans. Presently, the curriculum is being used throughout the City of Baltimore and is utilized in many classrooms nationally.

The summer institute was planned, guided, and presented by the staff of the National Aquarium in Baltimore. These personnel included many individuals who have both a strong content level background and substantial experience in providing teacher outreach to a range of districts (i.e., urban, rural, low student socio-economic status (SES), high student SES).

The grant was structured so that each summer a new cadre of teachers would attend the institute. Each multi-week institute was designed so that the majority of the LIW curriculum could be practiced and discussed. In addition to testing all the hands-on activities, content background was provided to summer institute participants. During the last week of the institute, time was devoted to the planning of outreach. Master teachers (those attending the institute) received three university credits for completing the institute and a stipend. However, to receive a portion of their stipend, institute teachers were required to present and document outreach in their own region of the United States. In order to conduct their outreach obligations, summer participants were provided with some funding for supplies.

Data Collection

During the first full year of school following summer institute attendance, School Year I, each master teacher was required to present at least a single one-day outreach in his or her school district. Each master teacher developed his or her own plan and carried out publicity, as well as recruitment. The majority of master teachers were experienced teachers who could tap science teacher networks at the local, state, and national levels. Clearly, a range of constraints such as school schedules, building availability, and administrative support influenced each outreach presentation in terms of duration, day, and structure.

Prior to the start of each one-day outreach institute, every attending local teacher was required to complete the self-efficacy scale of Riggs and Enochs (1990). This instrument was constructed so that survey items work together to define the latent traits of outcome expectancy and self-efficacy. (*Note*: Numerous papers reporting data collected with this instrument have been presented at past AETS conferences.) Local teachers were asked to supply their names as well as their mailing address. After they completed the survey, the teachers were informed that during the next school year (School Year II) they would receive a follow-up survey. Master teachers were to stress that completion of both surveys would enable the National Aquarium to improve workshops and outreach programs offered to teachers.

During School Year II, all local teachers who attended the outreach were mailed a self-addressed, prepaid, follow-up survey to complete. The teachers were asked to supply additional information: (a) percentages of their students as a function of ethnicity (i.e., Asian, African-American, Hispanic, Pacific Islander, Native American, White), (b) percentages of their students as a function of economic level (i.e., poverty, low income, middle income, upper income), and © percentages of students as a function of geographic region (i.e., rural, rural/suburban, suburban, urban). In appreciation of their completing and returning the School Year II survey, the teachers were offered one of three free items. In total, 440 local teachers completed the survey in School Year I, while 225 local teachers completed the School Year II survey.

Data Analysis

Although a range of data analysis techniques can be utilized to evaluate survey data, local teacher outcome and self-efficacy measures were computed as outlined by Riggs and Enochs (1990). However, rather than using raw numerical values, teacher ratings were first converted to an interval scale using the probabilistic Rasch model (Wright & Masters, 1982). This technique has been used in other settings to evaluate item bank responses as well as attitudinal data. The recent 1997 Third International Math and Science Study test item bank has been evaluated using the Rasch model, as well as survey data from Ohio's State Systemic Initiative (Boone & Kahle, 1997). In addition to utilizing teacher measures based upon the two scales outlined by Riggs and Enochs, the following data were also used in this study: (a) teacher ethnicity, (b) student ethnicity, © student economic level, and (d) student geographic region. The goals of the data collection and analysis were (a) to better describe and understand the types of teachers who attended the one-day outreach offered by master teachers, and (b) to consider changes which occurred in local teachers' self-efficacy and outcome expectancy from School Year I to School Year II. By better understanding the types of teachers who attended the one-day workshops, future institutes with master teachers who will conduct outreach programs can be improved and better targeted.

Results and Implications

Of the master teachers trained at the summer institute held at the National Aquarium in Baltimore, all presented at least one outreach workshop. The high percentage of compliance probably was the result of careful summer institute participant selection and the linking of stipends with outreach presentation. It is probably most important to screen applicants, but if workshop participants are to follow-up with grassroots dissemination, then a link to stipends may be a very important mechanism insuring that workshops are presented.

Over 440 local teachers attended the outreach institutes presented by master teachers. All attending teachers were reported to have completed the surveys. Of these teachers, 225 completed follow-up surveys: 100% response rate at institutes, 50% response rate nine months to one year following the institute. No information other than name was collected from teachers during the one-day institute, thus this study considered only those teachers who completed both surveys. Although it is certainly true that much might have been learned about the population of teachers who attended the one-day institute but did not respond to the follow-up survey, it was decided to emphasize teacher data that also included student and school characteristics. That information was collected only with the second data collection.

Analysis of teacher ethnicity indicated the vast majority of local teachers were White (i.e., 6% African-American, 1% Asian, 4% Hispanic, 1% Pacific Islander, 85% White, 3% Unknown). Information from local teachers indicated that although a low percentage identified themselves in minority categories, many local teachers taught in predominately urban districts. These data suggest that more must be done not only to attract minority teachers to summer institutes, but more must be done to encourage participation in outreach provided by master teachers. Certainly, there are many plausible reasons for the low percentage of minority teachers in the follow-up survey sample. For instance, urban districts with a high percentage of minority teachers often have great teacher mobility which may result in a lower response rate. Also, teachers in districts undergoing great changes are often hesitant to invest their time and money in a curriculum that may be allowed one year, but not allowed the next year.

Although not all local teachers returned the surveys, an average return rate of 50% describes the response of the typical set of local teachers at each inservice. Although the response rate varied, in general, a representative sample of teacher surveys from each workshop was received.

Students of Local Teachers Attending Outreach Offered by Master Teachers

Local teachers were asked to report the ethnicity of the students they taught. Responses indicated that a very low percentage of Asian, Pacific Islander, and Native Americans were taught by teachers attending outreach offered by master teachers. This means that, in general, the students of local teachers were White, Hispanic, or African-American. Seventy-one percent of local attendees reported teaching 0-30% African-American students. The remaining local teachers reported similar percentages of African-American students in the following categories : 30-50% of all their students, 50-70% of all their students, 70-90% of all their students, 90-100% of all their students. In general, attending local teachers reported mostly low percentages of Hispanic students: Sixty-seven percent of the teachers reported percentages ranging from 0-10% of all their students, while 8% report percentages ranging from 10-30% of all their students, and 4% reported percentages of 30-50% of all their students. Of the 240 attending local teachers, only 2% reported percentages of Hispanic students greater than 50%. Eight percent of local teachers reported a very low percentage of White students (0-10%), while 50% reported a very high percentage (70-100%) of White students. The remaining teachers reported that 10%-70% of their students were White.

In terms of student ethnicity, data from attending local teachers indicate that many of these teachers had classes composed of students who tended to be White. For those local teachers who taught classes with a substantial percentage of minority students, some percentage of White students are also present. These data suggest that dissemination based upon utilizing master teachers needs to emphasize methods of recruiting local teachers with high percentages of under-represented students. What factors may impede local teachers of minority students (commonly in urban or rural districts) from attending institutes? This issue must be considered in local programs.

Self-Efficacy of Local Teachers

Two measures of self-efficacy as outlined by Enochs and Riggs were computed for each local teacher who completed the follow-up survey. The two measures, outcome expectancy and self-efficacy, are reported in log odds units. The important aspect of these measures is to note that a higher positive logit value represents a lower self-efficacy (i.e., confidence) and a higher outcome logit value represents a lower outcome expectancy (i.e., belief in what students can do). Because the vast majority of local teachers who supplied follow-up data were White, it is important to note that general comments about local teachers are really comments about teachers who are predominately White but whose students have a range of backgrounds (e.g., ethnicity, SES, geographic region).

An analysis of local teachers' reporting of the percentage of students living at different economic levels versus outcome expectancy suggests that the spread of teachers' views toward outcome expectancy is approximately the same regardless of students' economic level, specifically poverty level. Three teachers with classes of students at poverty levels of 30, 60, and 98%, respectively, seem to have a slightly different outcome expectancy, but overall there does not seem to be a great difference. Thus, in terms of local teachers' outcome expectancy and percent of students reported at poverty level, these teachers do not seem to differ as a function of outcome expectancy. Other analysis of this same outcome expectancy data as a function of other self-reported student economic level data present a similar picture: some outcome expectancy outliers at particular student income levels, but no major differences overall in local teachers outcome expectancy. The teacher-reported poverty level data and change in outcome expectancy seem to suggest a range of change at each poverty level.

In addition to evaluating the percentage poverty levels versus outcome expectancy, analysis were also conducted to examine self-efficacy and differing socio-economic levels. The analysis showed that, overall, there do not appear to be large differences in teachers' self-efficacy as a function of socio-economic level.

An evaluation of socio-economic level versus *change* in teachers' self-efficacy (as was seen in the previous analysis) there does not appear to be a trend in changing self-efficacy as a function of socio-economic level.

The data supplied by teachers regarding students' geographic regions was also analyzed with respect to the initial survey outcome expectancy, as well as *change* in outcome expectancy. Interestingly, review of these data suggests no difference in outcome expectancy as a function of student geography. There certainly were outliers present, but no clear trend emerged.

An analysis was also conducted of student ethnicity as a function of teachers' outcome expectancy, teachers' change in outcome expectancy, teachers' self-efficacy, and teachers' change in self-efficacy. Although there were outliers in the analysis, no clear visual pattern emerged. A similar analysis was conducted with reported percentages of students' geographic local and teachers' self-efficacy. Again, although outliers exist, no clear differences were apparent.

Finally, although no clear differences emerge as the result of the analysis presenting teachers' self-efficacy, teachers' outcome expectancy, as well as changes in both measurers, an analysis of the local African-American teachers only suggests that they were most likely to be in an urban district and teaching high poverty students.

Quantitative Analysis of Data

Following the initial data analysis, a second data analysis was carried out. This analysis was conducted to quantitatively evaluate the data collected from teachers. The following sections for geographic location, socio-economic level, and race present a summary of trends observed in the data plots.

Rural, Urban, Rural-Suburban, Suburban

The majority of teachers work with students from urban areas, or they teach students who are predominately classified (at least in terms by their teachers) as being from suburban areas. Sixty-three percent of the teachers indicate that less than 50% of their students are from urban areas, with thirty-seven percent of the teachers indicating that more than 50% of their students come from urban areas.

An analysis of the teachers' reporting of students' geographic backgrounds indicates that 52% of the teachers report that over 50% of their students are from suburban or suburban/rural regions.

Socio-Economic Level

The local teachers were asked to estimate what percentages of their students were from the following economic categories: *poverty level*, *low income*, *middle income*, *upper income*. The greatest spread of responses was seen when the percentages for the *low income* and *middle income* categories were separately examined.

Race

The data collected from teachers with respect to the racial background of their students indicate that there are indeed some schools with high percentages of Asian, Hispanic, and Native American students. However, when the entire data set is considered, one can consider the students' ethnicity in terms of White and non-White.

Comparison of Means

In addition to considering a graphic presentation of the data, specific analyses of mean attitudinal measures were conducted: (a) how mean self-efficacy and mean outcome-expectancy varied as a function of subgroup, and (b) how mean group measures differed as a function of pre, post, and change (i.e., pre-post).

Urban (50% or more urban students)

No difference was observed in the outcome expectancy measure of teachers (pre, post, change) working with 50% or more, and 49% or less, urban students. No difference was observed in the self-efficacy measure of teachers (pre, post, change) working with 50% or more, and 49% or less, urban students.

Minority/Non-Minority (50% or more White students)

No difference was observed in the outcome expectancy measure of teachers (pre, post, change) working with 50% or more, and 49% or less, White students. No difference was observed in the self-efficacy measure of teachers (pre, change) working with 50% or more, and 49% or less, White students. However, with this same breakdown of teacher data, there was a significant difference in the self-efficacy measure (post) of those teaches working with 50% or more, and 49% or less, White students. As a group, those teachers who had a high percentage of White students had a tendency to have a higher logit measure. A higher logit measure meant a higher raw score total, and thus more disagreement on this part of the survey. This, in turn, meant lower self-efficacy. Thus, on the post survey, those teachers who taught with classes that were less than 50% White tended to have a stronger self-efficacy measure (p=.10).

Rural Suburban/Suburban (50% or more students)

The data collected from teachers was also evaluated in light of whether or not teachers reported a high percentage of students residing in rural subdivisions or from suburban areas. No difference was noted in the outcome expectancy measure of teachers (post, change) working with 50% or more, and 49% or less, rural subdivision/suburban students. A statistical difference was observed in the outcome expectancy (pre) with regard to the percentage of rural subdivision and suburban students. As a group, those teachers who taught at schools with 50% or more (combined rural subdivision and suburban) students had a slightly higher logit outcome expectancy measure than did those teachers who taught in schools with 50% or less rural subdivision/suburban students. This means that teachers who taught at schools with a significant percentage of rural subdivisions/suburban (not rural, not urban) students exhibited a higher logit value. This result can be interpreted as more disagreement, which means a lower outcome expectancy (less positive outlook). In other words, teachers who taught at schools that were over 50% urban or over 50% rural exhibited a higher outcome expectancy than those teachers working primarily with rural or urban students. No difference was observed in the self-efficacy measure of teachers (pre, post, change) working with 50% or more, and 49% or less, rural subdivision/suburban students.

Poverty/Low Income (50% or more students)

In order to compare mean attitudinal values, the reported percentages of students in the poverty and low income categories was combined. Thus, this comparison represents an evaluation of the teachers' attitudes as a function of percentage of students at the poverty or low income level. No difference was observed in the outcome expectancy measure of teachers (pre, post, change) working with 50% or more, and 49% or less, students with regard to income level. No difference was observed in the self-efficacy measure of teachers (pre, change) working with 50% or more, and 49% or less, students with regard to income level. A difference in the self-efficacy measure of teachers (post) working with 50% or more, and 49% or less, students with regard to income level was suggested by these data. Those teachers who worked with a high percentage (i.e., 50% or more) of students in poverty, or at the low end of economic scale, exhibited a more positive logit value, which means more disagreement on the survey, which in turns means lower self-efficacy than did those who worked with a smaller percentage of students in poverty. The pre value was nearly significant (p=.13). It is interesting to note that the outcome expectancy measure was not significant. Also, it should be noted that this is neither a geographic issue nor a racial issue, but rather was apparent through the analysis of the teachers' self-reporting of economic data with respect to the students (p=.01).

Useful Observations and Comments Regarding the Scale

In addition to considering the self-efficacy and outcome expectancy measures of teachers, this data collection and item response theory (IRT) analysis facilitated an initial evaluation of the self-efficacy instrument. Because the instrument is widely used, it seemed useful to mention trends in the data that provided information with regard to the functioning of the instrument.

Before the results of the Rasch analysis are presented, it is important to mention that the data were collected from teachers of Grades 4-7 and that a revised rating scale was utilized. Riggs and Enochs included the following scale: *strongly agree*, *agree*, *uncertain*, *disagree*, *strongly disagree*. The middle category only of the initial scale was modified for this study: *strongly agree*, *agree*, *barely agree*, *barely disagree*, *disagree*, *strongly disagree*. Analysis of these data suggests that inclusion of the *barely agree* and *barely disagree* categories was important, for many respondents utilized these two selections.

IRT analysis suggests that measurement error could be decreased with this group of respondents through the addition of items filling the following gaps on the two latent traits:

Outcome Expectancy

Providing items which fall between Question 7 and Question 25
Providing items which fall between Question 25 and Question 10

Self-Efficacy:

Providing items which fall between Question 23 and Question 12
Providing items which fall between Question 12 and Questions 5/8/18.

Fit statistics in IRT are used to flag items which may not define the latent trait in the same manner as other items presented on a specific instrument. The three survey items identified below may need to be reviewed, altered, or removed from future versions of the instrument:

Outcome Expectancy

Q13 *Increased effort in science teaching produces little change in some students' science achievement.*

Self-Efficacy

Q21 *Given a choice, I would not invite the principal to evaluate my science teaching.*

Q23 *When teaching science, I usually welcome student questions.*

Question 13's measurement ability may be influenced by the word *some*. All other items of the outcome expectancy scale and all other items of the self-efficacy scale seem to function very well.

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INNOVATIVE SCIENCE EDUCATION GRANT: FROM RECRUITMENT, THROUGH PRESERVICE, INTO ENTRY LEVEL SERVICE

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Oklahoma Teacher Education Collaborative

Project Overview

The Oklahoma Teacher Education Collaborative (O-TEC) is a consortium of higher education institutions dedicated to producing teachers better equipped for teaching science and mathematics to the students who will be the Oklahoma citizens of the next century.

The initial membership in O-TEC includes nine Oklahoma institutions of higher education. These encompass the major research universities (Oklahoma State University and the University of Oklahoma), a private comprehensive university (The University of Tulsa), four regional universities (University of Central Oklahoma, Northeastern Oklahoma State University, Southwestern Oklahoma State University, and Cameron University), the state's historically Black University (Langston University), and the state's largest two year institution (Tulsa Community College).

Initial funding for O-TEC comes through a grant of $5,000,000 over five years from the National Science Foundation.

Project Objectives

O-TEC will pursue systemic enhancement of teacher preparation by providing:

1. innovative methods for recruitment of potential teachers;
2. reform of the undergraduate curricula with revised science and mathematics courses and stress field-based pedagogical instruction;
3. increased emphasis on retention of new teachers in their initial years in the classroom.

Programs

O-TEC provides a variety of programs to :

1. attract (summer academies, multiple entry points),
2. train (Master-Teacher-in-Residence, revised science and mathematics courses, enhanced methods courses, field-based emphasis), and
3. retain (entry year in-service, technology) teachers.

Summer Academies

O-TEC institutions host summer academies in which potential teachers, who may be undergraduates or well qualified high school students, participate in model teaching experiences designed by master teachers. The academies will emphasize the rewards and enjoyment of hands-on science and mathematics instruction.

Oklahoma State University and Langston University worked together on the "SPLASH" academy based on "water". Southwestern taught science and math content and teaching skills to prospective elementary teachers. Tulsa University worked in conjunction with Indian Camp Elementary School, Bartlesville Professional Development Center, and the Department of Energy.

Multiple Entry Points

Led by Tulsa Community College, O-TEC is devising innovative curricula and a two year degree program for paraprofessionals. The program has as its goals:

1. production of quality classroom assistants for Oklahoma's schools;
2. program courses which will articulate to the four-year universities if the para-teacher wishes to pursue a teaching credential.

During the summer of 1997, O-TEC sponsored:

1. a physics based workshop at Northeastern State University which featured calculator based laboratory activities and matched a high school student with a mentor teacher;
2. a mentor teacher workshop at Tulsa University which prepared area teachers for the supervision of "field experience" students and intern teachers. These master teachers will now be utilized by the university to offer quality supervision.

Master Teacher-in-Residence

Each O-TEC institution has added a Master-Teacher-in-Residence (MTIR) to the faculty to assist in course redesign and to participate in team instruction. Among the duties performed by our MTIRs are:

1. Liaison to the community at large;
2. Develop and maintain connections with local school districts;
3. Observe classes for purposes of evaluation and modification;
4. Beginning teacher support;
5. Reform of undergraduate "block" classes and science/math methods courses;
6. Research causes of college student failure/dropping of college algebra;
7. Math lab improvement;
8. Summer institute planning;
9. Faculty committee service.

Revision of Mathematics and Science Courses

Each institution has developed a site plan to enhance courses in science, mathematics, and education, taken by pre-service teachers. The revised courses will reflect the best practices in teaching and be tied to real-world applications.

O-TEC has a series of faculty professional development workshops planned for our member institutions. The first of these was held in February 1997 in Tulsa.

Entry Year In-Service

O-TEC is developing in-service programs for entry year teachers to reinforce concepts stressed during pre-service instruction and to address concerns that may have developed during the initial year in the classroom.

Cameron University held the first Residency-Year workshop for O-TEC during the summer of 1997. The workshop emphasized integrating science and math using calculator based laboratory work.

Technology

O-TEC institutions stress the use of technology in pre-service training and its implementation in the classroom during the entry-year period. O-TEC institutions were awarded over $100,000 in technology grants in 1996. These awards were for the purchase of multimedia presentation equipment for use in teacher education.

Additionally, O-TEC

1. Operates a CU-SeeMe reflector which is available for use by any education institution;
2. Provides on-site technology service and training for area schools;
3. Maintains an information web page "http://129.244.43.78".

GOOD VERSUS BAD CULTURALLY RELEVANT SCIENCE: AVOIDING THE PITFALLS

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Introduction

In 1991 the Detroit Board of Education adopted its "Suggested Criteria for Reviewing Educational Textbooks and Materials" (Detroit Public Schools, 1991). Included in these criteria are explicit references to multicultural/multiethnic content in textbooks and other learning materials. Items are required to be screened for truth, balance, order, harmony, and degree of being bias-free and multicultural. What do these components entail? What led to this explicit reference to multicultural content? What is the state of existing materials hoping to be considered for such adoptions?

The authors explore these questions from two perspectives--that of a practicing anthropologist who specializes in Mesoamerican studies (Ortiz de Montellano, 1990) and that of a science educator particularly interested in the relationship between student and teacher views of the nature of science and scientific literacy (Loving, 1997). Both researchers have written about the status, evolution, and quality of multicultural or culturally relevant science materials available for U.S. classrooms (Haslip-Viera, Ortiz de Montellano, & Barbour, 1997; Loving, in press; Ortiz de Montellano, 1996; Ortiz de Montellano, Haslip-Viera & Barbour, 1997). Both are concerned that many materials currently in wide distribution across the country do, in fact, represent bad science. We use the Detroit Board's criteria combined with our assessment of a number of examples to provide the reader with our set of criteria for selecting good culturally relevant science materials.

What philosophical perspective do we assume in this study of culturally relevant science materials? First, we acknowledge that science is not culturally neutral and culture is an important component in much science. Naturally, culture will play a larger and more direct role in anthropology, as humans study humans, than, say, in theoretical physics. Research suggests, however, that world view--"the culturally-dependent, implicit, fundamental organization of the mind...composed of presuppositions or assumptions which predispose one to feel, think, and act in predictable patterns" (Cobern, 1991, p. 19) varies among different ethnic groups. The extent to which science teachers use culturally relevant materials and pedagogical techniques can often determine the extent of successful learning in many sciences.

We wish to avoid labeling ourselves as objectivists or subjectivists, realists or non-realists, or any of an array of constructivists. We take a centrist position, agreeing with fundamental notions of good science by well known science educators as Matthews (1994) and Driver, Leach, Millar and Scott (1996). This stance allows us to highlight the central tenets of good science--the quality of the evidence and the explanation and the relationship between the two.

Our challenge in science education is to do what Cortés (1994) calls the "Great American Balancing Act" (p. 6). He is referring to the notion of providing an education that will enrich and acculturate all students--yet not require assimilation. His brand of culturally relevant science would acknowledge and make best use of student backgrounds, while at the same time moving them towards important mainstream understanding. He uses the expression "E Pluribus Unum"--out of many, one-- to remind us what our goal should be in all classrooms. Students should feel part of a culture that goes beyond what they individually bring to class. Culturally relevant teaching results in "adducation", not "subtractucation," according to Cortés.

Status Of Current Culturally Relevant Materials

There is a glaring underrepresentation of minorities in science professions (National Science Foundation, 1995) and significantly lower achievement in secondary school science and mathematics among ethnic minorities (National Center for Educational Statistics, 1995). While attempts to increase minority role models in science and science teaching are a start, this is not enough. There is a great demand for approaches that tie culture with science, and the refusal of scientists and science educators to develop accurate and valid materials of this type has fostered the development of alternative science materials of dubious quality and their adoption by school districts with large minority enrollments. In 1987, the Portland Oregon School District published the African-American Baseline Essays, a set of six essays providing resource materials and references for teachers on the knowledge and contributions of Africans and African-Americans.

Our discussion will focus on the Science Baseline Essay written by Hunter Havelin Adams (1990) and a few other works. There are serious problems with this Baseline Essay, but because of the current pressure on school districts to incorporate multicultural material into the classroom and because of the dearth of this kind of material, it has been widely distributed. Hundreds of copies of the Baseline Essays have been sent to school districts across the country. They have been adopted or are being seriously considered by school districts as diverse as Fort Lauderdale, Detroit, Milwaukee, Atlanta, Chicago, Prince George County, MD, and Washington, DC. Even more widely distributed is its predecessor, Blacks in Science: Ancient and Modern, edited by Ivan Van Sertima (1984). Vine DeLoria, who is involved with Indian science education through the American Indian Science and Engineering Society (AISES) has recently published a book entitled Red Earth, White Lies: Native Americans and the Myth of Scientific Facts (DeLoria, 1995)

These supplements on multicultural science, expressly intended to "raise the self-esteem" of students, adopt a triumphalist approach to the material. That is, they present the achievements and the beliefs of the group described as superior and anticipatory to the achievements and beliefs of modern "Western" science. Thus, the Dogon of Mali supposedly studied Sirius B, which is invisible to the naked eye, hundreds of years ago. The Egyptians foreshadowed the Theory of Evolution thousands of years ago; the Egyptians also anticipated many of the philosophical aspects of quantum theory (Adams, p. 20), and they knew the particle/wave nature of light (p. 26).

Similarly, the need to defend native myths and religion as scientific and factual inevitably leads to antiscience and pseudoscience. Native American religions involve the creation of man in the New World. De Loria (1995) defends this view by denying modern humans evolved in Africa and subsequently Paleoindians migrated across the Bering Strait to people the New World. Instead, DeLoria presents a scenario in which in the distant past four groups (the Salish, the Sioux, the Algonquians, and "mean-spirited, white-skinned, bearded people" (DeLoria, p. 77) lived in North America. The first three groups remained in North America and the fourth migrated eastward to enter Europe as the Cro-Magnons (pp. 77-78). This contradicts all the paleontological evidence that humans evolved in Africa and that no skeleton of a hominid prior to "truly modern humans" has ever been found in the New World.

The defense of Indian myths as factual leads DeLoria (1995) to deny the validity of basic tenets of geology, physics, and biology--essentially aping the stance of defendants of another religious myth--Scientific Creationists, who claim the earth to be 6000 years old. Myths of the Warm Springs Reservation, Oregon describe an eyewitness view of the creation of Mt. Multnomah, but potassium/argon dating shows that this range was formed 25-27 million years ago. DeLoria, denying the validity of radioactive dating as he earlier denied the validity of the standard geological sequence, argues that this mountain is very recent and that the Indian forefathers actually saw the formation of the mountain (pp. 200-204). A further example of the "young earth" approach is DeLoria's claim that petroglyphs prove that Indians in Missouri actually saw a stegosaurus, perhaps as late as the 19th century and Indians in Arizona saw a diplodocus (pp. 240-244.)

Avoiding the Pitfalls of Bad Culturally Relevant Science

The brief examples from Adams, Van Sertima and DeLoria set the stage for our suggested criteria to be used by teachers as they choose culturally relevant science materials. The six criteria below with additional examples should aid teachers in avoiding the pitfalls of blatantly bad science and, we hope, encourage selection of materials that represent bona fide science from various cultures. The criteria ask teachers to check for: a) author's credentials, b) sufficient documentation, c) political agenda, d) "newspeak," e) sufficient depth and evidence, and f) pseudoscience, myth, religion, postmodern new-age beliefs.

Author's Credentials:

The credentials an author possesses to write about science should not be the only factor in their credibility because ultimately that should depend on the reasoning and the evidence presented. However, credentials are an important fact to consider. Credentials shouldbe written in such a way that it is clear that the person has credentials (in science a Ph.D. is desirable) in an area related to the topic being discussed, or has significant experience in that area as reflected by peer-reviewed publications and/or reputation among qualified peers.Watch out for descriptions that imply but do not clearly state a qualification. For example, describing an author as a "professor at Wayne State University" does not mean that the person is qualified to write about chemistry. He/she may be a professor in literature, political science, or drama. Some physicians (M.D.) and lawyers feel that they are qualified to write on any topic. Most are clinical practitioners without advanced research degrees, and they are not trained as researchers.

Examples:

1. Hunter Havelin Adams is described by the Portland Baseline Essay as a "research scientist at Argonne National Laboratory." Actually, Mr. Adams is an industrial-hygiene technician who "does no research on any topic at Argonne," and whose highest degree is a high school diploma (Baurac 1991; Marriot 1991).

2. Vine DeLoria is a political scientist with a law degree who writes of Native Americans evolving in the New World based on the concept that their origin myths are veridical.

3. Richard King is a psychiatrist with an M.D. but does no laboratory research on melanin. He claims that melanin has a number of extraordinary properties--but fails to make an important distinction between melanin in the skin and that in the nervous system.

4. José Ç Argüelles has a degree in art and writes about how human history has been shaped during the time of the great Maya Calendar Cycle 3113 B.C. to A.D. 2012 by a galactic beam through which the Earth and Sun have been passing. He predicts a great transition in 2012 and says Maya science and mathematics predicts this.

Documentation:

A very important thing to do before using any material is to check the documentation provided to determine how trustworthy and reliable the material is.

1. There is an order of credibility of sources of scientific information-- in order of decreasing credibility they are: peer reviewed scientific journals, texts from publishers like Academic Press, Wiley, Interscience, journals such as Scientific American, Bio-Science, Natural History. Books from university presses and commercial publishers can be good or bad, as some presses are quite selective, with excellent editorial staffs, and others are not. You should be suspicious of an over-reliance on newspapers, popular magazines, and vanity press books. Peer review gives some assurance that knowledgeable people have checked the work to see if sources were adequate and were cited correctly, whether claims are supported by evidence, and whether scientific claims are credible.

2. Information should come from primary sources. Authors should ordinarily provide you with citations to the original source of the information. Consistent reliance on paraphrases from second- or third-hand sources, or summaries in newspapers or magazines should make you suspicious about the accuracy and worth of the information.

3. You should be suspicious of a great reliance on old and obsolete sources. Acceptable scientific explanations and any given body of knowledge change over time. Science books and journal articles can become obsolete, or at least their explanations can become incomplete, in a few years. Sometimes this aspect is hard to verify with books because reprint editions may be cited without giving the original dates of publication.

Example:

King (1990) uses Churchward (1913, 1921) as his source for paleontological information, ignoring all the advances that have occurred in the 70 years since the original publication.

4. Check for complete citations, i.e author, title, place of publication,

publisher, year and page number. If these data are consistently missing, there is cause not to trust the material. Authors who are citing works carefully and accurately want their readers to be able to check their citations; those who may be misrepresenting their sources do not want readers to check their citations.

5. Watch out for many typographical or spelling errors. Authors who are careless on the little details tend to be careless with the larger facts.

Example:

Adams (1990) fails this test. He does not distinguish between what would be considered serious academic sources (i.e. refereed journals, academic press books), intermediate sources (popular science journals), very old sources which might be obsolete, and unreliable or very questionable sources (newspapers, magazines, vanity press books, "New Age" publications). Adams' citation style is not helpful either to teachers who want to get more information or to readers who want to verify quotations. For example, often quotations in the text are cited by author and title but the book is not included in the bibliography, and even when books are included, page numbers are not given in the footnote.

Example:

King (1990) argues that Black people are superior to whites because they have a lot of melanin. Much of the book, however, has passages such as the following: "Elevated levels of pineal MSH are strongly implicated in extrasensory perception and emotionality. The amino acid tyrosine, which is produced in the process of producing melanin, is also the precursor of coedine [sic], murphine [sic], mescaline, LSD, thyroxin, and norepinephrine (Riley 1972). These are chemicals that range from the psychedelic drugs mescaline, L.S.D. [sic], D.M.T. [sic], through the euphoric addictive drugs morphine and coedine [sic]" (King, 1990 p. 120). Or, for example, King (1990, pp. 58-59) "Calcium in the form of hydroxy appetite [sic apatite] or bone formation is found in the structure of the pineal gland."

Example:

Amen (1993) argues that Egyptians had advanced knowledge of electronics, but does not have a single citation or footnote in the book. The bibliography at the end is quite incomplete. The book is full of spelling and grammatical errors.

A Political Agenda Can Distort Even Simple Facts

1. One aim of Afrocentrism is to show that Egyptians and their culture actually had their roots in Sub-Saharan Africa. In support of this claim Adams (1990, p. 14) quotes the following:

> "They come, the waters of life which are in the sky,
> "They come, the waters of life which are in the sky,
> They come, the waters of life which are in the earth...
> The sky is aflame for you, the earth trembles for you,
> before the divine birth of Osiris-Nile."
> (Third Dynasty Pyramid Texts of Unas [2063]).

and on this basis claims that, "This profound statement symbolically speaks to the ancient Egyptian people's recognition that the river Nile was the umbilical cord that annually deposited the nutrient-laden, life-regenerating alluvial earth from the womb of the world, the Great Lakes/Mountains of the Moon region near the equator, all throughout the valley. Moreover, it indicates that the ancient Egyptians' belief of a celestial source of the Nile River. Supporting their extra-terrestrial origin of the Nile theory, evidence has been recently found showing that the earth today and for hundreds of millions of years, has been inundated by water-laden, micro-comets, which not only over time were the source of the ocean's water, but of river's water like the Nile" [Adams does not cite any source for this evidence].

The problem with this explanation is that the silt that is brought to Egypt comes from monsoon rains in Ethiopia carried by the Blue Nile--called that precisely because of its load of silt (Baines & Marek, 1980; Shaw & Nicholson, 1995). The Great Lakes/Mountains of the Moon area is the source of the headwaters of the White Nile. The White Nile doesn't figure at all in the silt deposition. Any Egyptologist would know this, and these sources can be verified in any map.

2. Melanists like Adams (1987, 1988) and King (1990) make a number of claims about the superiority of Blacks based on the properties of neuromelanin (melanin in the human brain), β-MSH (beta-melanin stimulating hormone) and melatonin and their higher concentration in black people compared to whites. However, there is no β-MSH in any adult humans (Robins, 1991, pp. 33-34) and melatonin has little if any role in human physiology. There is no relationship between skin melanin and neuromelanin (Robins, 1991, p. 81). Melatonin got its name because it causes blanching of frog skin. It has no relationship or similarity to melanin. Melatonin has no impact on puberty or skin color (Sizonenko, Lang & Aubert, 1982; Hastings, Vance & Maywood, 1989; Ebling & Foster, 1989; Robins, 1991, p. 34-37).

<u>"Newspeak" :</u> Watch out for the use of scientific sounding terminology or the inappropriate use of scientific terms. This is a tip-off to either sloppy thinking or of a fast one being pulled on you. Clear writing means clear thinking. If you cannot understand what a paragraph says, be suspicious of the author's intent. You should be able to tell someone else what a paragraph means. Try to render the following examples into simple declarative sentences and explain what the author really means.

Examples:

1. Adams argues that mainstream scholars have failed to get the REAL meaning of Egyptian hieroglyphs. "...thousands of hieroglyphic inscriptions, and yet over a hundred years and hundreds of scholars devoting their lives to translation, the essence of their meaning eludes us. This is primarily because the ancient Egyptians' polyocular epistemology renders their written style of communication, multicontextural. That is to say, there is a high degree of simultaneity and spontaneity, and also rhythm and symbolic logic in their thought; for example, superimposed upon a single image are many points of view and moments of time. For an 'expert' unfamiliar with Egyptian lifeways, translation could give the antithesis of the author's original intent" (Adams, 1990, p. 30).

2. "The reason for the intense subjective effects experienced by the human psyche lies in the overall impact of radioactivity and electromagnetic pollution on the infrastructure of the DNA, causing increased randomness and entropy of behavior. But this response of DNA experienced as socially disruptive behavior in the human realm, inclusive of rises in the incidence of cancer and new diseases like AIDS, is actually only a complement of what is occurring in the larger host organism, Earth" (Argüelles, 1987, p.146).

3. "As resonant structures, symbols literally create, work with, and inform the light body. The light body is the electro-resonant galactic code bank that informs the genetic code bank. It is the stuff of imagination, insight, all true understanding--and more! While the foundation of our light body corresponds to the vibratory infrastructure of the DNA, it can only be activated through a knowing use of symbols. Nor should this symbol-thriving light body be seen as separate from what we call our physical body. Rather, the resonant light body underlies and interpenetrates all of our functions" (Argüelles, 1987, p. 89).

4. "The resonant body of the Earth, the vibratory infrastructure that literally holds together the sense-perceptible body of the Earth, is in a condition of intense 'fever' called resonant dissonance. Remembering the planets as gyroscopes holding the frequency pattern of their particular orbits, we see that environmentally impactful effects since 1945 have actually set in motion a dissonant vibratory wave affecting the overall spin of the planet. If the dissonance is not checked, then, similar to an uncontrolled nuclear reaction, the end-result would be the development of awobble in the spin and a consequent shattering of the planetary form. The Earth could be broken up into smaller bodies not unlike the Asteroid belt"
(Argüelles, 1987, p.146).

5. "As ideographic symbols, there are many different ways in which these Signs can be read. Dense with meanings, the Signs demand an analogical understanding. Analogical thinking randomly floats and leaps to a conclusion by a like association linking dissimilar things. Analogical

thinking is also that which creates form on the basis of like proportions. As we have already seen, the Mayan number symbolism is completely based on fractal harmonics which are based on like proportions" (Argüelles, 1987, p. 97).

6. "Using the Harmonic Module as the template of the circuitry of the light body, and understanding the light body to be the true skeleton of the physical body, we can assert that the diseases and plagues which ails us--cancer and AIDS--are not cellular in cause but instead are the direct result of immersion in and addiction to various feedback effects of our deleterious technological environment. The cure to these Late Industrial Age diseases, therefore, is not to be found in chemicals or radioactive treatment, but in a radical shift in disposition accompanied by the development of genuine bioelectromagnetic medicine that accounts for the natural, organic restoration of intrinsic resonance as key factors in healing" (Argüelles, 1987, p. 182).

7. "Melanin granules act like tiny primitive eyes, forming a large neural network structure, whose function is to absorb and decode electromagnetic waves. Neural-network computers are learning machines which are made with a number of receptors that can adjust their weights (quantitative properties) to produce a specific output. The body of Africans contains massive amounts of melanocytes that encode all life experiences in their melanin production, with the aim of creating an actual-reality state after death" (Amen, 1993, p. 29).

8. "At low frequencies the conductivity of melanin is small, but at ultra high frequencies (UHF), melanin is a superconductor. Maximum current flows only in the skin, due to the skin-effect, at melanin's UHF resonant frequency. Melanin is the most important substance in the human body. It is an oxidized form of RNA, which enables the body to coordinate the production of proteins needed in cellular repair. Wherever there is cell damage melanin is seen surrounding the site, functioning as a neuro-transmitter in coordination with melanocyte protein production for the repair of damaged DNA. Knowledge of the medical value of melanin is suppressed by the Medical Establishment, in order to deny its supremacy" (Amen, 1993, p. 29).

9. "This myth handed down from Ancient Times, relate the events occurring in the eye of a radio galaxy. Where stars and planets are swallowed by the central black hole and resurrected as fourth-dimensional matter (plasma) [sic]. A plasma is characterized by its high electron content. About 95% of the matter of the universe is in this state. A low pressure gas plasma need not be strongly ionized to or [sic] produce electromagnetic effects. Black skin, which is composed of a layer of organic semiconductors can be considered a plasma or fourth-dimensional matter. And since neuro-melanin and melanocytes are the basis of higher mental activity, it stands to reason that our moral nature is an expression of more direct contact with God through the spirit" (Amen, 1993, p. 61b).

Sufficient Depth: Topics should be presented in enough detail that teachers can go beyond the topic facts and deal with the evidence, which should be included to support any claims made.

1. Culturally relevant science materials must avoid a long laundry list of the achievements of a particular culture without sufficient detail to understanding the concepts being listed (the "mentioning problem"), or lists of achievements that do not pertain to the grade levels being taught.

Example:

Adams (1990) work, which is aimed at elementary school, claims that Egyptians were the first to discover Darwin's Theory of Evolution, quantum mechanics, the wave/particle of nature of light, electroplating of gold, glider flight, etc. with no explanation of what these theories entail.

2. Conclusions should be stated with sufficient evidence. This is particularly important when extraordinary or very unorthodox claims are made; "extraordinary claims require extraordinary proof."

Example:

To state that Brazil is hot does not require much evidence besides pointing to the fact that it is near the Equator. On the other hand, to say that the Maya people were transmitted through space in the form of DNA code (claimed by Argüelles, 1987, p. 59) requires an enormous amount of proof (none was given).

Example Claim:

"[The ancient Egyptians]...anticipate many of the philosophical aspects of the quantum theory in contemporary physics" (Adams, 1990, p. 20).

Evidence presented:

"Chicago computer scientist, Levia Hoppzallern, offers morevaluable insights. To the Egyptians, he points out, time as a unit ofenergy expressed in the form of an entity or process that can be measured by its duration. Prior to an entity's or processes' manifestation, its 'time' does not exist. As such, they recognized that an entity or process exists in two states: Potential--a functional or trans-material existence before its 'first time', and actual--its period of manifestation or duration from its 'first time' until completion of its life cycle, its eternity. Thus each thing represents a unique dimension of time. Time was therefore multidimensional. In the 'Book of Caverns' (Quererets), a phrase illustrates this:

> 'Unin-nefer of the living who passes through millions
> of time dimensions'" (Adams, 1990, p. 20).

Pseudoscience , Myth, Religion, Post-Modern/New Age Beliefs

Some explanations presented as science are in fact pseudoscience, myth, religion, supernatural beliefs, magic or postmodern-new age beliefs masquerading as science. Be suspect if you see highly unusual methods, aims, theories, vocabularies or conclusions.

Example:

1. "Psychoenergetics (also known in the scientific community as parapsychology and psychotronics) is the multidisciplinary study of the interface and interaction of human consciousness with energy and matter. Magic is the conscious attempt of an individual to 'imitate' through ordinary sensorimotor means the operation of psychoenergetic (psi) phenomena. Thus, genuine psi phenomena such as precognition, psychokinesis, and remote viewing in the distant past as well as the present has always been closely associated with "magic", and the attempt to separate the two has only been a fairly recent activity. Psi, as a true scientific

discipline, is being seriously investigated at prestigious universities all over the world." (Adams, 1987, p. 41).

2. Quoting Lucy Lamy--"Maat is Cosmic Consciousness, the ultimate goal of creation and of every creature, the immortal fruit of a constant acquisition. Maat is the greatest treasure that a being might wish for." Adams (1987, pp. 11-14) concludes that, "This concept called Maat represents the first set of scientific paradigms: A set of general principles which serve as the basis from which the ancient Egyptians did all types of scientific investigations."

3. " If the Indian legend demonstrates the presence of people in North America, or even the Western Hemisphere, tens of thousands of years ago--or in the case of Mount Multnomah 25 million years ago--then that discrepancy should alert scientists and they should reexamine their doctrines in the light of the conflicting interpretations. The idea that people have only been in the Western Hemisphere for 12,000 years is simply an agreement among scholars who neither think nor read and who have been stuck on a few Clovis and Folsom sites for a generation. I personally cannot believe that any people could remember these geological events for tens of thousands of years. My conclusion is that these are eyewitness accounts [formation of Mt. Mazama, Crater Lake, Mount Multnomah, the Puget sound] but that the events they describe are well within the past 3,000 years. It is past time that this resistance be ended and a new scenario for the Western Hemisphere be constructed" (DeLoria, 1995, p. 206).

4. "... A number of tribal traditions describe creatures that may have been dinosaurs...Again, the Pacific Northwest peoples have a number of stories concerning oversized animals in their lakes and rivers. Since the current trend in dinosaur research suggests that these creatures, for the most part, were warm-blooded and had social and instinctual characteristics reminiscent of mammals of today, there is no reason to hesitate suggesting that some of these creatures, described as animals or large fish by observers were surviving individuals of some presently classified dinosaur species. That is to say, humans and some creatures we have

classified as dinosaurs were contemporaries (DeLoria, 1995, p. 240-241); the Sioux have a tale about such a monster in the Missouri river...I suspect that the dinosaur in question here must be a stegosaurus" (p. 243).

Conclusion

Science teachers need to be alert when selecting all texts and curriculum materials. In the current milieu with emphasis on diversity, equity, and multicultural education, they need to be particularly alert to the above six criteria as they seek to be more inclusive of all students in their teaching . While appealing to unique cultures and issues of equity and justice, culturally relevant science materials must be judged by some standard which gives both teacher and student some assurance that what is being presented is supported by evidence and is an accurate version of science, history, and anthropology.

Notes

[1] This does not mean that teachers should be able to read the scientific literature directly. Science has gotten so specialized that scientists in one field cannot read the technical papers in another field without extensive background reading. However, we are dealing here with material supposedly directed at elementary and secondary teachers who should not be expected to read research journals in science.

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THE CLASSROOM AS A STAGE FOR EXAMINING GENDER MICROINEQUITIES

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<u>Presentation Summary</u>

Reform documents in science and mathematics education remind us that a sound education in science and mathematics is the right of every child.

> A major objective of mathematics instruction must be that all students learn that they can learn mathematics. (Damarin, 1990, p. 150)

> All children need and deserve a basic education in science, mathematics, and technology that prepares them to live interesting and productive lives. (Project 2061,1989, p. 11)

Other current research literature such as How Schools Shortchange Girls (AAUW, 1992) offers evidence that there is much work to be done to provide schooling that is equitable.

> Women and most minorities study less mathematics and are seriously underrepresented in careers using science and technology. (National Council of Teachers of Mathematics, 1989, p. 4)

Authors Myra and David Sadker have written about differentiated treatment given to female students, treatment that often results in disproportionately low numbers of young women pursuing science and mathematics courses and related careers (1994). The first step in changing these destructive patterns is the recognition of the part each of us plays, often unwittingly, in furthering inequity.

Through the use of skits that dramatize real situations, we can open discussion of microinequities, those little occurrences that we often overlook but that can be the foundation for more serious inequities. The idea of using skits to address equity issues came from a 1989 meeting of the Committee on the Participation of Women of the Mathematical Association of America (MAA). Since that time skits have been performed at MAA meetings before ever-increasing audiences. High school teachers of science and mathematics developed and performed skits as part of the work of the Gender Equity in Mathematics and Science (GEMS) Congress sponsored by the Woodrow Wilson National Fellowship Foundation in 1993.

At the AETS session, participants played the roles in several scripted skits. Three examples are reproduced here as an Appendix. After each performance, there was discussion of issues raised by the skit, and sharing of personal stories.

The use of skits has several advantages for discussing gender equity. A situation presented as drama is removed from one's personal realm. No one is on the spot and everyone can examine the situation without personal revelation. The skits provide a starting point for conversation about equity. They also suggest a base line for examination of one's own practice as well as examination of institutional patterns.

When the skits are performed as amateur theater there is often some entertainment value as situations are overplayed for dramatic effect. This should in no way imply any lessening of the significance of these microinequities. However, the skits allow participants to examine difficult issues in a non-threatening environment.

The format modeled in this presentation at AETS has been used effectively with secondary science and mathematics teachers and with post-secondary mathematicians and mathematics educators. In some settings participants have begun the writing of skits based on their own experiences. Teachers and teacher educators have incorporated this use of skits into staff development sessions and classroom activities.

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<u>Websites</u>

Association of Women in Science www.awis.org

Mathematical Association of America www.maa.org

National Women's History Project www.nwhp.org

Woodrow Wilson National Fellowship Foundation www.woodrow.org

Appendix

<u>Skit: Registration Daze</u>

Scene: Spring in the High School Guidance Office. Sally Sophomore is meeting with Dr. Caleb Counselor to plan Sally's schedule for Fall.

Caleb: Come in, Sally. Have you chosen the courses you want for next year?

Sally: Yes, I've given it lots of thought. I want honors English, honors American history, pre-calculus, physics, and AP French.

Caleb: That's a heavy schedule, Sally. Let's talk more about this. What are you planning to study in college?

Sally: I'm thinking of international relations with a French Minor. Maybe law school down the road.

Caleb: Well, with those plans you certainly don't need all the work and anxiety of that math and science. Why don't you drop the science, and the math, too. You can take studio art and yearbook. You'd be very good on the yearbook staff.

Sally: My mom and I talked about this schedule. She really wants me to take more math and science.

Caleb: Don't worry. You can get those courses at the junior college - if you ever need them. For now, you really need to concentrate on building that GPA if you hope for a scholarship.

Curtain.

Discussion:

What are the stated and unstated messages in this scene?
How can you determine if such scenes occur in your school?
What can you do about similar situations in your school?

This skit was modeled on the work of the 1993 Woodrow Wilson Gender Equity in Mathematics and Science Congress. Skit writers at the Congress were: Kathie Anderson, Mary Gromko, Paul Jones, Linda Padwa, Loretta Rector, Teddy Reynolds, John Roeder, Jackie Simms, and Cathy Wick.

Reference: Woodrow Wilson National Fellowship Foundation, 1993, p. 71.

<u>Skit: Cafeteria Conversation</u>

Scene: A college cafeteria near the dormitories. The campus is hosting a meeting for research scientists. A husband and wife, Martha and George X are eating dinner together. They are approached by another couple, Fred and Ethel Y.

Fred: Hi, I'm Dr. Fred X and this is my wife Ethel. May we join you?

Martha: Certainly. I'm Dr. Martha X and this is my husband, George. He's a lawyer.

(Fred and Ethel are seated. Fred positions himself so that he is looking at George and has his shoulder to Martha and Ethel. The following dialogue takes place while the participants are eating, so interchanges are separated by pauses.)

Fred: Say, George, where do you teach?

George: I'm a lawyer; my wife is a science professor.

(Pause)

Fred: What's your field of research, George? Life sciences? Physical sciences?

Martha: Much of my work is in Paleontology. What do you do?

(Pause)

Fred: So, George, do you get to teach many graduate classes?

George: *(with increasing irritation)* I'm a lawyer, my wife is a scientist. Why don't you ask her?

Fred: I like teaching big, lower level classes occasionally, but I prefer the upper division and graduate students. How many classes do you teach each semester, George?

George: *(with great exasperation)* I'm a lawyer; my wife is a scientist. Please talk to her!

(Pause)

Fred: Tell me, George, do you use visual aids in your graduate classes?

Curtain.

Discussion:

What assumptions seem to be guiding these interchanges?
Relate this scene to a personal experience.

This scene was modeled on a skit developed from an actual incident that occurred at a mathematics meeting a few years ago.

Reference: Kenschaft & Keith, 1991, p. 3.

Skit: In the Physics Lab

Scene: In the physics class the experiment for the day involves Hooke's Law. Students have been randomly assigned to lab groups. Larry, Moe, and Curly Sue are getting down to work.

Larry: Go get the springs and washers, Sue. Moe and I will get the graphing calculators.

(All three gather equipment and return to their table.)

Moe: These washers aren't all the same. Maybe we should get them into piles of 5 grams each. Go and weigh them, OK Sue?

(Larry and Moe check the equations currently stored in the calculator and experiment with the graphing window settings until Sue returns. The group sets up their equipment and begins to collect data.)

Sue: Don't you think we'd better start writing down some of this information?

Larry: Yeah, sure. Why don't you do it, Sue. Your handwriting is better than mine.

...and on it goes...

Curtain.

Discussion:

What roles seem to be in place in this scene?
What could a teacher do to change the roles?

This skit was developed from an actual classroom incident reported by a student teacher in December, 1997.

MUSEUM & METHODS COLLABORATION: UNDERSTANDING SCIENCE TEACHING VIA DISTANCE LEARNING TECHNOLOGY

Timothy Barshinger, Purdue University

Museum and University Education Program Collaborations

Museums are taking on a more active role in the education of children. Bitgood, Serrell, and Thompson (1994) highlight the major advantage that informal learning environments have over the traditional classroom. These sites are often able to meld affective and cognitive learning experiences as academic enrichment occurs via recreational interactions. Teachers have capitalized on this role and the benefits that informal settings can provide (Martin, Brown, & Russell, 1991). Science and youth museums, in particular, have become favorites of teachers because they provide opportunities that extend beyond the traditional static museum. These types of environments provide direct interactive experiences with relevant materials that enhance students' curiosity and wonderment about science (Falk, Koran, & Dierking, 1986).

Because of these benefits, university education classes have recently begun developing cohort relationships with informal learning centers to provide pre-service and in-service teachers with a variety of educational ventures. A report published by St. John (1990) for the Association of Science and Technology Centers showed that over 90% of science/technology organizations offer programs for in-service teachers and over 40% provide similar programs for pre-service teachers. In addition, over 60% of these institutions work with university education programs in cooperative experiences. Ramey-Gassert, Walberg and Walberg, (1994) noticed that these professional development programs focus not only on designing successful field trip experiences, but also demonstrate methods and strategies that can help improve a teacher's own classroom science instruction .

Distance Learning Technology as the Medium for Collaboration

Many of these professional development programs are being implemented by means other than direct contact with the museum personnel; distance learning technology has enabled museums to teach science through a variety of electronic media (Semper in Ramey-Gassert, Walberg, & Walberg, 1994). The phrase "distance learning" is an umbrella term used to describe instruction that occurs by means of print or electronic communication in which those engaged in the instruction are separated by time and/or place (Jonassen, Davidson, Collins, Campbell, & Haag, 1995). Videoconferencing is one example of the many kinds of "distance learning" media that are increasing in educational establishments. This visual form of telecommunication originally utilized satellite-based technology that often was limited to one-way video with two-way audio via regular phone lines. However, the use of two-way audio/visual videoconferencing, delivered through ISDN (Integrated Services Digital Network) or fiberoptic lines, is beginning to emerge as a preferred means of remote interactions.

Jones and Knezek (1995) defined the "interactive" nature of this system as one which provides a level of intimacy in communication that is not apparent in other forms of distance learning technology. Colbert, Voglimacci, and Finkelstein (1995) also described videoconferencing as being synchronous (or real time); the teacher and learners experience parallel delivery and reception of information without a time delay. It is the intimacy and synchronous nature of videoconferencing that allows this form of telecommunication to offer a broader range of pedagogic opportunities over other forms of distance learning technology. This medium is said to be most successful when used in an interactive manner that emphasizes a constructivist approach to learning. Jonassen, et al. (1995) stated:

> Two-way real time-time video transmission of information implies a new definition of real-world context. Although video-mediated, constructivist learning environments could potentially include the actual environment or a close facsimile with which the learner could remotely interact. These

> collaborative problem-solving situations enhance knowledge construction through the addition of visual information and remote interaction with other learners. The video transmission of authentic, realistic contexts adds a significant dimension to anchored instruction and situated learning environments. (p. 18)

This integration of a constructivist epistemology with advanced technology utilization has been shown to be an appropriate methodology teachers can implement in their own classroom. Additionally, LeBaron and Bragg (1994) indicated that such an approach can be equally successful in teacher preparation programs.

A Collaborative Project Between a Museum and a Methods Course

The following describes a project initiated between the interactive science gallery called "ScienceWorks" at The Children's Museum of Indianapolis and a section of an elementary science methods course at Purdue University. This collaboration utilized two-way audio/visual videoconferencing technology as the means of providing an interactive experience between the Educator/Curator of the ScienceWorks Gallery and the methods students. Three main goals provided the focus for this venture. The first goal was to promote discussion among the course instructor, the methods students, and the museum educator on the nature of children's learning in both formal and informal science settings. The second goal was to facilitate interactive experiences among the course instructor, methods students, elementary-age children, and the museum educator through a required course assignment. The third goal was to expose the methods students to an emerging technology and its possible uses in an elementary classroom.

Information on Videoconferencing Technology at The Children's Museum

Many institutions that possess videoconferencing technology utilize a stationary audio/video set-up isolated within a single conference room. While The Children's Museum does have a dedicated distance learning classroom, it also possesses a mobile camera and monitor unit. This unit can be plugged into fifty-four different receptacles located throughout the five-story gallery spaces and collections department house in the basement. These receptacles are wired to an in-house cable network located on the third floor. This central network serves as the head-end from which all broadcasts are received and transmitted via fiberoptic phone lines. This technology has provided the museum the capability to broadcast and receive transmissions from almost anywhere within its 250,00 square foot facility. Thus, any of the museum environments can be brought virtually to schools or classrooms that possess the appropriate equipment. For this project, museum broadcasts were conducted from both the dedicated distance learning classroom and from the floor of the ScienceWorks Gallery. The methods students received those transmission and broadcasted their signal from the distance learning lab located in the Liberal Arts and Education Building at Purdue.

Description of Project

This two-phase project has been implemented in two different models. What follows are descriptions of each of the phases and the modifications of those models.

Phase I: Building an understanding of children's informal science learning.

In the first phase, the methods students and course instructor were "linked" to the museum educator to discuss how children learn science. This connection occurred in the beginning of the semester during which many students were still developing their initial understanding of elementary science. Since this was the first time many of the students had participated in a videoconferencing experience, the lab technician began by explaining the appropriate etiquette and protocol of the technology. Additionally, all television monitors were capable of producing a PIP (picture in picture) thereby allowing students to see their out-going broadcast as well as the incoming one.

The museum educator presented from the "Fossil Wall Exhibit" located in the ScienceWorks Gallery. After introductions, she began by explaining her beliefs of how children learn science concepts based on her experience as a classroom teacher and museum educator. She continued by discussing her views on how teachers can help facilitate science learning both in informal settings and the traditional science classroom. Many of her comments paralleled the constructivist notions the students were being exposed to in course lectures and readings. In order to maintain an interactive rapport, questions were asked throughout the presentation from both sites. Students presented questions to the museum educator regarding issues such as: classroom preparation for field trip visits, parent and family involvement in the gallery, museum resources available to teachers, and strategies for maximizing learning when children are visiting museum settings. The educator also elicited responses and opinions from students related to topics such as: the decrease in positive attitudes towards science in upper elementary grades, beliefs about how children share science ideas with peers, and methods of assessing students' science learning.

A goal of this first phase was to present students with a rationale for promoting activities that encourage science investigation through guided facilitation. This could best be accomplished by modeling an exploratory approach that would also demonstrate the interactive potential of the technology. Therefore, during the latter half of the first session, the course instructor introduced the manner in which a two-way audio/visual videoconference could be used beyond didactic presentation or oral discussions. The museum educator explained a manipulative used by ScienceWorks staff members for the Fossil Wall Exhibit. *Fossil Concentration* is an interpretive activity in which participants must match identical types of fossils that are hidden under lids of the playing board. The museum educator used the museum-manufactured example (which consisted of an 18 section wooden box, lids, and fossil samples from the museum's natural science collections) to explain the manner in which gallery personnel conducted the matching game. The methods students participated from their site with a simplified version of the activity using empty yogurt containers and fossil samples donated from the university's Earth Science Department. As the students made fossil matches, they placed them under a document camera which broadcasted the images to the museum educator. She helped verify student predications by "zooming-in" on a fossil identification wheel located in the exhibit area.

The final portion of the presentation highlighted the ability of the technology to help students immediately "put theory into practice". Since the broadcast occurred during open gallery hours at the museum, the museum educator invited on-site children to participate in a "Fossil Wall" exploration. The methods students were able to observe children's behavior and observe the museum educator demonstrating various methods of guided facilitation. This particular visual experience provided a catalyst for in-depth discussions that focused on questioning techniques and strategies for encouraging exploration.

Phase II: Exploratory center critique.

An assignment for this methods course was a small-group project that involved the research, design, and facilitation of a science exploratory center. These centers were developed for a local partner elementary classroom and focused on a single science topic (i.e. magnetic attraction, color mixing, animal adaptations, etc.). This center incorporated the use of "productive questions" which, according to Jelly (1985), are questions that are answerable by all children because they are derived from direct experiences with materials and promote science as a way of thinking and doing. A final criteria for the centers was that they be designed so that they would not only be facilitated by the classroom teacher, but would also successfully generate independent exploration by the children.

As a preparation for the second phase, the museum educator and course instructor videotaped children interacting with the exploratory centers a few days after the methods students had introduced them. While videotaping, children's responses to the included productive questions were elicited. The museum educator then reviewed and edited the video segments. During the second videoconference link, which was broadcasted from the museum's dedicated distance learning classroom, the museum educator provided a critique of the centers based on criteria such as: developmental appropriateness of concepts and questions, feasibility of the center, ability to generate independent exploration, and face-presentation value (how well its physical appearance could attract and hold attention). As the museum educator explained her evaluations, she interspersed the video vignettes of the children's interactions. This provided concrete examples related to the critiques. Students were given opportunities to discuss why certain aspects of their center were successful, as well as inquire about strategies for improvement.

Phase II: A modification

While students enrolled in a shortened summer session were also required to complete group-generated exploratory centers, the elementary school's calendar prevented the experience of utilizing the centers with a cooperating classroom. The course instructor still wanted to provide an opportunity for the methods students to facilitate the centers with elementary-age children. Therefore, an arrangement was made with the museum educator for the methods students to present their centers at The Children's Museum. Following the Phase I link, the students traveled to the museum on a Sunday afternoon to set-up their center outside the entrance to the ScienceWorks Gallery. As visitors traveled in and out of the gallery, the methods students invited children and family groups to interact with the centers. The students were also encouraged to observe the manner in which both children and parents approached and participated in the center.

Student Response

Student reactions to this collaboration were positive. Many mentioned that this was their first experience with videoconferencing and found the approach *"interesting"* and *"exciting"*. Some suggested that the teleconference be even longer and that more of them be incorporated throughout the semester. While the actual experience with the technology was viewed as successful, it was also the focus of criticism. It was the equipment, as opposed to the content, that students felt needed the most "tweaking". Many noted that occasional audio scratchiness and other audio/visual anomalies proved to be the biggest distraction. Such feedback emphasizes the necessity of "electronic clarity" to promote truly successful experiences with this technology.

When asked to reflect upon the content of the Phase I link, many students highlighted the museum educator's explanation of constructivist philosophy as superb and felt she had an excellent understanding of how children learn science. One student commented that: *"This conference proved that there are institutions that reinforce the idea that science is relevant in everyday life and that it's fun and exciting"*. While the majority of students felt they had gained a context for children's learning in informal environments, some also found it difficult to see connections to the content and philosophy of the methods course. This may be a result of the links occurring toward the beginning of the semester as the students' understanding of science epistemology was just beginning to emerge. Additionally, comments from the Phase I link regarding more opportunity for asking questions, enabled the Phase II links to be viewed as more interactive. Both the museum educator and course instructor made a more conscious effort to encourage active participation during those latter links.

Even though the structure of the exploratory center component of the project varied, both groups overwhelmingly enjoyed this portion of the collaboration. Those who participated in the original Phase II found it beneficial to observe children interacting, via videotape, with their centers. Since the structure of the methods course only allowed the students the opportunity to introduce their exploratory centers to their partner schools, students commented that this feedback provided them with a concrete assessment of the success of their centers. While the museum educator provided plenty of praise for all the projects, the instructor initially felt that the students may become defensive when the educator suggested areas of improvement. However, the overall consensus was that this critique was necessary as students respected the feedback and recognized its importance for their professional development.

Those who experienced the on-site visit to the museum for the modified Phase II component expressed enjoyment for using that setting as their "classroom". Many appreciated the opportunity to work with diverse groups of children and their families. One student commented: "*This activity demonstrated the many ways that children do an activity. They all have individual thought processes that they go through to complete an activity. This was very helpful.*". Another student commented on the benefit of the immediate feedback that became available through working with museum visitors and observing their reactions *"on the spot"*. These reflections and general climate of the class during the link suggest that this project could be a fruitful supplement to the science methods' experience.

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TEACHING PRACTICES THAT PROVIDE COGNITIVE SCAFFOLDING FOR CLASSROOM INQUIRY

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Cognitive scaffolding is what a teacher does when working with a student "to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts" (Wood, Bruner, & Ross, 1976, p. 90). As a psychological construct, it refers to the interaction between the knowledge and skills of teacher and student. A computer, textbook, or laboratory materials may serve as proxy for a "teacher." Considering that scaffolding is typically a dynamic process, reflecting adjustments based on student responses, arguably the most important source of scaffolding in a classroom is the flesh and blood teacher. The teacher decides, consciously or unconsciously, how and when to use a computer, textbook, or laboratory materials. The actions of the teacher are also the primary mediator of the scaffolding effects of other classroom materials. This paper is part of a research program whose purpose it is to design instruction for scaffolding classroom inquiry in middle school classrooms.

Problem

Science educators and teachers need a better picture of what inquiry instruction looks like as it is being practiced in a typical classroom. Current models describe inquiry as a matter of steps or phases conducted in succession or in cycles expressed in terms of expected student cognition. Descriptions of teaching practices to elicit and maintain cognitive engagement have remained at a level of generality that leaves the operational meaning up to the classroom teacher (Romberg & Carpenter, 1986). Teaching practices are typically stated in terms of "engaging students in discussion" or "doing an activity" that causes "cognitive conflict". To work out the operational form of instruction, a teacher must be skilled in a variety of strategies (see Figure 1) in order to design instruction that maintains the desired cognitive demands of inquiry while adjusting to the constraints of a typical classroom. Sometimes the teacher must settle for an approximation of inquiry instruction. As a result, instruction may looks less student centered, as the accepted view

Figure 1

Teaching Skills that Support Classroom Instruction in Science.

- Execute methods for presenting content in the form of problems that stimulate selected aspects of inquiry.
- Model or demonstrate inquiry so that students can copy the traits of an expert.
- Execute skills needed for designing, implementing, or evaluating hands-on investigations.
- Teach skills and procedures for interacting in small groups.
- Execute procedures for promoting interaction between existing student knowledge and new knowledge.
- Execute explicit instructional methods for teaching specific knowledge, process skills, or scientific attitudes.

of classroom inquiry implies, and more teacher centered. That is, where students are not functioning sufficiently well with the content or materials for any of a variety of reasons (see Figure 3), the teacher must carry more of the burden for organizing the content, raising points for consideration, and planning subsequent steps in the instruction.

Current models of inquiry-oriented instruction do not account for classroom variables that teachers face when operating under typical classroom conditions. These models suffer from three structural problems. First, they are too highly structured and narrowly focused. For instance, as implemented, the learning cycle converges on a conceptual target that presupposes students are modifying their personal conceptions in light of scientific principles. There are other reasonable outcomes of a learning cycle lesson that are pedagogically sound stopping points but the model as applied rarely assumes other outcomes. Second, students are asked to perform complex cognitive tasks for which they are unprepared. The instructional targets for current models expect students to analyze data and synthesize conclusions without first achieving an operational understanding of what it means to do analysis and synthesis. Third, current models of instruction are presented in isolation from each other. Models do not contain heuristic supports for helping teachers decide when a model might be useful or how it would work with other kinds of instruction such as listed

Figure 3

Some traits shown by underachievers*

Say they are bored
Indulge in idle chatter
Fail to do homework
Fail to take care over work
Rarely have pen, pencils, books, etc.
Lose things
Respond better to individual attention
Disrupt other pupils' work
Are distrustful of teachers and of authority
Form unstable or weak friendship bonds
Are often late for lessons
Are absent more frequently than other pupils
Claim that what they learn is of no use
Feel that school is an imposition
Wish to leave school to earn money
Express non-involvement in their form of dress
Are disrespectful of property
Are attention seeking
Dress untidily

* Source: Reid, D. J. & Hodson, D. (1987). Science for all: Teaching science in the secondary school. London: Cassell Educational Limited.

in Figure 1. Skilled teachers work out methods that overcome these structural problems as they occur. Observing their methods for creating an inquiry-oriented environment and scaffolding student participation should offer insight for how to begin providing operational detail on inquiry models of teaching. This approach has been used in other studies in science education. The work of skilled and practiced teachers have been regularly used to establish context and find starting points for instructional research. Tobin and Fraser (1990) observed skilled teachers to examine parameters of excellent science teaching. Effective teachers were contrasted with ineffective teachers to establish parameters of what constitutes "effective."

The purpose of this exploratory study was to analyze the practices of two skilled and experienced middle school teachers with respect to a model of instructional scaffolding. The research question was, What do skilled, experienced teachers do when scaffolding inquiry-oriented instruction?

Method

Two experienced teachers were selected from a field of eight. Seven of the eight potential subjects were teachers participating in an extended inservice program for improving knowledge and skills in teaching science. The eighth teacher with similar inservice experience was recommended as being a good candidate for this study. Five of the eight agreed to participate in an initial observation period that lasted from six to eight weeks. Based on in-class observations partially supported by video tape records, two middle school teachers were selected for in-depth study. They were selected because they not only exhibited the knowledge, skill, and intent to create an inquiry-oriented instructional environment, but also presented teaching routines that were used to provide a continuous thread of inquiry across lessons. Teachers A and B have 10 and 13 years of experience in middle level teaching respectively. Teacher A currently teaches sixth grade and sees all of the sixth graders in his school. Teacher B teaches seventh grade and sees all of the seventh graders in his school. Both teach physical education as part of their assignment. Both have been participants in several inservice programs related to improving science teaching. Both regularly attend national and state professional science teacher meetings.

Field notes were supported in part by video tape during direct observations of teaching. Each teacher was observed six times and video taped was used twice with each teacher as a means of triangulating interpretations with field notes and interviews. One 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.

Analysis

Field notes and partial transcriptions of video and audio tapes were analyzed using an operational definition for scaffolding instruction derived from Palincsar and Brown (1984) and Palincsar (1986). A synthesis of the literature on the psychological construct of scaffolding resulted in the criteria listed in Figure 2. The validity of this definition for scaffolding is based on an analysis of the literature and on my own empirical work in examining the practices of expert teachers (Flick & Dickinson, 1997; Flick, 1996; Flick, 1995). The content validity was checked by showing Figure 2 to two science educators with 10 and 15 years of teaching experience each. They were both familiar with the literature in inquiry science teaching and the nature of science. Their assessment was that the formulation presented in Figure 2 was a more comprehensive definition of scaffolding than was typically used in the literature. They felt that all elements were appropriate to the construct and could be assessed in instruction.

Figure 2
Elements of Scaffolding*

- Selection of task that teaching a skill emerging in the learner
- Evaluation of task for difficulties it will present to learner
- Structuring opportunities for student participation
- Render the task accessible to learner
- Accentuate critical features of task
- Organize task for presentation
- Identify and represent appropriate approaches to the task
- Identify and represent approximations of successful completion
- Elicit and sustain interest
- Designing assessments to calibrate the level of difficulty
- Providing learner with feedback on her production and on correct production
- Adjust levels of instructional support toward gradual withdrawal

* adapted from: Palincsar, A. S. & Brown, A. L. (1984) and Palincsar, A. S. (1986).

Construct validity is the more important form of validity in this case and more difficult to establish. The central question is, Does the stipulated definition differentiate between teachers who do scaffold inquiry and those who do not? To accomplish such a judgment it is necessary to settle on a valid definition of what classroom inquiry means and a valid form of assessing the outcomes of its implementation. These are steps being taken in the next phase of this research program. It is not possible to make a judgment of construct validity at this time.

Teaching episodes from both teachers were analyzed against the criteria shown in Figure 2. The analysis examined the specific classroom context across lessons and content to reach an evaluation of the level and nature of instructional scaffolding for fostering inquiry in a middle school classroom. A model of classroom inquiry based on Rowe (1973) was defined to include the following components: (a) addressing a specific question, (b) applying specific background information, (c) performing procedures for the purpose answering the question by collecting observations, (d) making inferences from these observations with the purpose of answering the question and (e) interpreting new experiences using concepts they already have or using concepts developed through instruction. This model of inquiry was validated by the same two science educators described above and, as a result, modified to include (f) presenting results to others, sharing ideas or techniques and (g) using social skills to engage in all elements of inquiry within a small group context.

Table 1 shows a detailed analysis of elements of teaching for each teacher that fit under each category of scaffolding. Each category also includes an element of teaching where additional scaffolding was possible and would have improved instruction. This analysis of contrasts shows that applying the stipulated definition of scaffolding will typically show contrasts between actual practice and "improved" practice especially for instruction not designed to meet these specific criteria.

Extended description of each teacher's practices characterized instruction based on all the observations. Each characterizations offers an analysis of both instructional practices and their relation to the elements of inquiry.

Table 1
Analysis of Instruction for Elements of Scaffolding

Elements of scaffolding	Gary	Levine
A. Selection of task that teaches a skill emerging in the learner	+ Reflection exercise is designed to address a skill or concept currently part of instruction, e.g. looking for trends in data. - Reflection tasks that focus on a concept, e.g. density, teach only that concept and do not emphasize learning skill development, e.g. reflecting on the purpose of the question.	+ Selects video emphasizing science as human endeavor based on student emerging awareness of broad scientific questions, e.g. how did life begin on earth? - Discussion sometimes falters because questions and topics become too esoteric. Target skill is not clear.
B. Evaluation of task for difficulties it will present to learner	+ Wording of the Reflection question is examined along with potential conceptual difficulties. - Some Reflections focus on a small part of an ongoing lesson and is not calibrated for the overall development of inquiry skills. These can be too difficult.	+ Mediates high level content in video or inquiry activity by linking to current student knowledge. Linked to earlier lesson on seeing problems from another's point of view. - Sometimes the zeal of teacher overrides the original nature of the task and discussion becomes too difficult for students.
C. Structuring opportunities for student participation	+ Attention to the task is demanded, students are called on, small group discussion time is provided. - Not regular provision for <u>all</u> students to explicitly participate, e.g. instructions for small group interactions.	+Video is broken into short sections supported by study guide. Students write own questions about major issues to prime thinking on topic. - Wait-time is very short. Pace of class to too brisk for some students to get opportunity to speak.
D. Render the task accessible to learner	+ Notes, handouts, and class discussion provide feedback specific to student responses and offers a variety of explanations to aid conceptual	+ Combines short brainstorming sessions with responding to study guide to provide time to think and process information. - Teacher directs much of the classroom

	understanding. - Conceptual difficulties, time, and numbers of students sometimes combine to make the task less accessible.	interactions in an effort to make efficient use of class time. There are many limits to how many issues the teacher can respond to.
E. Accentuate critical features of task	+ Feedback maintains focus on main purpose of Reflection, e.g. finding errors in data collection. - Because of variety in tasks, sometimes critical features have not been thoroughly thought through or the task it too complex.	+ Reminds students of lesson purpose and how video or activity helps address it. - Reminders are typically given by teacher and students only listen and do not have to fashion a response. Sometimes task is too complex and critical features have not been carefully examined.
F. Organize task for presentation	+ Reflection is always written on board and supported by visual aid. Students use notebooks for responses with clear format and routine for handling logistics. -Because the tasks are written in a short timeline and tailored to the current lesson, sometimes visual or concrete supports are missing.	+ Study guide, segmenting video, and preassigned student groups organizes setting for interactive presentation. - Pace of class is so fast at times that structures in class can not be used effectively or frequently, e.g. effective small group interaction.
G. Identify and represent appropriate approaches to the task	+ Provides verbal and visual feedback on how to think through the Reflection problem. - All students do not benefit from feedback due to lack of attention or misunderstandings.	+ Features of study guide are pointed out, time allowed to record responses and to share responses. Provides feedback on producing responses. - Strategies for processing information rely heavily on discussion lead by teacher that limits the number of approaches that can be presented.
H. Identify and represent approximations of successful completion	+ Highlights specific student responses and helps shape correct responses. - Discussion is often fragmented, guided by student questions and some students are unable to follow train of thought.	+ Rapid and purposeful feedback focus attention on expected responses. - Ideas are dealt with quickly and few students are checked for appropriate responses.
I. Elicit and sustain interest	+ Uses relevance of problems, humor, and fast pace to keep student interest.	+ High energy presentation, laced with humor, allows for student input., while

	- Some problems do not arouse interest and pace is too quick for some students.	reinforcing value of video and importance of content. - When discussion becomes too difficult, interest wanes resulting in minor disruptions.
J. Designing assessments to calibrate the level of difficulty	+ Every Reflection is graded with feedback to student and to teacher. Feedback from students is used to judge difficulty and indirectly calibrate assessments. -There is no systematic way to calibrate Reflection problems. Design is specific to instruction and varies from year to year. There are no long-term learning goals targeted by Reflections.	+ Attends to student input as a general source of knowledge for calibrating assessments. -May calibrate next task based on outcome of previous task but usually only adjusts grade in response to perceived difficulties.
K. Providing learner with feedback on her production and on correct production	+ Whole class and small group discussions are conducted so that all have opportunity to hear. Selected students get feedback and corrections. - No systematic provision to provide all students with feedback and corrections.	+ Individual and group worksheets are regularly marked with feedback. Often debriefs assessments with class. - Feedback is highly teacher-directed with little accountability on the part of individual students concerning corrected responses.
L. Adjust levels of instructional support toward gradual withdrawal	+ Students take varying degrees of control in solving problems as a function of degree of difficulty, attitude of students, and attitude of teacher. - No systematic communication that students are moving toward independence in cognitive tasks.	+ Provides explicit instruction concerning small group procedures and other classroom routines and expects students to independently perform these tasks. -No systematic communication that students are moving toward independence in performing cognitive tasks.

+ indicates actual observations of elements of scaffolding.
- indicates elements of scaffolding not observed but relevant to the instructional context.

Characterizing Instruction: Mr. Levine

Levine opened most classes with a warm-up problem presented on the overhead. Because math and science were taught in a 90-minute block, instructional patterns were somewhat conflated across the two subjects. However, there was a clear emphasis in math to teach specific problem-solving skills while in science the content was more conceptual in nature. As a discussion leader, Levine helped students engage with the warm-up problem or question through direct hints or prompts concerning the expected answer. While student responses were solicited and encouraged, Levine's instruction directed them toward a statement of the expected answer in a fast-paced and efficient manner.

Levine created cognitive supports in the form of words, phrases, techniques for processing information, or analogies for how to understand the problem. Following the warm-up, Levine introduced an activity (e.g. video, lab, creating a product, or worksheet) around which he eventually developed more discussion of the target concept. Most of the work in the class was conducted either in small group structures or as whole class discussions. There was very little individual seat work. Levine employed specific procedures to structure transitions to and from student-student interactions. The goal was to establish and maintain an atmosphere of academic work, attention, and courteous behavior. These rules became so well known by the students that only a minor prompt was needed to review them. For example the rules for small group work were: (a) quiet voices, (b) invisible walls symbolizing that small groups were not to interact, (c) polite disagreement, (d) stay focused, and (e) encourage participation and value all ideas. Levine himself modeled these behaviors in whole-class work and through this structure he established an atmosphere conducive to the divergent thinking of inquiry. However, these small group work did not generally include presentation of results to each other.

Inquiry questions were posed and specific background information was brought to bear on these questions. Students perceived the class as a safe place to offer ideas and there was a specific expectation that they speak out. Some questions tended to be broad and not directly researchable by evidence generated in the classroom. For example, students discussed causes for the extinction of dinosaurs. Other questions were more accessible to investigation. Students examined the composition and structure of rocks and devised their own classification schemes. Rarely did students actually perform procedures, collect data, and make inferences for the purpose of answering questions. The mix of these inquiry elements was informal but did lead to the application of concepts to new experiences. In the case of dinosaurs, they analyzed the research presented in a video presentation.

Levine used a video from the PBS series Scientific American Frontiers entitled "Life's Big Questions." Students were arranged in groups with a worksheet that outlined the content of the video and posed questions for recall and reflection. Levine stopped the video at appropriate points to check to see that students were attending to important points. He encouraged student note-taking on worksheets and offered questions and prompts that embellished what was presented in the video. The ensuing discussion modeled his expectations of student behavior in small groups and he reminded them of these points (i.e. stay focused, polite disagreement, encourage participation, and value ideas). In the process, student ideas were elicited and he explicitly expressed that the ideas were important and valued. Students offered interpretations and original points of view. Each video segment lasted not more than 10 minutes and Levine's structured feedback required review and synthesis on the part of students. He was careful to call on a wide range of students covering most of the class. During activity sessions and even during whole class discussions, he noted positive and negative behaviors relative to maintaining a productive and inquiry-oriented classroom atmosphere. He regularly provided specific feedback to the class about these behaviors in the form of complements and how to improve. These reminders about the conduct of work in the class was also connected with the nature of the work. That is, the desired atmosphere was important because students needed to be focused on solving a problem and discussing notes or ideas.

Characterizing Instruction: Mr. Gary

Gary opened nearly every class with a routine he called "Reflections." In a Reflection, Gary posed a question or problem for the purpose of applying a concept or developing a skill.

Reflections were structured as an open-ended question about half the time, but during every discussion Gary solicited and valued divergent points of view. This procedure established an atmosphere of inquiry through reflective thinking that students were expected to engage in. In this sense, students were regularly asked to address specific questions and apply appropriate background information. Written responses to Reflections were recorded in a special student notebook and collected periodically for evaluation. A Reflection exercise could take anywhere from 10 to 35 minutes depending upon how productive the discussion and how many supports were needed for students to produce a response. Gary provided cognitive supports in the form of prompting questions and summary statements. These were generated often enough to keep active discussion going. This could mean a new statement or question as often as once a minute or as little as one in 10 minutes as explanations and ideas were exchanged. The prompt always connected work done during the most recent lessons with a planned activity or lab. Cognitive support also came through student questions and statements that attempted to address the prompt. From the prompt, "How can you increase the density of water?," students offered the following ideas: freeze it, compress it, or turn it to a gas and compress it. Each of these ideas stimulated additional comments from the class mediated by Gary's summaries and restatements.

The pace was kept brisk with short wait-time in the course of whole class discussion. He structured wait-time in the form of brief discussions with pre-assigned partners. Typically he allowed 30 seconds for students to generate a question or a response to a problem currently under discussion. During that time he was circulating among the groups asking questions to focus or redirect attention. He also gathered examples of ideas that he could use to prompt participation from less vocal students. The transition from whole-class to partners and back to whole-class wasted no time and student attention was not allowed to wander very far.

The goal of Gary's instruction was to direct attention to the focus problem stated in the Reflection written on the board. At some point where Gary felt the discussion had ceased being productive, he introduced or reiterated a specific answer. It was presented in the context of all the ideas offered during the class and students were expected to write their own synthesis of this discussion. Many students wrote reflections during the class discussion but Gary provided a specific time to write at the end of the discussion.

The Reflection helped to introduce or follow-up a lab activity, such as measuring the density of various materials, building a small electric motor, or designing a small car. Gary closely monitored the activities by offering observations and suggestion concerning procedure and results. Questioning in this context was different from the Reflections portion of the lesson. Teacher-student interaction was far more directed, convergent, and explicit. Students had a product to produce and Gary helped them do it. It was likely that some aspect of the lab work would become the focus of the next Reflection. Formal investigations, such as testing a consumer product, combined with Reflections provided opportunities for students to perform procedures, collect data, and make inferences to answer specific questions. Reflections offered regular opportunities to interpret new experiences using the results of investigations. The presentation of results to other was usually done in the context of small group discussions during the Reflection portion of the lesson.

Results

Both Gary and Levine were active in creating scaffolds for instruction that supported learning in science in general and learning through inquiry in particular. They created learning environments and procedures that allowed students to do what they would otherwise be unable to do if unaided. They did not structure these learning environments in the same way nor did they create all the elements of scaffolding as outlined in Figure 2. While there were several differences in methods of scaffolding, there were interesting similarities in those elements of scaffolding that were not in evidence. Each teacher is discussed in turn followed by a summary analysis.

Gary taught science to all seventh graders in his middle school. His scaffolding focused heavily on creating opportunities for students to engage in reflective thinking about the concepts or tasks upon which the class was working. At the beginning of each period, students were presented with a problem to which they would respond in writing in a special notebook. Through whole-class discussion, discussion with partners, and individual written responses, Gary scaffolded instruction that guided students through analysis of the problem and application concepts. A reflection problem might involve application of ideas to a novel setting such as examining a US map showing the location of atomic power plants and answering the question, Why are there more atomic power plants in the east than in the west? Other problems focused on ongoing investigative activity such as, Identify three possible sources of error in your data.

Gary's daily routine provided opportunities for accentuating critical features of important tasks in an investigation such as how to identify trends in data or how to write an hypothesis statement that met specific criteria. Multi-step investigative tasks or complex applications of concepts were beyond the capabilities of most of Gary's students. Through the classroom routines for examining selected problems or examining the characteristics of important procedures, Gary helped students identify approaches to performing these tasks, guided practice to approximate appropriate cognitive behaviors, and provided corrective feedback for target responses.

However, even with these routines in place and almost daily practice, many students participated marginally or not at all. During small group work or structured conferences with partners, Gary circulated around the room often answering the basic question "I don't understand what to do?" Gary observed that even several weeks into the term, some students would enter class, forgetting their notebook unaware that other class members were already reading and discussing the reflection problem written on the board. Many of these behaviors fit the description of underachievers shown in Figure 3. Gary's classes was an average, middle class students in terms of standardized test scores and socio-economic status. Yet despite the supports and advantages associated with middle class living, there was a significant portion of the class that did not respond to Gary's scaffolded instruction. We will see that this was also true for Levine's middle class students.

Levine taught science to all the 6th graders in his middle school. His scaffolding focused heavily on creating opportunities for student participation in discussion and activities. He designed specific routines and rules of behavior that promoted student input and specifically required that students listen to one another. This was particularly effective in soliciting points of view when attempting to identify a problem or understand a problem for investigation. His code of conduct and expectation of mutual respect was also invoked when soliciting background information to apply to a problem. Early in the year, he structured a lesson where students inductively answered the questions, What is science? The lesson involved several steps with students generating personal examples of "science", writing them on paper, taping them on the board, and participating in a categorization process. Scaffolding in this case involved (a) specifically requesting and publicly acknowledging all student input, (b) making and managing the large visual display on the board, (c) questioning to prompt summary and synthesis of emerging categories, and (d) reminding students of rules for whole class and small group interactions. The result is that nearly all students were involved and most receives feedback directly or indirectly by hearing other student-teacher interactions. This lesson is typical in that it reaches a successful closure.

Levine was very active throughout his lessons and his own energy often seemed like the main force that drove the discussion. Levine reflected on this general state of affairs:

> My plan is supposed to build a concept but I feel I am doing most of the thinking. Some students are actively thinking and some of these are trying to make comments. However, there are individuals you hardly have a clue what is going on.

Levine's comment captured problems with the scaffolding process with both teachers. Neither teacher was generally satisfied with participation with the class as a whole. Students in both classes were well coached in how to behave, provided with carefully selected tasks that had been rendered accessible through various kinds of support, and given feedback on their prompted input. Most students were successful in learning content objectives. However, neither teacher sensed that the students had an understanding of the direction of instruction or in some cases even the purpose of instruction. Instructional routines were designed to scaffold student participation in inquiry-oriented activities but not to understand the inquiry nature of those activity. Figure 4 is a list of observed instructional effects resulting from instructional routines.

Figure 4

Effects of Instructional Routines Based on Classroom Observations of Teachers in Study

- Communicate expectations common to entire class.
- Provide guidance for specific behavior at various stages of instructional activity.
- Provide a starting point for action.
- Structure a way to coordinate the efforts of an individual student with those of the entire class.
- Reduces emotional stress caused by uncertainty about procedures and releases more working memory for thinking about content.
- Provides check points for progress or metacognitive prompts.
- Becomes a model that can be used independently reducing the need for repeated instruction and supervision.
- Becomes a general tool for use in other academic work.
- Deviations from routines can be used to make a point or focus attention on new or alternative elements.
- Repetition inherent in the use of a routine aids in memorization of steps and the development of automaticity and the development of effective variations and adaptations.

There were elements of scaffolding as shown in Figure 2 that neither teacher employed in their instruction. Neither systematically evaluated tasks for difficulties; nor calibrated difficulty of assessments; nor gradually reduced levels of support to promote independent learning. Tasks were selected to be challenging and meaningful within the context of instruction. Instruction scaffolded student engagement with the specific problem and students were reminded of the general purpose. However, there was little attention given to the relative difficulty of the task and how or if students would eventually accomplish the task on their own. Adjustments were made at the level of procedures within a lesson but not at the level of the overall task or its purpose. In neither class were students verbally informed of the intention that they were expected to became capable of handling selected inquiry-oriented tasks on their own. For instance, Gary allowed students to take varying degrees of control in solving the daily inquiry problems (see Table 1), but there was no specific statement to students that they were learning "how" to respond to these problems. Levine communicated to students that they were expected to follow specific procedures for working together that included scaffolding for sharing ideas and roles within small groups (see Table 1), but there was no scaffolding that supported students achieving skills to tackle the tasks independently.

An analogy to coaching a soccer team makes a useful contrast between learning content and achieving skills for independent learning. Let's say these two teachers were soccer coaches and coached their teams in ways similar to the scaffolded instruction used in their classrooms. They would present problems in defense that required certain physical skills. Students would practice these skills in the selected problems, perhaps rotating through different positions such as goalie and defender. However, they would not be coached in how to size up different defensive problems as they occur in a game. Further the problems they were presented would not have been selected nor adjusted for improving skills. Rather, they would be selected for their relevance to specific problems deemed important for "learning" soccer. Students would learn how to set up plays but only under the guidance of the coach and not with the goal that they were responsible for learning how to "solve soccer problems" on their own.

Instructional scaffolding was focused on using inquiry skills and not on learning the skills themselves nor how and when to employ those sills in scientific problems. Put another way, the teachers paid more attention to using inquiry as a method for teaching science than teaching how to do inquiry. Elements of inquiry were used as a means for teaching science principles or facts but neither the elements of inquiry themselves nor the thinking necessary to engage in inquiry were the subject of instruction.

Suggestions for Further Research

Both teachers were successful in eliciting and maintaining a high degree of student attention, participation, and cognitive involvement. A feature of instruction that was effective in both classrooms were specific teaching routines that fostered student behavior that supported student participation in inquiry-oriented procedures (see Figure 4). Could routines effective in fostering behaviors that supported participation in activities be applied to the support of thinking skills important for engaging in inquiry?

Palincsar and Brown (1984) showed that "reciprocal teaching", a form of instructional routine, was effective in fostering comprehension and comprehension-monitoring in seventh-grade students reading science texts. They focused on development of a set of skills shown to be in common across many reading comprehension studies. These skills were summarizing, clarifying, stating questions answerable from the text, and predicting the content of the next portion of text. Are these skills useful in promoting cognitive skills for engaging in inquiry? What other cognitive skills are important for engaging middle school students in the meaning and purpose of inquiry? Are these skills developmentally appropriate for early adolescent children? What instructional routines are effective in communicating instructional goals of fostering cognitive and metacognitive behaviors the support inquiry? How can instruction be designed to develop cognitive skills, calibrate the difficulty of tasks, and gradually reduce instructional support to promote independent inquiry at the middle school level?

A fruitful direction for further research in support of reform-based instruction is to examine the nature and function of instructional routines that target cognitive and metacognitive skills that are predicted to support learning science through inquiry.

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THE IDEAL ADVISOR: GRADUATE SCIENCE STUDENTS' PERSPECTIVE

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Introduction

The nature of the relationship between the graduate student and his/her advisor is perhaps the most important determinant of a student's success or failure in any graduate program (Bargar & Mayo-Chamberlain, 1983). This relationship is even more important in science where in addition to being the student's advisor and mentor, the advisor is usually the head of the laboratory in which the student conducts her/his research. Sheila Widnall (1988) points out that because the Ph.D. thesis in science is primarily an apprenticeship in research, a graduate student's success greatly depends on the nature of the relationship with her/his advisor. According to her "the advisor is the primary gatekeeper for the professional self-esteem of the student (p.1743)." Advisors are also the most readily accessible professional role models to their graduate students.

Conceptual and Empirical Foundations of the Study

Research indicates that the nature of the relationship between graduate students and their advisors is the single most important factor in the success of graduate students. Studies show that students' satisfaction with doctoral programs is directly related to satisfaction with advisement relationships (Carter, 1983; Daniels-Nelson, 1983). In fact, the quality of the interpersonal relationships between graduate students and their advisors has been found to be a better predictor of success in a doctoral program than a student's GRE scores and undergraduate grade point average (Sorenson & Kagan, 1967). Unfortunately, the advisor-advisee relationship is often perceived as the most disappointing aspect of many students' experiences in graduate school (Bargar & Mayo-Chamberlain, 1983; Carter, 1983).

According to Winston, Miller, Ender, and Grites (1984), the graduate advisor performs a minimum of five essential roles: a) being a reliable information source, b) acting as a departmental socializer, c) acting as an occupational socializer, d) serving as a role model, and e) being an advocate for the advisee. Furthermore, it is essential that advisors of incoming graduate students take the initiative in establishing sound interpersonal communication grounded on trust, openness, and mutual willingness to grow (Bargar & Mayo-Chamberlin, 1983).

Ideally, advisors become true mentors to their students. According to Anderson and Shannon (1988), mentoring is an intentional, insightful, supportive process "in which a more skilled or more experienced person, serving as a role model, nurtures, befriends, teaches, sponsors, encourages, and counsels a less skilled or less experienced person for the purpose of promoting the latter's professional and/or personal development (p. 39)." Furthermore, the mentoring process involves three stages: "modeling," "coaching," and "fading." The mentor "models" by revealing his/her problem-solving strategies; "coaches," by supporting the students' attempts to perform new tasks; and "fades" after having empowered the students to work independently (Brown, Collins, & Duguid, 1989).

Students who have a mentoring relationship with their advisors feel professionally affirmed and are more productive after graduation (Heinrich, 1991; Subotnik & Arnold, 1995). Research indicates that successful scientists often have had, at some stage of their career, supporting and influential mentors (Subotnik & Arnold, 1995). Female students who join science graduate programs with few or no female faculty are at a greater risk of leaving a promising career in science when their advisors show little interest in their success. Subotnik & Arnold (1995) argue that women, in particular, who may question their ability to be successful, do best in colleges and universities that offer responsive mentors.

According to Walter C. Randall (1982), the ideal advisor/mentor advises his students to the best of his ability and wants to make them as good or better than he is and as quickly as possible. In addition, an ideal advisor/mentor allows his students to make mistakes and while pointing out their oversights, admits and shares his own past mistakes with them. Advisors who have mentoring relationships with their students use an "androgynous" approach and are "gender-sensitive." These advisors assume "father-daughter/son" and "colleague-colleague" roles with their advisees (Heinrich, 1991).

This purpose of this study was to investigate graduate students' perceptions of: the level of mentoring in two graduate science departments, their relationship with their advisor, and the characteristics of an "ideal advisor."

Methods

The study took place in two graduate science departments, biology and chemistry, at a large research university. Quantitative and qualitative methodologies were used in data collection and analyses. Results were based on a 5 point Likert-type scale survey questionnaire from 170 students (71 females and 99 males) and interviews conducted with 32 students (16 females and 16 males). Six of the students interviewed had left the program before completing their degree. The survey items examined students' perceptions of their relationship with their advisors as well as students' perception of the level of mentoring in their department. A T-test and a chi-square test were performed on each survey item in order to determine departmental and gender differences. The comments to the items in the survey and their answers to the interview questions were analyzed using the techniques of naturalistic inquiry described by Lincoln and Guba (1985).

Results

Ten of the survey items were designed to assess the nature of the relationship between the graduate students and their advisors. In addition, two items (11 and 12) tried to determine the level of mentoring in each department (see Table 1). Results indicated that the level of mentoring in both departments was not very high. This view was particularly common among the female students in chemistry. Only 24.1% of these students agreed that the level of mentoring in their department was very high, whereas a much larger percentage of them (48.3%) agreed that the level of mentoring in their department was inadequate. These responses were significantly different from the other three groups (see Items 11 and 12 in Table 1 and Table 2 below). The female students in chemistry were also much less likely to agree that their advisor was often available for support, that he had equal expectations for his male and female students, and that he asked his female students for their opinion (see Items 3, 6, and 7 in Table 1 and Table 2 below). Of the students in the other three groups, between 55.6% and 60.0% of them felt that the level of mentoring in their department was very high (see Item 11 in Table 2).

Table 1
Students' Relationship with Their Advisor: T-test Results

Statement	Biology Dep. Females	Biology Dep. Males	Chemistry Dep. Females	Chemistry Dep. Males
1. My advisor has equal expectations for his/her male and female students.	3.62	3.60	3.33	3.59
2. I often feel my comments/ideas are taken seriously by my advisor.	3.67	3.84	3.60	3.81
3. My advisor is often available for advice and/or support.	3.59	3.62	3.37*	3.75*
4. I have learned a lot from my advisor.	3.66	3.76	3.70	3.83
5. I feel my advisor has the same expectations for me as for my female colleagues.	3.77	3.57	3.66	3.59
6. I feel my advisor has the same expectations for me as for my male colleagues.	3.62	3.83	3.37*	3.74*
7. My advisor asks for the opinion of hi/her female students even when there are male students around.	3.59	3.61	3.43**	3.83**
8. My advisor asks for the opinion of his/her male students even when there are female students around.	3.84	3.65*	3.87	3.90*
9. My advisor knows how to deal well with his/her male students.	3.28*	3.53	3.67*	3.77
10. My advisor knows how to deal well with his/her female students.	3.15	3.47	3.24	3.52
11. The level of mentoring in my department is very high.	3.32**	3.36	2.69**	3.44**
12. The level of mentoring in my department is inadequate.	2.59**	2.59	3.17**	2.54**

Note. The higher the score is, the stronger the agreement.

*$p < .05$. **$p < .01$.

Table 2
Percentage of Students Agreeing with Each Statement

Statement	Biology Dep. Females	Biology Dep. Males	Chemistry Dep. Females	Chemistry Dep. Males
1. My advisor has equal expectations for his/her male and female students.	76.9	73.3	56.7	72.5
2. I often feel my comments/ideas are taken seriously by my advisor.	76.9	91.1	73.3	86.5
3. My advisor is often available for advice and/or support.	76.9	77.8	63.3	80.0
4. I have learned a lot from my advisor.	73.3	82.2	83.3	86.5
5. I feel my advisor has the same expectations for me as for my female colleagues.	84.6	71.4	75.9	73.5
6. I feel my advisor has the same expectations for me as for my male colleagues.	76.9	85.0	56.7	82.0
7. My advisor asks for the opinion of hi/her female students even when there are male students around.	75.7	72.7	63.3	85.4
8. My advisor asks for the opinion of his/her male students even when there are female students around.	89.2	74.4	86.7	89.6
9. My advisor knows how to deal well with his/her male students.	51.3	72.1	76.7	80.8
10. My advisor knows how to deal well with his/her female students.	46.2	65.1	58.6	60.0
11. The level of mentoring in my department is very high.	56.8	55.6	24.1	60.0
12. The level of mentoring in my department is inadequate.	21.6	15.9	48.3	16.0

Various students' comments to items in the survey also alluded to shortcomings in their relationship with their advisors. Females seemed to be particularly affected by the lack of proper mentoring in their department. "If I tell him something, he asks the nearest male for his opinion. I'm never included in their conversations," wrote a female chemistry student. A female biology student who had quit commented: "He was rarely available for advice and was never supportive of our efforts. I found myself avoiding talking to him because it was always a depressing experience."

Although many students talked kindly about their advisors, rarely did students use the term "mentor" in referring to them. The great majority of the students referred to their advisors as "boss." The reason was probably due, at least in part, to the organization of many research projects. When students joined a laboratory, many of them became part of a team that was working on a large project managed by their advisor. The advisor provided financial support to the students and in turn the students performed the work necessary to the success of the advisor's project. As a result, these students had little input in most aspects of their own training and perceived their advisor as their "boss." The following passage from a male student in the biology department reflects this view.

> I don't know if you know this, but in sciences like ours and I think in chemistry and physics as well, a lot of times people come into a graduate program, a Ph.D. program specifically, and are given a project by their research advisor. And they rarely, I think, understand why they're doing this project and even less frequently have any real input into what they're going to do. It's sort of a bargain, and the bargain is that you go in, they give you a project to do because, of course, they need to get this research done for their own purposes. You fulfill your part of the bargain by doing this research for three or four years, you get a Ph.D. The person, the advisor, will then get a number of papers from that, put their name on them, of course, then be able to secure more grant money to continue another research project to get more people to come in...

When during the interviews a male student in chemistry was asked why most students referred to their advisor as a boss, he mentioned another aspect of a boss-employee relationship that he felt was the norm in most laboratories. According to him, in addition to being told what to do, students were monitored periodically on the amount of time they spent in the laboratory as well as the amount of work they accomplished.

> Ya, I think that's pretty accurate [the term "boss"]. I would see my advisor as more of a boss than a mentor. I mean, he certainly is very good about talking with you about your research and giving you advice. But, on the other hand, I feel like periodically I'm expected to prove to him that I'm doing research. And in that sense then, it's much like an employee-boss relationship where you have to prove to your boss that you're worthwhile or else, you know, maybe you won't be around much longer. And so in that way, I think it's fairly true.

Similarly, when asked if she felt her advisor was more like a boss who told her what to do and how to do it, a female in biology replied:

> Absolutely. I guess I worked for him. In fact, it was almost more along the lines of an overseer instead of just a boss. You know, our ideas as students counted almost nothing.

Hackett (1990), contends that the utilitarian approach taken by many advisors is due to the competitive pressures for research money. In addition, the tight research budgets, with little discretionary money, force faculty members to take a more instrumental view of their subordinates, viewing them more as research labor than as students. According to him, today's faculty members must be businesspersons, entrepreneurs, as well as teachers and scholars. This premise seems to be supported by the comments of a chemistry faculty member who commented that "the job of a faculty member in the sciences is quite entrepreneurial. You can accomplish not only to the level of your intellect, but to your level of gamesmanship."

Indeed, some laboratories look like small entrepreneurial organizations with as many as 25 students. In this type of laboratory most of the advisor's efforts are spent securing funds and in finding efficient ways of running their operation. As productivity becomes the advisor's main concern, the mentoring of students is forgotten and they become replaceable hired hands. According to students, in such laboratories senior students are also responsible for the training of incoming graduate students. The following example was provided by a male student in the chemistry department.

> One group I can think of in particular, students maybe see their advisor, talk with their advisor, every two months, and they have to depend a lot on each other. Especially the newer graduate students usually wind up being paired off with a more advanced graduate student, and they do most of their learning that way.

The Ideal Advisor: Graduate Students' Perspectives

All students interviewed for this study were asked to describe their view of an "ideal" advisor. Most students described their ideal advisor at two levels: personal and professional. On the personal level students felt it was important to find an advisor whose personality and philosophy of life matched one's own and someone who could discuss other topics besides his/her area of expertise. A male student from the biology department expressed this view particularly well:

> The other things I value a lot are a certain degree of candor and casualness in the relationship. I've known some advisors who are stiff and rigid in dealing with their underlings in the lab, and that's fine early on, but if it never changes, if you work with someone for five years in the same room and they're always kind of stand-offish and are never willing to talk about anything except the details of science that you're working on, that's emotionally not a very welcoming environment. So I'm lucky; my boss likes to talk about politics, about culture, you know, I consider him my friend as well as my scientific advisor. So we have a very relaxed relationship, but yet tense in the sense that in the back of our minds we are both focused on the science. But it's like he feels he can break out from his role as scientific mentor from time to time, and I really appreciate that.

The relationship illustrated here appears to be what Heinrich (1991) calls "colleague-colleague" roles between student and advisor. This type of relationship was identified in a study of graduate students who characterized their advisors as mentors. Heinrich also identified another set of roles assumed by advisors and advisees in mentoring relationships -- "father-daughter/son." The description of the ideal advisor provided by a male biology student illustrates such a relationship:

> Well I think the first thing would be a professor who genuinely cares about the students; that's their primary concern. In other words, I realize that this is a research field, and I am a researcher myself, but if you're not interested in the students, you should not be teaching. He has to have the basic skills of the field, but if he is not interested in the students, then the skills are lost, they won't be transferred. So I think that's a very important feature, deep down, you've got to really be interested in those students, and you've got to be..., it's almost like a father and son or mother and daughter type relationship. You have to have that feeling for them in a level that..., it's got to be more than just a job; it can't be just a job...

On the professional level, the ideal advisor gives his/her students the proper combination of guidance and autonomy. Guidance so they will not feel completely lost when reaching a dead end in their research, but sufficient autonomy to allow them to try their own creative ideas. Most students felt that guidance was particularly important during the first two years of their graduate work. The following description of the ideal advisor provided by a female student from the biology department echoes this perspective.

> An ideal advisor for me would be one who is encouraging and is supportive and when you bounce off some ideas as you're developing your research is able to help direct your research but not be in control of it. And also someone who is willing to allow a lot of individualism on the part of the student. I think that this is one of the most difficult things for advisors because they do science in a particular way and yet they're working with a lot of different people who may approach science differently. And so being able to sort of direct but also allow the students who have an individual approach to contribute would be my ideal of an advisor.

Providing quality feedback is an important aspect of the communication skills of an ideal advisor. The ideal advisor points out weaknesses and pitfalls in the student's work in order to prevent him/her from getting into situations that may be detrimental to his/her success. Although making mistakes may be a useful aspect of the learning process, mistakes may be costly to students, particularly before they have been accepted to candidacy. A female student in the chemistry department stressed the importance of such communication in the following manner:

> An ideal advisor communicates well with his students. He does not necessarily have to do hands-on work with them in the lab, but is in frequent communication with you on the progress of your work and on your standing with him. I can't emphasize how important the communication aspect is and how it's very important to communicate well and give good feedback, both positive and negative, so the students don't all of a sudden get kicked in the butt when it comes down to their candidacy exam or something else important like that, because they've been doing something wrong.

An ideal advisor is empathetic and encourages his or her students. Although students feel that it is important for their advisor to point out their mistakes and weaknesses, they also want someone who after pointing them out encourages the students to go on. The following statement from a biology female student captures well the importance that encouragement plays in a student's perseverance necessary to succeed in graduate school.

> My ideal advisor or mentor would be somebody who is very positive because research can be very frustrating. And if you have somebody who is constantly on you saying, "When is this going to be done or Why didn't that work?" You're going to come down harder on yourself. You have to have somebody who says, "Keep trying, it'll work. Keep going." And to keep you moving in the right direction.

Encouragement and support was also very important to students who were not planning to pursue a career in academia. This was especially important to students who liked science, but were planning to work in industry or as teachers in non-research institutions. These students wanted their advisors to believe in the seriousness of their commitment and work. An ideal advisor would provide affirmation and support to the student's goals, regardless of what they were, instead of dismissing them or considering them trivial. In the words of a female chemistry student, the ideal advisor is "supportive in whatever you decide to do in the future, and considers you a serious scientist even if you don't want to follow through with academia."

An ideal advisor is a good manager. Managerial skills are particularly important when the advisor runs a laboratory with a large number of students. Some students work in laboratories with anywhere from ten to twenty five students. Running such a laboratory probably requires just as much managerial skills as would be required of anyone in charge of a small firm. In addition, because the advisor is the main authority in the laboratory, his/her managerial style sets the tone for the work environment in the laboratory. According to a chemistry female student advisors "set the tone for their laboratory. The way they manage the laboratory is the way the students are going to behave. And if they don't discourage behaviors, then they manifest themselves."

Comparisons Between Reality and Ideal

When asked the extent to which their advisor matched their ideal, students' responses ranged from "very close" to "not at all. However, only one student, a male student from the chemistry department, characterized his past advisor as the "ideal."

> My advisor was excellent. He wasn't overbearing, he never made you 'stay' in the lab for hours on end. He was 'hands off.' He didn't push people; he wanted people to push themselves. He trusted us and respected our ideas. You could go to him any time and talk about things. He tried to teach us more than chemistry. He taught us how to write and how to work the ropes. I respected him and liked him a lot. In my mind my advisor was the "ideal."

The interviewer probed this student's response by asking, "would you consider him a mentor?"

> Sure! Before I left he told me what he thought my strong points were and what he thought my weak points were and gave me good advice about what he thought I could go from there...

The next group of students had advisors who were very close to their ideal. Even though their advisor was not exactly what they would consider the perfect ideal, they felt fortunate being under the supervision of such advisor.

Most students however, had advisors with various degrees of the "ideal" characteristics. Good managerial skills seemed to be a weakness in many advisors. Even students who described their advisors in an affable manner, felt they lacked in good managerial skills. However, these students realized it would be difficult to ever find their "ideal" and were happy that their advisor had most of the ideal traits. The following passage from a male student in the biology department exemplifies this perspective.

> But of course they all can't have everything. You'll have people who have very good managerial skills but they're not very good at getting you motivated on your project. Or people that are very good at getting you motivated on your project but they can't manage the lab. So I think it's rare that you can find someone who can balance everything out.

When asked if his advisor was close to his "ideal" the same student replied:

> Ya, he's very close to that. His downfall is managing people but he has all the other qualities and most of us will take him at that.

Becoming a good manager of people is probably one of the biggest challenges facing any advisor. Students differ in personalities. While some students may prefer advisors who have a "hands-off" approach to the running of their laboratories, other students may prefer advisors who take more of a "hands-on" approach. The following passage from a faculty member in biology illustrates some of the challenges that advisors face in this area.

> I think the challenge I wasn't prepared for was dealing with people. Because in my area most of us who get an academic career are pretty well trained in the sciences. But as a manager of people, generally of say 20-24 years old, and having to deal with what they expect from you is the most difficult part.

The advisor's ability to be personable with his/her students was another area of weakness reported by some students. Because students were in the last stage of their training for a career in academia or industry, many of them wished their advisors would become more personable with them and treated them more like colleagues. While discussing his advisor, a male biology student commented:

> He is pretty close, except that he's not very approachable. And he's not a very personable guy, he doesn't like to hang around and talk and chat. And although that's not exactly required of him, I think that can also be a good thing. He doesn't really care at all about your personal life or any of that kind of stuff.

One student from the chemistry department felt that perhaps one of the reasons his advisor did not interact very much with his students on a personal level was due to the culture of the department. According to him, professors were discouraged from socializing with their students.

> One thing that I would prefer that he doesn't necessarily have, is that he is very friendly and sociable and we talk about things other than just work, but he doesn't... Some advisors do mix with their students sort of on a social level as well as outside of work, though apparently that's frowned on by most of the professors in the department. When I've gone to meetings with him we go out to dinner together, we sit around and talk, and that's something that doesn't happen when we're back at the university.

Some students, particularly returning students who were older and who had work experience, resented the lack of collegiality with their advisors. Students wanted to be trusted; they disliked being treated as hourly workers. While discussing this issue a male student from the chemistry department pointed out:

> I think there should be more of a measure of trust than there really is. Because a lot of the students that I know feel like their advisor is always looking over their shoulder or checking up on them to make sure they're working hard and I don't understand that because I would think everybody who is at this level should be mature enough to be able to work on their own.

Perhaps these professors felt that if they were more "soft-handed" their students would not perform to the level they expected of them. However, most students did not believe the more strict approach led to better results. According to them, professors who trusted their students and treated them as responsible adults got as good or better results than the professors who kept a close watch over their students. When asked if she knew a lot of professors who trusted their students a female chemistry student replied:

> Well, there are some. There are at least three people who run their groups like that, and their students are really happy people. They're always talking about their boss in a really positive matter.

When asked if these professors had a higher success rate with their students the same student replied, "most certainly they do! They do retain more people and they attract more too."

The interviewer probed this student's response further by asking, "but isn't there a belief that these students may not be as well qualified after getting their Ph.D. from these professors?"

> No, most of the time everybody knows that they are as qualified as the others. They work as hard as others, they are just happier. There has been a couple of cases where people have gotten their Ph.D. who wouldn't have gotten it in one of the tougher environments. But they are not good representatives of those groups. There's two ways of motivating people, one way is motivating by fear and one way is motivating because they want to do well for their advisor, they admire him.

The nature of the feedback provided by advisors was another area of weakness pointed out by students, particularly chemistry students. According to them, most advisors did not seem to have any difficulty in providing negative feedback when students made mistakes. However, they appeared to have a harder time providing positive feedback. Some advisors seemed to forget that students also needed a "pat in the back" once in a while. The following account from a male chemistry student illustrates this problem.

> In six years that I've been here, I've been told I was doing a good job once. And that was this year. So I went for six years without it. It's definitely a big hit on your morale, you know, when you are working hard you expect..., I mean, you definitely need to be recognized for that; to keep encouraging you to keep doing it. There have been times when, for a month straight, I haven't left the chemistry building much except for a few hours of sleep a night and to go eat. And when you are not told, you know, 'that's great!; good job!,' there's no incentive to do that anymore, although ultimately that's what you need to do to be successful in this department.

To some students the constant negative feedback was demoralizing as they noticed their self-confidence erode quickly away, as the following passage from a chemistry female student illustrates.

> I really can't deal with always having negative feedback. If you concentrate on a person's weak points then you find those, but you never know what your strengths are and then you start questioning, 'do I have any strengths? Am I really good at anything?

Positive feedback might be particularly important to incoming students who need to be affirmed about their capabilities to succeed and to students, especially females, who may be a little more sensitive to negative feedback. Students need positive feedback first as a source of encouragement and energy to keep going, and second as an indication of the students' standing in their advisor's judgment of their capabilities. According to Lunneborg (1982), students look to their advisors for perceptions of aspirations they have for them.

There were also a number of students who did not have very positive opinions of their advisors. They felt that their advisors used favoritism and did not treat all students in an equitable manner. Other students felt their advisors used a Social Darwinistic approach to the running of their laboratory. The following comments from a female student in the chemistry department illustrates this approach.

> My advisor takes the approach..., he gives you enough rope to hang yourself. And if you're taking a wrong course, he's not going to stop you, which to a certain extent is a learning experience, but after a while it becomes a little dangerous. He has used the term 'survival of the fittest,' and that's how he believes his lab should be run. That's how he believes the department should be run; survival of the fittest...

Another female student in chemistry shared the same view.

> I thought our group would work more as a team, and I thought professors would help you like a "leader" would. I think my professor runs his groups so that we compete against each other. I'm competitive and I can compete against other people, but it's not really the type of atmosphere that I was interested in.

Unfortunately these experiences where not unique in the chemistry department where the female attrition rate averaged almost 50%. In addition, the five female students interviewed for this study who had quit, attributed their leaving to the poor relationship they had with their advisor.

The ability to show interest and concern for all students may require that advisors tailor their mentoring differently from student to student. Incoming students have different needs. Some students may enter graduate school with more research experience than others. In addition, some students may be very independent and require less guidance whereas others may be more insecure and need periodic affirmation from their advisors. In laboratories where female students are a small minority, advisors need to show genuine interest in their work and make an effort to help them feel welcome.

In a study of women doctoral recipients, Heinrich (1991), identified three approaches used by male advisors in their advising of female students: (1) traditionally masculine, (2) traditionally feminine, and (3) androgynous. Advisors who used a traditionally masculine approach to advisement were task-oriented and handled conflict with their advisees by direct confrontation. On the other hand, advisors who used a traditionally feminine approach to advisement, overly emphasized the interpersonal dimension and avoided conflict with women advisees at all costs. However, advisors with an androgynous approach to advisement were gender-sensitive mentors. Instead of using gender role stereotypes mentioned in the two previous approaches, these advisors tailored their mentoring to the needs of their individual students by using a combination of masculine and feminine principles. These advisors combined "task- and goal-oriented" approaches while attending to the interpersonal dimension of the relationship with their advisees.

Conclusion

Although some students used more complex descriptions in their characterization of the ideal advisor, a number of characteristics were common across most descriptions. Students wanted an advisor who while providing the necessary help and expertise, would also give them the opportunity to try their own ideas. Students wanted advisors who were approachable, and who could relate to students outside the realm of the discipline. They also wanted advisors who were empathetic of their needs and difficulties. The ideal advisor trusted and respected his/her students while treating each one as an individual. Lastly, the ideal advisor used good managerial skills in the running of his/her laboratory. A female biology student's characterization of the ideal advisor provides perhaps the best illustration of all the attributes that students felt were part of an ideal advisor.

> It's someone who, rather than trying to dominate a student, provides the student with a language and a framework so the student can sort of follow the interests that he/she has already instinctively chosen. It's someone who is critical in the positive sense of the word. It's someone who is engaged in your work at an intellectual level regardless of how far removed it may seem to his/her own interests. It's someone who wants you to succeed and recognizes that your success is an extension of his/her success. And it's someone who is flexible and comfortable with the different rates at which different students make progress. Someone who can say, 'well this student may need from me to be like this so I may need to change my advisement style just a little bit with this particular student.' Rather than having what they think is a formula that works well for all students. It's someone who appreciates that graduate school is tough and it requires a lot of personal sacrifice and someone who is sensitive to that as well. That we've all make a lot of personal sacrifices to be here. And it's not someone that's necessarily going to agree with you a hundred percent of the time, but that's all right. It never concerned me that I was going to be disagreed with from time to time... Someone who is just involved and not absent... I guess that's what I would say my perfect advisor is.

Although some students felt their advisor was very close to their ideal, the majority of them pointed out various shortcomings in their advisor's advising/mentoring approach. Students were aware that it would be almost impossible for an advisor to be a good mentor to all students, particularly those who had a large number of them. However, students' comments indicated that some advisors did not use a mentoring approach in the interactions with their students. In fact, some students appeared to have very few interactions with their advisors. They were periodically obliged to turn in to their advisor reports to account for their work and the number of hours spent in the laboratory.

Students joined their program expecting to find in their advisor a mentor who would guide and support them as they progressed through their socialization into a career in science. However, results indicated that a relatively small percentage of students felt the level of mentoring in their department was very high. The perception of the lack of mentoring was particularly prevalent among the female students in the Chemistry Department.

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MODIFYING HANDS-ON SCIENCE LESSONS FOR STUDENTS WITH SPECIAL NEEDS: A MODEL OF COLLABORATION

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Essential Factors for Effective Adaption and Modification

Adaptation and modification of science instruction require collaboration between all educators involved in delivering the curriculum. Collaboration is not an activity but a style professionals choose to use to accomplish shared goals (Cook & Friend, 1993; Friend & Cook, 1996). In this case the goal is to educate all students to become members of a scientifically literate society by actively engaging in inquiries that are interesting and important to them (National Research Council, 1996). To achieve this shared goal, educators who work collaboratively must trust and respect each other, believe their contributions are equally valued, share their resources, their responsibilities for making decisions, and the accountability for outcomes (Cook & Friend, 1993; Friend & Cook, 1996). The collaboration between educational professionals in elementary and secondary schools can be effectively modeled in teacher education programs.

Why Science

Systemic science reform is guided by the principle that science is for all students, and that learning science is an active process. Science is a system of knowing the universe. An understanding of science offers personal fulfillment and excitement - benefits that should be shared by everyone (NRC, 1996). Effective science teachers use the constructivist learning theory that suggest that knowledge is most effectively acquired by evoking personal meaning in the learner. From a constructivist viewpoint, conceptual knowledge is constructed by learners over time within a meaningful social setting (Adams, D., & Hamm, M. 1998). Cooperative learning activities, group problem solving, peer and cross-age tutoring are now generally accepted as useful tools for helping students get the most out of inquiry-based science program. This cooperative interaction with others is an important element in giving all students an opportunity to make sense of what they are learning (Tobin, Tippins, and Hook 1992).

Foundation of the Collaboration

The need for collaboration was identified, based on the career experiences and needs of the authors as classroom teachers then district supervisors then college professors. Houtz's experience as an elementary and middle level science teacher with the mainstreaming or inclusion of students with special needs, made the need clear to her for appropriate modifications to lessons and instructional techniques to ensure success of all students. Later, as a district science supervisor, science teachers expressed the same concerns. In particular, the teachers wanted to meet the individualized education outcomes of students with special needs, while aiming for excellence and maintaining the integrity of their science program, not "watering it down."

Watson's experience as a K-12 special education teacher and supervisor, involved with both mainstreaming and inclusion, showed her that, even though students might be well-behaved in a science classroom, they often needed assistance from the special education professional. Students with special needs struggled when modifications and adaptations were not made to attend to their learning challenges.

As professors preparing the same students to become teachers in inclusive classrooms, the need was evident to model collaborative efforts in modifying instruction for students with learning disabilities. Houtz and Watson sought to demonstrate the teamwork and effective instructional strategies necessary to meet the needs of all learners.

Efforts to work collaboratively were facilitated by a block schedule in which the pre-service elementary teachers studied science methods, math methods, and special education methods together during the same semester. Pre-service secondary science teachers also studied science methods and special education methods in the same semester. The instructors had similar work schedules and habits, and offices in proximity. An ease of communication existed, based on mutual trust, respect, and parity. Both recognized each others' role, worth and expertise that filled the other's knowledge gap. They shared the belief that collaborative effort is beneficial to the Preservice Teacher and to the students they will teach.

Procedures

Houtz, the science methods instructor, selected a hands-on /minds-on science activity with relevant science content that involved several process skills in the inquiry. The lesson was one with which she was familiar and comfortable and that elementary and middle level students as well as pre-service teachers found captivating and enjoyable. The original lesson plan had been easy enough for children of average ability and reading skills to manage. However, students with learning challenges needed assistance or relied on other members of the group to follow the instructions.

Figure 1
Original Lab Sheet

TITLE: DRACULA'S DILEMMA

PURPOSE: ______________________________

PROBLEM: Dracula complains of experiencing terrible reactions after biting certain victims. He needs to learn about universal donors and universal recipients to avoid mixing his blood with that of mismatched "donors."

MATERIALS:

Clear (O), blue (B), red (A), and purple (AB) colored water (250 mL each)
5 test tubes and a test tube rack

PROCEDURE:

1. Fill each of four test tubes half-full with water from each of the four beakers.

2. Label the test tubes to match the labels on the beakers. For our purposes, the different colors of water will represent the four major blood groups.

3. Use the fifth test tube to add red (tube A) water to each of the labeled test tubes. Check for any color changes. Mark the data sheet with a (-) to show color change, and with a (+) if there is no color change. You are looking for total color changes - bluish-purple or reddish-purple is still purple.

4. After recording your observations, rinse out all five test tubes.

5. Repeat the procedure three times, using the fifth test tube to add a different color of water to the labeled test tubes each time.

6. Complete the data table and answer the questions.

DATA Donor

Recipient

	A	B	AB	0
A				
B				
AB				
0				

A color change (-) means blood-type incompatibility; no color change (+) means blood-type compatibility.

Questions

1. Which blood type is the universal donor? _______________

2. Which blood type is the universal recipient? ____________

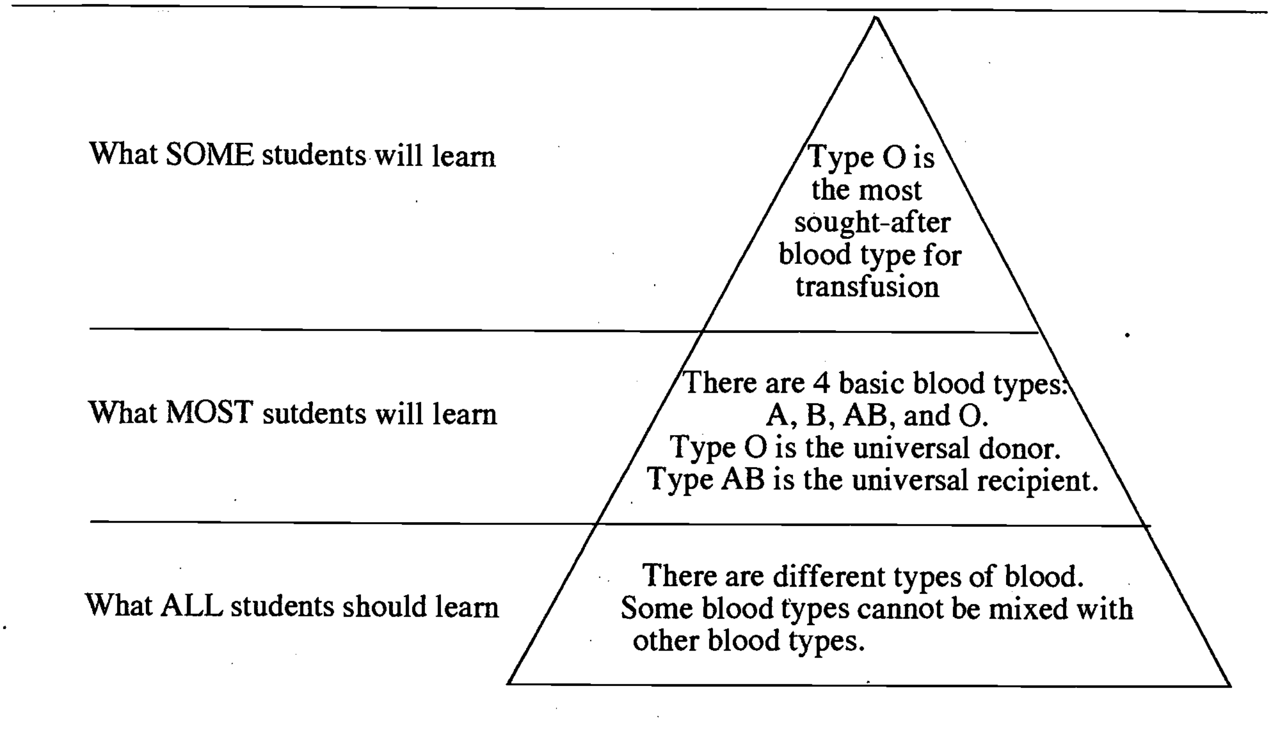
3. The Frankenstein monster has type-B blood. Dracula has type-O blood. Can the monster give blood to Dracula? _______

4. The Werewolf has type-AB blood. Can he receive blood from the Frankenstein monster? ____

As Director of Special Education, Watson looked over the lesson as written and asked herself, "How would I teach this?" As a non-science person with English as her second language, she looked critically at what it would take to make this particular lesson more manageable and relevant for herself and for students with special needs. Watson shared her expertise with Houtz and their mutual students regarding adaptation and modification of instruction based on the knowledge of several areas of difficulties exhibited by a great number of students with disabilities. Educators need to understand how those areas of functioning affect students' performance and inhibit their success in school (Mastropieri & Scruggs, 1992; Scruggs & Mastropieri, 1994; Wood, 1998).

The science objectives were clearly identified and remained intact. Watson made specific modifications of the lesson on knowledge of the characteristics and needs of the special education student. The basic procedures remained the same. However, different levels of learning and achievement of the lesson objectives were indicated.

Figure 2
Planning Pyramid



Together Houtz and Watson collaborated on making appropriate and broad-ranged modifications, including appropriately sequencing the procedure steps, detailing and illustrating the materials needed, and clarifying the language and wording of questions. The modified lesson appears as an appendix at the end of this paper.

Watson and Houtz made a joint presentation to their shared pre-service teachers. Each explained her role and experiences. Watson detailed characteristics of students with special needs, elaborating particularly on learning disabilities and specific appropriate modifications to instructional techniques typically used in a science classroom.

Houtz introduced the "Before" and "After" science lesson, pointing out that the science objectives remained the same, but the approach and the activity sheet had extensive modifications to aid all students. The pre-service teachers proceeded with the hands-on/minds-on activity, following the lab sheet with revisions.

Throughout the semester, Houtz and Watson communicated on objectives and procedures in their classes. Houtz shared the lessons modeled in science and mathematics methods classes;

Watson then assigned their mutual students to make appropriate modifications for students with specific needs.

The pre-service teacher's learning was assessed not only by the lesson plans they modified or created for students with special needs, but also by their performance implementing appropriate teaching strategies in practicum settings.

Conclusion

Collaboration is expected between classroom teachers, special education teachers, and other professionals in the child's learning environment. This collaboration can be effectively modeled in teacher education programs when the importance of these efforts are recognized and the opportunities are available. Successful collaboration existed in this teacher education program because all parties were guided by the principle that science is for all students. The teacher educators for both science/math methods and special education methods utilized the opportunity to communicate and collaborate in offering their pre-service teachers a dynamic and pragmatic modeling of effective teamwork. This approach provides teacher education programs ideal opportunities to meet many of the criteria to meet the National Science Education Standards Professional Development Standards B and D (National Research Council, 1996). More importantly, it can move students with special needs in the direction of scientific literacy along with their classmates in inclusive elementary and secondary settings.

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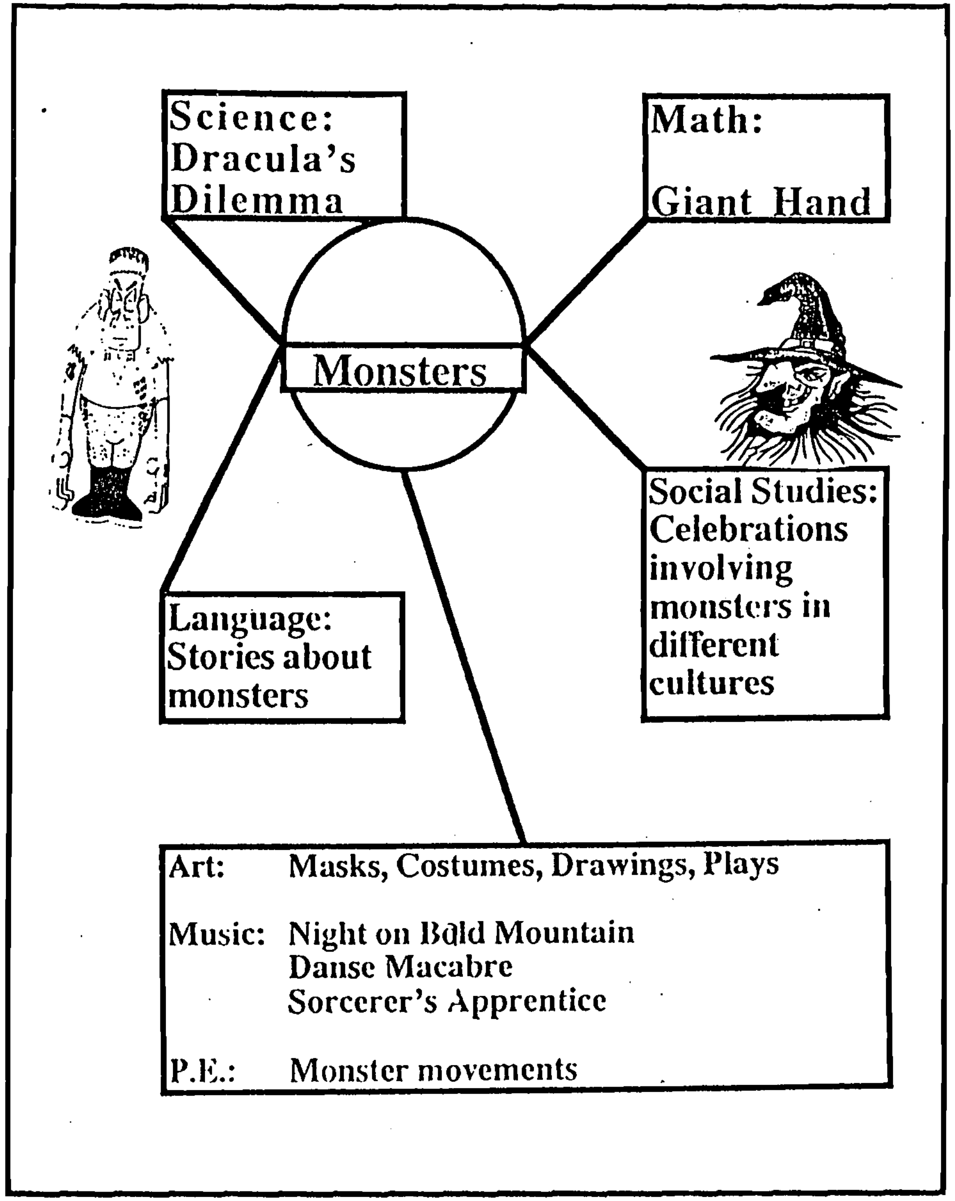
[Appendix: Modified Lesson]

The topic is connected to other curricular areas in a web.

Literature and other tie-ins provide background knowledge of Dracula legends and vampire characteristics.

Teaming with other teachers, including specialists, is encouraged.



Overlapping helps build and reinforce vocabulary in a variety of contexts.

Multicultural approach is infused in the thematic unit.

The teacher may need to weigh the "political correctness" issues associated with witches, monsters, and other traditional Halloween images.

489

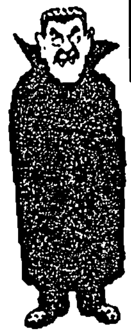
490

Student pages are numbered, collated, and stapled to help maintain order.

Pages could be triple-punched for inclusion in a lab notebook, journal, or portfolio.

The purpose statement is clarified.

Although the sample shown here is reduced in size, the print size used on the page is no smaller than 12 point.



DRACULA'S DILEMMA

Names of Group Members: ____________

____

____

____

Purpose of Dracula's Dilemma Lab Activity

The purpose of this lab activity is to

investigate ____________________

____

Dracula's Dilemma
??????
?????????????????????

- Dracula complains of experiencing terrible reactions after biting certain victims.

More white space is available for ease in reading. Larger spaces are provided to facilitate writing for students with fine motor skill difficulties.

Numerous graphics are interspersed to maintain interest and motivation.

491

492

Instead of simply stating a problem, students are expected to formulate an hypothesis. This incorporates appropriate scientific methods approach and terminology. It encourages critical thinking and risk-taking.

Vocabulary words are included to help students understand terminology prior to completing the activity. The number of words was limited.

The font of the lettering was changed from Courier to Helvetica to avoid having letters with tails (such as at the bottom of "t" or curly-cues, which prove problematic for some students in their reading.

- ***PROBLEM:*** **Why is Dracula experiencing terrible reactions after drinking certain victims' blood?**
- ***HYPOTHESIS:*** ______________________________

____

____

Vocabulary

- **Dracula**
- **Dilemma**
- **Blood Types**
- **Donor**
- **Recipient**
- **Compatibility**
- **Universal**
- **Shades of Color**

The question is stated in more simple, direct terms. The language is simplified.

White space is available for students to put written or visual clues.

The visual copy is a clean, crisp, clear image that is photocopied without blurs, dark edges, or bent corners. It is not reproduced on ditto or mimeograph, both of which sometimes prove difficult for students to read.

2

493

494

Materials lists offers number and picture cues to help students who may have reading difficulties, may not be familiar with the items, or have limited English proficiency.

Checklist blanks have been added to the left side of each listed item. Students can put checkmarks as items are gathered.

Use unbreakable containers whenever possible. Plastic beakers are available from science suppliers and elementary materials catalogs. Simple household items can be substituted, including clear plastic cups.

Materials

__ 1 Pencil

__ 9 Labels

__ 4 Beakers

__ Water

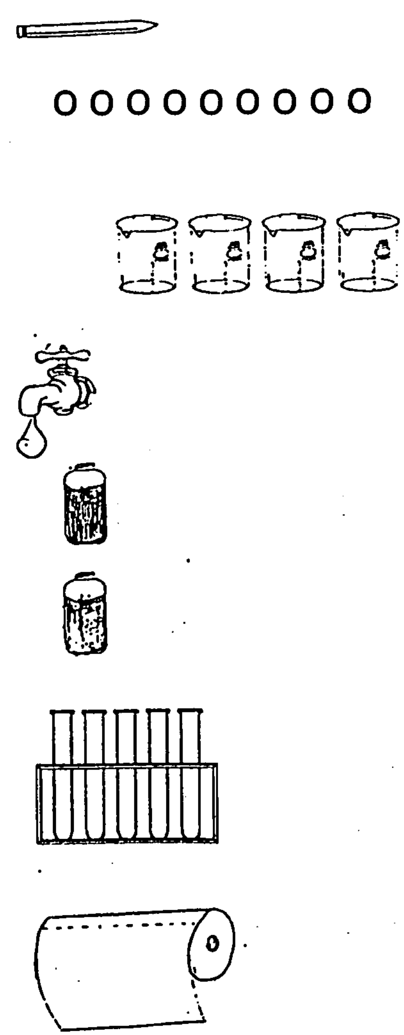
__ Red food coloring

__ Blue food coloring

__ 5 Test tubes

__ 1 Test tube rack

__ Paper Towels



List is all inclusive. It is not assumed that students already have items like writing utensils.

Use of pencil which is erasable is encouraged over use of ink.

Clear plastic testtubes with tops are recommended over glass testtubes. Medical laboratories are often willing to donate these supplies for educational purposes.

Clean-up supplies have been included.

3

495

496

Directions are short, simple and sequential.

Space is provided for students to check off each completed step. The checklist helps students follow direction steps sequentially.

Use simple verbs. Consider underlining verbs or putting them in bolder print.

Procedure steps can be modeled by the teacher.

Remember to follow classroom safety rules.

PROCEDURES:

1. ___ Label the beakers:

   __ A (Red Water= Type A Blood).

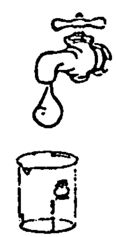
   __ B (Blue Water = Type B Blood)

   __ AB (Purple Water = Type AB Blood)

   __ O [illegible] Blood)

A B AB O

2. ___ Fill each beaker with approximately 200 mL of water.



3. ___ Put 6 drops RED food coloring in beaker A.

Always document that safety issues have been addressed. Review your classroom rules and procedures related to handling broken glassware and spills. Never work with or handle human body fluids, especially blood, because of the risk of blood-borne pathogens.

These steps allow students to practice measuring. The activity could be further simplified, if appropriate, by eliminating the measurement amounts, and/or by having colored water pre-made by the teacher.

4

497

498

Student lab sheets are numbered, collated, and stapled to aid students in sequencing.

Lab packet could also be three-hole punched in advance to become part of a lab notebook, journal, or portfolio for assessment.

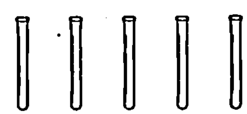
Rather than one lab sheet per group, we recommend that each student has his/her own copy. Students with learning challenges do better with a copy directly in front of them. If the teacher maintains learning portfolios, it eliminates the decision of whose portfolio the sheet goes into.

4. ___ Put 6 drops BLUE food coloring in beaker B.

5. ___ Put 3 drops RED food coloring plus 3 drops BLUE food coloring in beaker AB.

6. ___ Beaker ⓞ must remain [illegible] water.

7. ___ Label test tubes A, B, AB, and ⓞ.



8. ___ Fill each of the 4 test tubes half-full (1/2) with liquid from each of the beakers matching the labels.

If it is not realistic to provide each student with his or her own color copy, color transparencies can be visible as students move through the activity.

Leadership roles can be left to chance, randomly assigned, or specifically assigned according to students' abilities, behaviors, and needs. Teachers can identify specific cooperative participation roles and expectations such as Leader, Engineer, Materials Manager, and Reporter/Recorder.

5

499

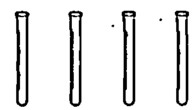
50

Notes:

9. ___ Fill the 5th test tube with RED Water (Type A). 

At this point you should have 2 test tubes with RED water.

10. ___ Add a small amount of RED water from the 5th test tube to each of the labeled test tubes (A RED, B BLUE, AB PURPLE, [illegible]).



A B AB [illegible]

11. ___ Observe each test tube to see if the color remained the same. Remember that reddish-purple or bluish-purple is still AB PURPLE.

12. ___ Complete the first row of the data table.

Mark "YES" if the color remained the same.

Mark "NO" if the color changed.

13. ___ Empty the test tubes in the sink and rinse.

14. ___ Fill each test tube half-full again with the corresponding blood type.

Reiterate the issue of safety of the environment with your students, as well, including proper handling and disposal of laboratory chemicals and materials. This activity is environment friendly. All liquids can safely be disposed down the sink.

Notes:

15. ___ Fill the 5th test tube with B BLUE water.

16. ___ Repeat the compatibility testing and mark the second row of the data table.

17. ___ Repeat the compatibility testing using AB PURPLE and mark the third row of the data table.

18. ___ Repeat the compatibility testing using O Clear Water and mark the fourth row of the data table.

Notes:

7

5 3

5 4

Data table uses more consistent terminology than original.

Color cues aid in completing and interpreting the data table.

Word bank is provided for those students who have difficulty with vocabulary and spelling.

Blood Type Compatibility Table

Mark if color remains the same when Donor gives to Recipient.

RECIPIENT (Dracula, who receives blood)

DONOR (Victims who give blood)

DATA	Type A	Type B	Type AB	Type O
Type A				
Type B				
Type AB				
Type O				

Same color = Yes
Color change = No

Help Dracula solve his problem by making deductions from your observations.

DEDUCTIONS FROM OBSERVATIONS

WORDS FOR FILL IN THE BLANKS:

CHANGE	NO CHANGE	UNIVERSAL	RED	CAN
CANNOT	WILL NOT	WILL	TYPE A	TYPE B
TYPE AB	Type O	DONORS	RECIPIENTS	

Interpreting observations and recording data is less confusing. Instead of "color change = minus = incompatibility" data is recorded as "same color = yes = compatibility"

5 5

856

Data table uses more consistent terminology than original.

Color cues aid in completing and interpreting the data table.

Word bank is provided for those students who have difficulty with vocabulary and spelling.

Blood Type Compatibility Table

Mark if color remains the same when Donor gives to Recipient.

RECIPIENT (Dracula, who receives blood)

DONOR (Victims who give blood)

DATA	Type A	Type B	Type AB	Type O
Type A				
Type B				
Type AB				
Type O				

Same color = Yes
Color change = No

Help Dracula solve his problem by making deductions from your observations.

DEDUCTIONS FROM OBSERVATIONS

WORDS FOR FILL IN THE BLANKS:

CHANGE NO CHANGE UNIVERSAL RED CAN

CANNOT WILL NOT WILL TYPE A TYPE B

TYPE AB Type O DONORS RECIPIENTS

Interpreting observations and recording data is less confusing. Instead of "color change = minus = incompatibility" data is recorded as "same color = yes = compatibility"

8

5 7 5 8

Statements using "If ... then" and "when" help lead students to understanding of cause and effect, which can be difficult for students with language disabilities.

1. When clear water (Type O Blood) from the 5th test tube was mixed with colored water (BLUE, RED, PURPLE), we observed ________________ in color.

2. If no change in color was observed, then Type O Blood (clear water) is a ____________________ donor.

3. When any of the colors was added to PURPLE water (representing Type ___ blood), no color change was observed. Therefore, Type ___ blood is a __________________ recipient.

4. If Dracula has Type B blood, he _________ take Type O blood. Dracula ____________ get sick after biting a Type O blood victim.

5. If Dracula has Type O blood, he ___________ take Type A blood. Dracula ____________ get sick after biting a Type A blood victim.

6. If Dracula has Type O blood, he can only take blood from Type _______ blood, but he can give blood to Type(s) ______________.

7. If Dracula has Type A blood, he ____________ take Type AB blood. Dracula ____________ get sick after biting a Type AB victim.

8. If Dracula has Type A blood, he cannot give blood to Type(s) __________.

9. If Dracula has Type AB blood, he ___________ get sick after biting a Type O victim.

Closure.
Students articulate their findings.
Assessment of student learning outcomes.

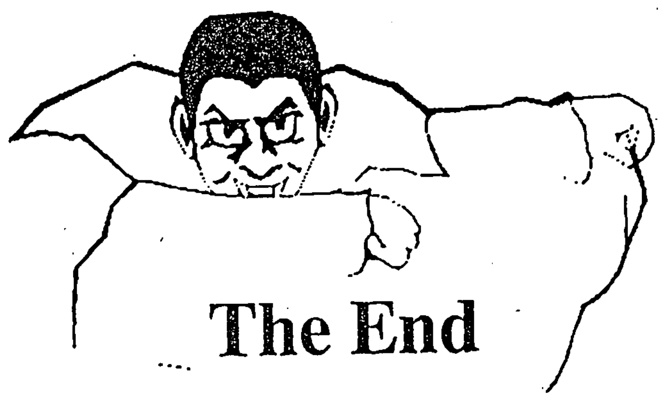
Students form conclusions and check their hypotheses.

- ***Possible solution for Dracula's dilemma:***

If Dracula is experiencing terrible reactions after biting certain victims, he probably needs to learn about __________ donors and universal __________ to avoid mixing his blood with that of incompatible "donors." Dracula could not have Type ______ blood, which is the universal recipient.

Clean-Up

1. ____ Pour all clear and colored water down the sink drain.
2. ____ Rinse all beakers and test tubes.
3. ____ Replace materials in lab kits for next class; OR if you are last group of the day, place beakers and test tubes on drying rack.
4. ____ Be sure food coloring containers are tightly sealed and properly stored.
5. ____ Wipe tabletop with paper towel.



Teachers can follow-up with discussions or lessons or research or investigations on related relevant topics, including the need for blood donors.

Notes:

PUSHING THE COMFORT ZONE: CONFRONTING THE PERCEPTIONS OF TEACHING AND CLASSROOM CULTURE

Marcia K. Fetters, The University of Toledo

Pre-service teachers often come with very strong views of what it means to be a teacher. After all, they have experienced many years of being a student in the presence of teachers. From a student perspective they have a set of characteristics in their mind that define who a good teacher is and what kinds of things they do. In education courses and even during student teaching it is common to hear statements from pre-service teachers such as, "If this were my class I would never allow students to just shout out answers, it makes the class so chaotic" or "There is no excuse for late homework; if a student doesn't get the work done it is not the teacher's problem" or "If schools would just kick out the trouble makers, kids who want to learn could." When asked about these responses and why they feel this way, preservice teachers usually say that they are echoing frustrations they felt as a student. As individuals who are considering teaching as a profession, for the most part, these individuals have been successful in school. They point out that they were often frustrated by the behavior of a peer who they saw as interrupting their learning, and frustrated by teacher and administrative decisions that appeared to give breaks to some students, and kept more disruptive students in the classroom.

Intellectually they know that a teacher is responsible for all of the students in their class. Through earlier education courses they have come to know some of the history and goals of schooling. By the time they get to a methods course, they can often talk quite eloquently about teachers' responsibility to meet the needs of all students. They will often frame this discussion in terms similar to those of the national reform efforts (American Association for the Advancement of Science, 1989; National Research Council, 1996). These reforms call for quality education for <u>all</u> students regardless of cultural background, socio-economic background, physical condition or learning style.

> "All students, regardless of sex, cultural or ethnic background, physical or learning disabilities, future aspirations, or interest in science, should have the opportunity to attain high levels of scientific literacy." (National Research Council, p. 22)

> Language and sex, or economic circumstances must no longer be permitted to be factors in determining who does not receive a good education in science, mathematics, and technology. (American Association for the Advancement of Science, p. 214)

These goal statements for science education clearly indicate the student populations to whom <u>all</u> science teachers are responsible. *Science for All Americans* (American Association for the Advancement of Science, 1989) makes addressing student diversity a charge in it's phrasing "must no longer be permitted." This moves past the passive "must be aware off" or "should take into consideration" that often is typical of the treatment that diversity receives in methods courses. These two quotes from national reform documents provide the framework for the range and type of diversity issues that this methods course attempted to address.

One of the barriers that face teacher educators lies in the conceptions of teaching and classrooms that pre-service teachers bring to their education classes. The images of teaching with which pre-service teachers come to education classes are in large part based on their years as students. It is common for teacher education candidates, after an intensive field experience, to comment about how much schools have changed since they were in school. In secondary education, we teacher educators are somewhat amazed that they actually say this, when most of them are less than four years away from their last day as a high school student. It is during these intensive field experiences that they first start to view the classroom and teaching more from the teacher perspective than as a student. It is here that pre-service teachers start to explore many aspects of their chosen career, and start to understand that what they saw as students in a classroom was only part of the teacher's role.

It is part of our task as teacher educators to make the invisible parts of teaching visible to our candidates. As students, they were not (as a rule) explicitly aware of the local, state or national guidelines shaping curriculum decisions. They were not aware how a teacher makes decisions about whether a project should be done individually or as a group project. As they progress through a teacher education program, they learn the vocabulary used by educators, and by the time they take a methods class and enter student teaching, most pre-service teachers can talk or write quite eloquently about the role of science in everyday life, and why it is important for their students to learn science. However, this dedication to teaching <u>all</u> students appears to falter when confronted with activities that push the pre-service teachers to take ownership of complex situations and propose alternative actions, or when, as student teachers, they are faced with teaching in a classroom with a diverse student population.

This presentation will share some of the activities that this presenter has found productive in helping pre-service teachers recognize the diversity in their classrooms, and the effort that it takes to effectively meet the needs of their students. These ideas and activities draw on a wide variety of previous teacher education work. In particular, this work is strongly influenced by work on reflective practice (Posner, 1996; Schon, 1983; Schon, 1987; Winitzky, 1989), case study approaches (Harrington & Garrison, 1992; Parker & Tiezzi, 1992; Stake & Easley, 1978; Sykes & Bird, 1992; Wassermann, 1993) portfolio and alternative assessment models (Chittenden, 1991; Cohen, 1994; Haney, 1991; Hein, 1991; Maeroff, 1991; Perrone, 1991a; Perrone, 1991b; Shavelson, Baxter & Pine, 1992; Stock, 1991; Tamir, 1993; Zessoules & Gardner, 1991). It also builds on work done on the identification and development of strategies for inclusive classroom settings (Ford, Davern & Schnorr, 1992; Giangreco, 1992; Graden & Bauer, 1992; Sapon-Shevin, 1992; Stainback & Stainback, 1992; Stainback, Stainback & Jackson, 1992a; Stainback, Stainback & Moravec, 1992b; Villa & Thousand, 1995).

Using Video Resources as Opportunities for Reflection

A wide variety of video resources are available for use in a science methods course. The resources highlighted below are ones that I've explored with the focus on meeting the needs and learning styles of all students.

Provided for each video is a brief description of the video episode and examples of questions posed to pre-service teachers for consideration prior to watching the tape, or to respond to after viewing the video clip. Case materials, both written and video, have long been used in education, and each year additional ways of making use of these resources are being explored (Harrington & Garrison, 1992; Parker & Tiezzi, 1992; Stake & Easley, 1978; Sykes & Bird, 1992; Wassermann, 1993). The following descriptions of videos and related activities are meant as the beginning of a conversation of possibilities.

How Difficult Can This Be? (Lavoie, 1989)

This video tape may not seem at first like an ideal tape to use in a science methods class, but based on student feedback is a very powerful tape whose images stick in a student's mind long after the course ends. This tape is approximately 70 minutes long and allows the viewer to feel like a participant in a workshop lead by Richard Lavoie as he helps parents, teachers, students, and community members experience what it might feel like to have a learning disability. In this video he describes several fairly common types of learning disabilities, and provides some strategies for how teachers could modify their instruction to support a student who may have this learning style.

The tape is very useful in a variety of ways, but two sections in particular highlight very common difficulties that many of our students, as well as experienced teachers, face. One of the segments deals with perception, and points out that a "b" (depending on orientation) can also look like a p, d, or q, each with its own traits, sounds and uses. After viewing the tape, methods students brainstorm different concepts or skill areas in science where this type of learning style could really cause difficulties. A short list of often-named concepts that students have come up with in the last couple of years includes: microscopes, stereo chemistry (left or right handedness), chemical equations, cyclic reaction sets (krebs, nitrogen, etc.), diagrams for setting up labs, orientation drawings used in physics and astronomy (phases of the moon, vectors, etc.), any left or right hand type of rule explanation

In one of the other powerful images from the tape, the presenter gives the workshop participants a list of words and asks them if they have any difficulty with any of the words, or if there are any words with which they are not familiar. The words in the list are: are, making, between, only, consists, often, continuously, with, corresponding, one, curve, points, draws, relation, variation, set, graph, table, if, values, isolated, variables, and known. After getting their assurance that they know all of the words, he presents them with the following paragraph.

> "If the known relation between the variables consists of a table of corresponding values, the graph consists only of the corresponding set of isolated points. If the variables are known to vary continuously, one often draws a curve to show the variation." (Basic College Math, M. Michael Michaelson, 1945)

Only an engineer in the group can make sense of the paragraph. Most of the students in a methods course can also make sense of the paragraph, but the tape shows that a cross section of the general public had difficulty with this paragraph. This reinforces a running theme through the course that sometimes the language we use in science and mathematics is not as accessible as we (who are interested in the fields) may believe.

In science classes we often use vocabulary that is commonly used in day-to-day life, but has a very specific definition when used in a science classroom. Students will often indicate to us, as science teachers, that they understood all the vocabulary or readings, but a bit of questioning and observation indicates to us that they do not have that level of understanding. This finding highlights the difference between decoding and understanding. As a methods class, we often brainstorm a list of terms or words that might cause difficulty if not explicitly addressed. A partial list of these terms includes:
light, sound, wave, food, air, oxygen, system, model, speed, weight or mass, see, measure, position, orientation, color, dark, time, reflection.

At the conclusion of this tape students are asked to add 3 things to their learning portfolio: 1) A beginning list (that they can add to as they begin teaching) of perception or orientation concepts or skills that they should be prepared to address; 2) a parallel list of terms or samples of writing that use common words or phases in specific ways that their students should be made aware of; and 3) an action plan for how, as teachers, they could learn more about or work with other teachers, parents, community members to meet the needs of students with a range of learning styles and abilities. Specifics about "action plans" are discussed in a later section of the paper.

Failing at Fairness: Part 2 (Sadker & Sadker, 1994b)

This video clip, from NBC's Dateline program, is a second look at Myra and David Sadker's work. Based on their book of the same name (Sadker & Sadker, 1994a) (Sadker & Sadker, 1994b) this tape takes the viewer to a high school physics class at a magnet high school. The physics teacher at this school offered a females-only section of his physics course. In this section of the course, he moved away from his traditional drill-and-practice style of physics instruction, made the course much more hands-on, and used multiple explanations, in different contexts. Unlike his traditional course where most students worked individually and in a more competitive atmosphere of racing to the right answer, in this all-female section he gave students the opportunity to work in small groups and explore the physics concepts in multiple ways.

This video tape rarely evokes neutral emotions from the students. Male students often view it as one more case of "male bashing" and female students often view it as something that may have been important a few years ago, but is no longer an issue (after all, they are females in science). The class is generally in agreement that the all-female section of the class is a better physics course, and that all students should have access to this type of learning. Looking at this instruction in light of the national reforms reinforces this view that all students should experience this type of teaching. It is only during their field experiences that their dedication to this style of teaching starts to fall apart, when they realize how much thought and planning is required to be able to give students multiple examples of concepts and hands-on opportunities.

To help students recognize that gender differences still exist in science classes, students are asked to survey the chemistry and physics teachers in the high schools where they have field experiences. When whole-class data is reported back, the pattern of fewer females in the advanced sciences in high school becomes clearer. Individual reports and estimates of the breakdown often do not bring this situation to light. Along the same lines, methods students audio tape or video tape one of the lessons that they teach in the field, and keep a tally of males versus females called on, or who asked questions. To keep track of this, the methods students fill out a log sheet that tracks teacher/student questioning patterns. Figure 1 is an excerpt from a pre-service teacher's (Sarah, May 1996) question analysis log. This type of analysis was expected three times during student teaching, once for the cooperating teacher and as part of the analysis of the videotapes of their lessons:

Figure 1
Sample Question Analysis Log

Question/Who Asked?	Type	Response	Responder
Who remembers what we were discussing yesterday?- T	R	Living things	Rob
		Biogeni...something	Tim
Biogenesis? OK -- what else? - T	R	maggots and meat	Sean
		Pasteur	Christy
Do we have to write this down? - Kim	P	This should be in your notes from yesterday.	T

Question Types: R=recall, I=inquiry (open ended), P=procedure

A High School Science Lesson with Barbara Neureither (North Central Regional Educational Laboratory, 1995)

In this video lesson, a high school biology teacher describes her approach to teaching and her views on how students make sense of science and build science understanding. This interview is interspersed with clips from her classroom. The viewer is given a glimpse of the hidden part of teaching, the planning and thought processes involved in teaching.

This tape is used to model the instructor's expectations for the students, an example of what they should be able to do and explain as part of their rationale for a lesson or unit. In the interview, Barbara talks about the role of the state guidelines in her planning and her goals for students. Through her interview and classroom segments, the observer gets to see both the planning process and how this is enacted in the classroom.

While watching the tape, students are asked to identify Barb's main goals in teaching and her teaching philosophy. They are also asked to identify the strategies that they see Barb talk about and use during the tape. In doing this, they are to provide evidence that the ideals Barbara talks about in her teaching can also be observed in the classroom setting. The goals of using this tape are: 1) to use it as a reference point for discussion and as a prompt for methods students to evaluate their field experiences, 2) as a tool for working on developing their own teaching styles and philosophies. Using the "right" words is not sufficient -- any observer who enters your room should be able to have some sense of what you value and your goals for your students. To jump-start this issue, at the beginning of the semester students write a journal entry that describes their ideal lesson. Then, this assignment is repeated at the end of the semester.

At the beginning of the semester, student responses to this assignment are usually quite brief, and filled with many of the words that the pre-service teacher believes the instructor wants to hear. Alternately, the student may provide a description of a high school classroom in which they were successful (in the student role). Sometimes their descriptions seem to be based on what they had hoped they would see in their field experiences. Their descriptions often focus on student behavior and teacher actions, with less of a focus on content. Following is a fairly typical journal response for the beginning of the semester:

> In my ideal lesson the students would all be really interested in what I am talking about. The students are polite to each other and have done their homework. They ask really good questions and don't interrupt me or other students. This class might be following a lab or some other activity. In this ideal set up we would have a great lab set up and all the materials we need to do labs. Students would be involved in lots of hands on activities. (Matt, Winter 1997)

This early journal response starts a written conversation between the pre-service teacher and the instructor. Instructor responses offer prompts and questions back about content, what the pre-service teacher would consider to be a "good" question, what kinds of facilities are needed to do labs, what type or what is the structure of labs, or whether work is done individually or in cooperative groups.

The similar journal response at the end of the semester is usually more detailed. Instead of building descriptions on phrases, such as: hands-on, cooperative learning, and respectful, content plays a more central role in these descriptions, and they provide details about what the students would be doing and what the teacher would be doing.

Valerie: Exploring the relationship between doing science and teaching science (Rosebery & Ogonowski, 1996)

This video tape asks observers to think about the relationship between learning and doing science, and teaching science. One of the quotes from Valerie is, "high school really killed science for me." It is clear from the tape that this woman is a bright, inquisitive person, but her high school and college science experiences were neither enjoyable nor enlightening.

The follow-up classroom discussion and journal assignment that are used with this tape focus on identifying features of science classes in high school and college that make the classes so unpleasant, and on thinking about specific steps or strategies that a teacher could use to identify this student perception of science, and to work toward modification of this view. The following list is one that students Spring of 1997 brainstormed, and to which they responded in their journal entries:

What "kills" science for some high school students?

1. lots of vocabulary and definitions
2. story problems
3. boring lectures
4. too many notes
5. always having to do all the work

6. never getting to DO anything, just read about it or see videos
7. long lab reports
8. lots of calculations
9. rowdy class/horseplay
10. not enough equipment
11. hard tests that aren't over class stuff
12. not relevant/real

Students chose 2-3 things from this list to address in their action plans. Each semester, this activity had been done. The list varied a little, but the general theme of too much passive learning was persistent.

<u>This question is just too, too, too easy</u> (Warren & Rosebery, 1994)

This video tape allows observers to watch a science discussion in a Haitian-Creole bilingual classroom. The conversation occurs in Haitian-Creole with English dubbing. This tape shows a very interesting discussion in which students question each others' interpretations and conclusions, and as they try to develop an explanation, they push each other for evidence. Just stating information is not accepted as fact here; students challenge each other and ask for clarification.

The instructor's original intent in choosing to show this tape to methods students was to provide an example of a classroom where students actively tried to make sense of science, were engaged in conversation, and had a truly interactive experience in a science classroom. The tape was not given a great deal of set up, but students were asked to keep track of the various science concepts students were using, in order to be able to describe the role of evidence in the discussion. Their reaction to the tape was very strong, but not in the way that had been anticipated.

The pre-service teachers expressed shock at the discussion; they could not believe how rude the students were with each other. While the tape was chosen to show a strong example of scientific discussion in a classroom, the pre-service students viewed the classroom as out of control. Yet, in the classroom shown, students weren't looking to the teacher for support or verification, they were demanding it of each other. Students in this class openly challenged each other with raised voices. My predominately white middle class pre-service teachers found this conversation style very problematic, and had great difficulty in seeing the science part of this interaction. The style of conversation had them focusing instead on behavior, and it was very difficult to convince them to look past the conversation context in order to focus on the content of the conversation.

The most effective use of this tape in this secondary science methods course is still under constant revision and modification. One strategy used with moderate success is showing the tape twice. The first time, students are asked to write down the dynamics of the classroom interaction; the second time they are asked to focus on the role of evidence, and identifying the range of science concepts that are implicitly or explicitly part of the conversation. The journal assigned is: What does a teacher need to do to prepare students to have a scientific discussion/ argument? What types of content could be taught in this manner? What behavior norms need to be established prior to the discussion? What role does the teacher play during these discussions?

Additional Activities

Beyond the use of video cases and the associated assignments that go with each of the videos, there are five other activities that students complete that build awareness of their individual beliefs, and provide evidence of their plans and commitment for addressing diversity in their classrooms. These activities are: 1) Teacher Belief Inventory, 2) Student Belief Inventory, 3) Action Plans, 4) Unit Plans, and 5) a Resource Portfolio. Each of these types of activities are briefly described in the following sections, along with student reactions to some of these assignments.

Teacher Belief Inventory and Student Belief Inventory

One of the required texts for the field component of the methods course is a book by George Posner call *Field Experience: A guide to reflective teaching* (Posner, 1996). The activities in this text prompt students to reflect and write about the community their schools are located in, the school, the classroom, cooperating teacher and students where they are placed for their field experiences. The appendix of this text has two inventories that students are asked to complete and to use to analyze their beliefs about teaching and learning. These two inventories share most of the same categories: control, diversity, learning, role of teacher, and school and society. The teacher inventory also includes a category for knowledge.

The inventories have a parallel set of questions, for the student inventory they answer based on their experiences as a student, and for the teacher inventory as if they were in charge of a classroom. It is not uncommon for students to answer quite differently on the two inventories. Once the discrepancies, especially in the areas of control and role of teacher are pointed out to them they are always a little embarrassed. As a student they want control and generally want the teacher to be personable; as a teacher they believe that teachers should have a great deal of autonomy of the curriculum and the classroom, and view themselves as disciplinarians who will relax rules over time. At one level these individuals are very consistent -- they want control, what they come to realize is that in their classrooms students who are very much like them also want control, so a compromise on both sides may be called for.

There is often a parallel set of issues when it comes to examining beliefs on diversity. The inventories use a 4 point scale with 1 being 'strongly agree' and 4 being 'strongly disagree'. For the student inventory the diversity statement is:

> As a student I want to be treated like all other students when it comes to each of the following:
> a) methods
> b) evaluation criteria
> c) time offered to students
> d) teacher's expectations for my achievement level
> (Posner, 1992, p. 130)

The teacher inventory statements include:

1. I would employ multiple and diverse criteria to evaluate learners. It is not fair to use the same criteria to evaluate all learners.
2. If I taught classes that differed with regard to learners' academic ability; I would teach them differently.
3. I would not expect learners from economically disadvantaged backgrounds to assume the same degree of responsibility for their learning as learners from more economically advantaged backgrounds.

4. One of the main problems in classrooms today is diversity among pupils.
5. There should be set standards for each grade level and subject, and as a teacher I would evaluate all learners according to these standards.
6. I could probably to most for learners who want to learn.
7. I would attempt to devote more of my time to the least capable learners in order to provide an equal education for all.
8. I would lower my expectations regarding academic performance for those learners who come from economically disadvantaged backgrounds.

(Posner, 1992, p. 132)

The results of these inventories are shared in small group discussions and students are asked to write summary statements about their beliefs in each of these categories. By examining their beliefs in both student and teacher roles, implicit beliefs become explicit. This sets a context for many of the other activities in the course.

Action Plans

Throughout the semester students are asked to develop action plans in three areas: Learning styles; Gender; and Cultural Diversity. An action plan includes a summary of the current situation and eight to ten specific steps or resources that could be implemented. For each of these areas students view videotapes, read articles, and participate in class discussions or activities, prior to developing these action plans. Some sample areas that students usually address in these action plans include: for learning styles, learning styles and abilities, and multiple strategies; for gender, physics as female-friendly, and learning styles; for cultural diversity, ethnicity and conversation style. A sample action plan is provided in Appendix A.

Unit Plans

Students plan and teach a three-week unit in local high school and middle school settings during this course. A major part of their grade is based on their unit plans and their ability to analyze the effectiveness of their units. Issues of diversity sometimes get lost as they develop these units. Evidence of attention to diversity issues is evaluated in the unit plan by examining it for the images of content it represents, variety of strategies, variety of assessments, and daily reflections and analysis of the unit. This activity appears to be one of the places where previously voiced commitments to diversity issues seem to evaporate. In the midst of planning their unit and teaching their unit, students are often overwhelmed with the richness of the setting and the complexity of planning and teaching. Their focus is on breaking down content and structuring class activities, and they have a difficult time taking into consideration issues of diversity.

When the students do attend to these issues, evidence of this attention may be shown in a great variety of ways. In examining these unit plans, this instructor uses questions to guide evaluation of the effort to address issues of diversity, for example:

1. when history of science advancements are presented, are the contributions of several cultures discussed?
2. are most concepts presented in more than one style (visual, auditory, tactile)
3. do students have more than one way of demonstrated their understanding of a concept?
4. do the multiple forms of assessment draw on different skills and learning preferences?

Resource Portfolio

Through the semester students are encouraged to develop and maintain a resource portfolio. This portfolio is meant to be the beginning of an organized format for collected teaching resources such as:

1. the unit that they have developed,
2. lesson plans developed for this course and for other courses,
3. activities shared by other classmates or cooperating teachers in the field,
4. a list of agencies, professional organizations, nonprofit organizations, corporations or individuals (with contact information) who could be useful,
5. reflections of class activities or field experiences.

This portfolio also contains pieces that will eventually (during student teaching) become part of their professional portfolio, such as early draft versions of their teaching philosophy statements, resumés, job search letters, letters of reference, and possibly videos of microteaching or classroom experiences.

Students are encouraged to use their reflection on the student and teacher inventories to write their educational philosophy statement. Evidence for commitment to diversity can be found imbedded in these philosophy statements (an example is located in Appendix B), in the activities the students collect and value highly enough to include in their portfolios, and in the types and range of organizations represented in their portfolios.

Conclusion

We cannot afford to let pre-service teachers view the responsibility of teaching diverse populations as something they will do when they have a better handle on teaching and "life settles down a bit." Teaching and learning are life-long processes and constant modifications are always necessary. As teacher educators it is our responsibility to help students see those invisible parts of teaching and planning that allow teachers to make accommodations and modifications to best meet the needs of individual students.

One of the dilemmas of secondary science education is that often these pre-service teachers have been very successful in school, and they truly love their content. Building the awareness that teaching is much more than content knowledge is often the first barrier that science educators face in working with pre-service teachers. As science-discipline specialists, secondary level educators can easily get tunnel vision and think mainly about their content. This is appropriate, as long as they also recognize that preparing to teach that content means taking into account the full richness of the school and student context. Planning for diversity can not be passive. No teacher intentionally makes the content inaccessible to students, though that is what often happens when diversity is not directly taken into consideration during planning and instruction.

This instructor has chosen not to make diversity a topic for the week, or to focus on just a couple of aspects of diversity. Instead, it is woven through the fabric of this course and program as a running theme that is manifested in a variety of ways, as demonstrated by these activities. It is the goal of this instructor to keep this from being left to the hidden part of teaching.

This paper is not intended to be a formula for the "best way" of developing these ideas in a science methods course. The goal of this paper is to further the conversation, put forward some strategies with sample results, and provoke further conversation about these issues. We cannot allow pre-service teachers to merely adopt the language used to talk about diversity, nor is it sufficient to have a couple of activities that support a variety of learning styles. It must be a significant part of each and every day and class period.

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Appendix A - Action Plan

Cultural Action Plan -- March 1997
Robert, Winter 1997

Sometimes when we get hired for a job we will not live or know about the area around the school where we are moving to. We really can't expect all kids to act the same or know the same kinds of things. I grew up in a middle to upper middle class suburb. I know that most of the job opening are in city schools and the city schools pay more so that is probably where I will get my first job. My field placement this semester was in an inner city school. It hardly seemed like the school had any grounds, just building and parking lots. Nothing like the high school that I graduated from. I don't think I really want to teach in that kind of school but if that was the only place I could get a job I could do the following things to get to know about the students in my school.

1. Read the paper and look for references to the streets and areas around the school.
2. Watch the evening news and do a similar thing.
3. Ask other teachers in the building about the area and the students.
4. Read the student news paper if the school has one.
5. Go to sporting events and start talking with parents who attend.
6. Go to a few stores around the school and do most of my shopping there -- see what kinds of things are sold, prices, etc..
7. Visit churches or youth centers and talk to folks.
8. Call the police and get the crime statistics.
9. Drive around the neighborhoods near the school and see what the houses or apartments look like and what kinds of cars people drive.
10. Visit a Realtor and ask them about the area.
11. Visit neighborhood parks and hang out.
12. See if there are any books in the library about the neighborhood or try to find out the history of the area.
13. Ask students what their parents do for a living.
14. Listen in as kids talk in the hall or in class about their lives.

There are probably lots of other things I could do but this is the start of my list. I did some of these things during this field placement and was real surprised that these kids had pretty normal lives.

Appendix B -- Teaching Philosophy

Becoming and Being a Teacher
Lee, Spring 1996

I plan on being a teacher who touches children's lives. I will not be the passive fact machine, just telling students the facts about science or showing them how to work math problems. I want to show them that science and math are all around us and part of almost every part of our lives. Science and math are real not just something found in books. To do this I believe in using day to day examples and problems to teach science and math. USING and DOING are the important parts of teaching math and science.

The journey to becoming a teacher as been a long and varied one for me. I was sure that I wanted to be an engineer, that the real joy in science was using it. I was one of those folks who really believed that those who could did and those who couldn't taught. Plus why go through all that schooling and major in a science field for the lousy pay that teachers get? No way -- not me, I was going to earn big bucks and have a life. Then I started tutoring ...whoops -- this is fun, more fun than spending my days starring at a computer all day. Before I knew it -- it was "Hey Mom and Dad -- I'm changing my major again!"

When I am teaching I don't feel like I'm an actor just playing a role. I get to be myself. I get to show my students by example that it isn't just nerds who like and can do science and math. The students are just going to have to accept me -- goof ups and all. I don't expect them all to love science like I do -- but if they just don't hate it I'll be happy. I want my class to be so enjoyable that they won't know I've been working them hard, and pushing them. I want my students to be life long learners and that mean's I have to show them that I'm always learning too. I have high expectations for myself and I will have high expectations of all of my students.

TEACHING ABOUT CLASSROOM MANAGEMENT IN A CONSTRUCTIVIST METHODS CLASS ENVIRONMENT.

R. Paul Vellom, The Ohio State University

Among the National Science Education Standards (National Research Council, 1996) are Professional Development Standards which state,

> Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. Learning experiences for teachers of science must
> -Address teachers' needs as learners and build on their current knowledge of science content, teaching and learning.
> -Use inquiry, reflection, interpretation of research, modeling, and guided practice to build understanding and skill in science teaching. (pg. 62)

In preservice teacher education, methods courses seem to be the ideal (and often designated) place to concentrate on these standards. Among middle school and secondary programs, approaches are varied, as are the structure of programs within which methods courses are nested. For instance, some programs include a sequence of methods courses, while others may only include one. Regardless of this varying structure, it is clear that methods courses bear the burden of assisting preservice teachers to move into teaching in ways that many of them have only minimally experienced, from the role of student.

Recent research and modification of preservice teacher education programs in science education has included applying conceptual change constructs (Stofflett, 1994), as well as emancipatory teaching (Koballa & French, 1995) in preservice coursework. Both of these approaches build on constructivist ideals, which include moving from teacher-directed to student-centered instruction, in order to model effective teaching and encourage a wider range of interactions among participants in the course. However, many of the major barriers that commonly stand in the way of preservice interns developing student-centered teaching approaches are issues of classroom management. Simply put, while many interns can see and understand the benefits of inquiry learning for their students, they have not the least idea of how to go about teaching in this kind of a setting. Primary on their minds is how to control a class in which students are given some freedom to choose paths for exploration. To preservice interns who lack significant experience in schools in the teacher's role, freedom to choose paths of inquiry is confounded with freedom to do other things, many of them potentially undesirable, disruptive, or divergent from the learning path of the lesson. These barriers to inquiry can be captured in a small number of questions: 1) How can I <u>manage</u> student-driven inquiry? 2) How do I minimize behavior problems? 3) How do I handle them when they occur? 4) How can I <u>plan</u> for group or individual inquiry in ways that support learning along productive paths, and still give students some freedom in inquiry?

Preservice interns, given the opportunity, will often note that their biggest concern going into a school setting is, "handling the disruptive student", or "classroom control". While they put the concern in these terms, a common response to these concerns is to focus on question #3 as the majority of the answer. That is, planning is seen as the essential element of control. A well-worn axiom is, "Keep them busy, and they won't have time or occasion to create a problem". A colleague put it another way, "The primary reason for discipline problems is poor planning".

The preservice program in Mathematics, Science, and Technology Education at The Ohio State University - Columbus campus is a post-degree program of four or more (typically five) quarters, beginning in the summer of each year. The interns take an intensive summer of study in education, coupled with completion of coursework for certification in mathematics, sciences, or technology (formerly vocational education). During this summer, they do not work in schools, but rather experience peer teaching in a variety of settings at the university. As the Autumn quarter begins, they are placed in schools-- many of them for the first time-- for four mornings per week, and on Friday attend a clinical seminar designed to support and extend their learning about schools, teaching, and themselves. This clinical seminar is their first real methods course, and provides the setting for this study.

Challenging preservice interns to define the role of the teacher:

One goal of the methods class described here is to help preservice teachers add to the teacher-directed approach that they've experienced most in their coursework, by embracing a student centered approach to designing instructional situations for their classrooms. This movement is complicated by a concurrent move from the receptive roles of students that most students bring to teacher education programs, to the active, determinant role that most teachers must play in designing and enacting instructional events and sequences in their classrooms.

Most prospective teachers do not come to their methods courses with a well-elaborated view of teaching, but rather regard the primary task of the teacher as transmitting information. This common perception can be rooted in earlier experiences in science in elementary and high schools, where science may have been represented as a set of terms to be defined and memorized, and reinforced in more recent experience with college where lecture is the dominant teaching strategy. In many of these college courses, recitation sections are a complement to the lectures, and this situation creates an expectation among students that "teaching is telling", that the substance of learning for students is "getting lots of information down in a short time", and that students should be eager receivers of that information, seeking to assimilate the same information as the teacher, in the same structure. Essentially, they are to learn what the teacher knows, the way the teacher knows it.

A set of implications for methods courses emerges when the principles, "We learn what we live", and "We teach how we were taught", are considered in relation to this experience and related assumptions. Some research has illustrated the persistence of personally-held theories in science learning (Driver,date; A Private Universe) and have made a case for similar theories-in-action (Schon, 1979) in teaching. Essentially, Schon posits that teachers teach as they were taught, unless they develop convictions that push them to adopt (and personalize) new models. This change occurs best when the teachers are given time, a supportive atmosphere in which to test and try new ideas, and a range of strategies from which to choose (Barth, 1990).

Many traditional methods courses have been comprised mainly of lectures related to the history of science education, lesson planning, classroom/lab management, lab safety, curricular design, some laboratory work or sampling of activities, surveys of existing curricula, and the development of a small number of unit plans. This construal of "methods" fails to meet students' expectations for what a methods course should provide, and does not support the development of dynamic, personalized models of teaching at the preservice level.

In contrast, the methods class examined here was designed to challenge students' assumptions about teaching, students, and schools, while engaging students in ongoing study of their own activity, and reflective writing. Koballa & French (1995) enumerated a rationale for methods courses, which we share:

> Not surprisingly, these preservice teachers, who during their careers will have a critical impact on the cognitive and social development of hundreds of young students, have never been asked to take charge of their own learning and/or to assist others to do the same. Courses built around experiences that encourage preservice teachers to reflect on their own actions, value their own ideas, and function autonomously should prepare them to do so (61).

<u>How was this methods class "constructivist"?</u>

The constructivist label implies that a transmission model of learning was not the focus, but instead that students made their own knowledge. There are some problems with setting this up as a dichotomy between transmission and construction, however. One problem is that the transmission model has everything to do with the <u>teacher</u> as the director of learning. It is, by nature, a description of <u>teacher action</u>.

Constructivism, on the other hand, centers on what happens from the student perspective-- and in this case, what happens between the students, between students and teacher, and between all of the elements of each instructional event. It's very name comes from the process of <u>constructing</u> that students (and teachers!) do in the process of learning.

So, there is a shift here that we should acknowledge, and perhaps consider more carefully. It could be, for instance, that transmitting information, known to be a common and efficient teaching model (lecture), is an important part of the constructivist classroom.

I regard the essential element of constructivist classrooms to be reflection, or reflective action. This is the place where participants make sense of all that they have access to at a particular point in time. This includes, for each participant, understandings at the moment, all past experiences, the information and experiences that might form a part of the current instructional event, and particular constraints or challenges to which participants may be responding. It is the hallmark of constructivism that students and teachers not only be afforded the opportunity to put these things together into some sensible formulation, but that we each be required to do so.

In each of the instructional events described below, I (the instructor for the course) assumed that students should bring some of themselves or their experience to the instructional event. Often, this 'something' was an artifact of reflection. Making the students' understandings and reflections play a central role in each instructional event ensured the kind of engagement described by Newmann (1992) as a "psychological investment" in learning. This investment was critical in determining what each student would later take from the situation; what they brought to the instructional event deeply influenced what I as instructor could give back to them, what my reactions and interactions would include, and how I would shape my message. Reflexively designed instruction resulted, in which all participants were encouraged to engage, challenge, reflect, posit, and justify.

Course activities focusing on Classroom Management

In the course of this instruction, the preservice interns were challenged to reflect, describe, and personalize information and experiences in a variety of ways. Below, six instructional events are presented as examples, all focusing on classroom management in order to illustrate how a series of related events, over time, can assist interns and the instructor to build understanding. These events are presented in chronological order (the order in which they occurred in the course).

In each case, a description of the event and how it fit into the larger context of the course is presented. Next, actual intern's responses, excerpts from reflective writings, or a tabulation of some sort is included, to give the reader some ideas of the kinds of interactions that ensued. Last, a brief discussion, including information about extensions or connections to other coursework in the program, ensues.

1. Eliciting expectations for field experience, as well as concerns and questions:

Description:

At the outset of the course (before they reported to schools for the first time), interns were asked to list (write out) their expectations for the field experience by responding to the following questions: 1) What do you hope to learn? 2) What do you hope to do? 3) In what ways do you expect to grow?

At the end of the first class meeting (also before they reported to their field experience schools) interns were given an opportunity to list their questions and concerns, and if they had indicated concerns, to rank their level of concern using a 4-point scale (4=very high, 1=low). Written expectations were then sorted and tallied by the instructor, as were concerns, and the results examined for major trends. Since the responses indicated several kinds of things (goals, hopes, anxieties, needs), the set of responses was also kept in original form, for reference during later parts of the course.

Intern Responses:

While many interns did not rank their responses, 31 of 34 mentioned "classroom management" or "discipline" as concerns. In these 31, taking those who ranked their responses, all marked these as "very high" or "high"(4 or 3 on the scale). To the instructor, this was seen as validation of his planning in this area for this course. Intern concerns, sorted, were:

Concerns ranked 4 or 3	**n**
Establishing appropriate relationships with students	5
How to prepare for field experience, details of experience	18
Classroom management / discipline	19
classroom management / logistics, flow	1
Substantial fear related to personal ability	1
Integration (content areas) in teaching	2
Assessment in classroom practice	1

Level of concern: (4 = very high, 3 = high, 2 = moderate, 1 = low)

Discussion and Extensions:

These writings were seen as important indicators of the student's notions of what they would experience in schools, and their hopes for themselves. Underlying most responses to these prompts were statements of need, and personal goals and priorities. While many interns did not rank their responses, 31 of 34 mentioned "classroom management" or "discipline" as concerns. Among those who ranked their responses, none of them marked these as "moderate" or "low". To the instructor, this was seen as validation of his planning in this area for this course.

The term "classroom management" can be related strictly to discipline and control-related issues, but often also includes spatial arrangements within the classroom, teaching challenges such as transitions from one activity to another, personal attributes of teachers such as organization, and a host of issues related directly to engagement and cognitive work done by the students. Good & Brophy (1984) distinguish preventative management issues from reactive ones. This distinction was seen as productive, and informed the design of the course.

2. Observing in mentors' classrooms and looking for "unwritten rules":

Description:

Interns were given the following assignment:

Perform a clinical observation of at least 15 minutes, during which you are to make records focused on sensory inputs, using the following format:

Time	What I see, hear, sense	What I think, question

> You are to try to focus your written records on the "Time" and "What I see, hear, sense" columns. As you observe, if you have questions about motives or wish to record judgments or other thoughts beyond what your senses tell you, you may write these in the "What I think, question" column.

Interns were asked, after they had completed the observation, to reflect on the experience and to try to write the "unwritten rules" for activity and interaction in the classroom during the observed period. Interns then presented and justified these claims in small groups in the methods course.

All of the interns willingly completed the observation during their first week in the schools, and brought these (written observations and reflective elaborations on the underlying rules) to class as assigned. In class, I asked them to pair up, swap, and read; then, a round of questioning for clarification ensued. Once pairs had finished this activity, I asked them to form groups of 4, and to discuss what they had observed in light of a goal of coming up with "teaching principles" that seemed to be in effect in their classrooms. I asked them to write all of these for the group on a big sheet of newsprint, and at a later point, these were all hung up for consideration by the whole class.

<u>Intern Responses:</u>

Some interns indicated (via conversations with me, feedback given verbally during class, and the course evaluation discussed below) a positive view of the observation exercise, and seemed to appreciate the structure and observer-role approach to examining classroom interactions and ground rules. These same folks indicated that the questioning for clarification was also a valuable part of the exercise, as they got to probe for additional information to help them understand what was going on in their partner's classroom, and to better appreciate the differences between their own classroom and that of their partner.

A wide variety of teaching principles resulted from the last part of the exercise. These are attached as Appendix A. These principles reflected, at least in some sense, the areas of most concern to these interns (by preponderance of number). However, one might also look at the principles as indicating the most significant features of their classrooms. Whatever the interpretation, all six of what George Posner (1996) called the basic issues in teaching were represented in the listed principles:

1. Control: Who should control what goes on in teaching, and what should be the range of their control?
2. Diversity: How unique are learners, and how should one treat learners on the basis of their differences?
3. Learning: How do people learn in terms of both the process of learning and the motivation for it?
4. Role: How formal (versus personal) should teachers be in their relationships with the learners?
5. School and Society: To what extent do the sources of and solutions to teacher's problems require structural changes in schools or society?
6. Knowledge: What is knowledge? Is knowledge a given set of facts, concepts, and generalizations to be transmitted, or is it more a personal or social construction developed by processes of reasoning and negotiation? (46)

Some examples of intern-generated principles for each of these issues are presented below:

1. Control: Who should control what goes on in teaching, and what should be the range of their control?

   -The teacher sets clear expectations for the class and gives students freedom to exceed them

   -Students will perform to teacher expectations

   -Student responsibility and accountability are important

2. Diversity: How unique are learners, and how should one treat learners on the basis of their differences?

   -Students take responsibility for their own learning

   -Students and teachers are co-responsible for students' learning

   -High expectations for all diverse learners

3. Learning: How do people learn in terms of both the process of learning and the motivation for it?

   -Student practice of concept applications is important for effective processing of knowledge

   -Practice makes understanding

   -Praise & encouragement are key student motivators

   -Question-guided lessons and independent thinking are essential for learning

4. Role: How formal (versus personal) should teachers be in their relationships with the learners?

   Content overrides personal relationships

   -Teachers should only accept the best effort from students and self

   -Personal relationships and respect of students is important

   -Teachers should be consistent in all things

5. School and Society: To what extent do the sources of and solutions to teacher's problems require structural changes in schools or society?

   -Proficiency tests are more important than the textbook

   -Students can't handle much

   -As long as the students are not being disruptive, I don't care what they do

6. Knowledge: What is knowledge? Is knowledge a given set of facts, concepts, and generalizations to be transmitted, or is it more a personal or social construction developed by processes of reasoning and negotiation?

   -Teachers should make learning meaningful to the students

   -Teachers should be open to new ideas

Discussion and Extensions:

This activity was designed to move the interns beyond summary judgments of their mentors, a tendency that had been observed in earlier preservice cohorts at this institution. I wanted them to gather data, and to be free to write (and temporarily dismiss) judgments and questions, instead working hard on observing. After collecting the data, I wanted them to make personal sense of it, and since this was subject to some interpretation, to then have to justify their claims in small peer groups. The additional benefit of seeing and hearing colleagues' experiences was intended to lead each intern to more productive understandings of his/her particular setting, and the range and nature of school settings in the surrounding area. Finally, I also wanted each intern to commit to some statement(s) about what they perceived in the school setting, and to try to reason through the benefits and costs inherent in different instructional and management strategies. I saw the process of making a personal commitment in relation to various teaching principles as an essential activity in defining themselves in their classrooms.

3. Reading about research on teacher attributes and management:

Description:

Looking in classrooms (Good & Brophy, 1984) chapters 6 and 7 were recommended reading for interns, as a source of information that they might need in order to know where to start on classroom management. This reading was assigned early in the course, but no specific exams, tests, or quizzes were designed to "cover" the material.

Intern Responses:

No response mechanisms were built into the course for this particular resource. However, the resource was selected based on earlier program evaluation surveys which indicated a broadly felt need for "textbook information" on classroom management. The Good & Brophy presentation is in a textbook format, with sections addressing different areas of concern. As indicated above, the survey data was validated by the relatively high concern for classroom management that was broadly noted at the outset of the course. The instructor judged that this reading would fulfill, at least in part, the need expressed, and that students would seek this information as they needed it. Indeed, several students indicated (in the course evaluation) that they appreciated this information, and that it had been significantly useful to them.

Discussion and Extensions:

As noted above, one of the strengths of this text is that the authors distinguish preventive management issues from reactive ones, and the instructor liked this formulation because it assumes that most discipline and control problems emerge from poor or inadequate planning. Putting planning first in discussing management allowed the students to take the idea of these two kinds of management out into the schools with them, and to use them as an analytic construct as they watched and participated in classrooms. Many used the distinction in journal writings, and also made reference to other ideas from this text that were helpful.

The instructor's idea was to utilize the text as a rich information resource, and in so doing to help move interns beyond the "technician" view of teachers towards the "artisan" view. That is, Good & Brophy were seen as the right kind of text because it lacked a prescriptive quality. Instead, the text presents ideas and principles for consideration, and discusses practical aspects of their use and disuse. Interns found this a rich mining ground for strategies and for developing principles to guide their decisionmaking about teaching.

4. Role-playing and analyzing difficult student-teacher interactions:

Description:

A role-play of an angry, public interaction between a student and teacher was used to introduce the problem of handling disruptive students. A student was selected during a class break, and asked to wait until class was largely begun, and then to challenge the instructor to provide additional clarification on the grade for an assignment. The instructor asked her to wait until later because the class was waiting, the student refused, and the conflict escalated until the instructor called it and thanked the student. The instructor invited critique of the situation, and then interns were provided a construct for analyzing roles in these situations, called 'Rights and Responsibilities' (adapted from Campbell, 1991):

Rights and Responsibilities allow us to analyze uncomfortable or emotionally charged interactions, in order to more clearly understand what happened, and to choose appropriate measures to remediate the situation.

Briefly, whenever one person has a right, the other person has a responsibility.

So, you will list these on the same line on a page, so that you can see how this plays out. Here's what I suggest:

1. Capture the situation briefly by writing a description of what happened, trying to avoid judgmental language. You may include your version of actual words and interchanges in order to reconstruct the situation.
2. Set up columns labeled "Right" and "Responsibility".
3. For each right you can think of, begin with the person's name to whom it belongs, and write the right.
4. Go to the other column, put the other person's name, and write the corresponding responsibility.

We will try this briefly in class, and you may take notes below. Listing of rights & responsibilities goes on until exhausted:

RIGHT	RESPONSIBILITY
Student: To request and receive clarification on grading of paper within a reasonable time span Teacher: To defer providing clarification until individual attention can be given	Teacher: To provide clarification on grading of paper within a reasonable time span Student: To accept decision to defer

The interns were then assigned to record and reflectively analyze (in their journal for fieldwork) one such interaction they observed during the quarter. The instructor also indicated that he would like to read these and give feedback to each student.

Intern responses:

The instructor received and reviewed only a handful of analyses during the quarter, and these revealed a general appreciation for the need to carefully think through interactions in order to maintain a learning environment. Interns expressed some appreciation for the construct and technique, as 3 indicated on the course evaluation that it specifically was one of the most valuable aspects of the course.

Discussion and Extensions:

While "the jury is still out" on interns' work with this technique, the heated role-playing event, which most students initially believed was a real scenario, became an icon in the culture of the intern cohort, being mentioned several times, both orally and in student journals over the course of the quarter, as an event that made an impact. One intern indicated that the idea that teacher and student could be co-responsible for negative interactions was an eye-opener to him, and had changed the way he thought about teachers' interactions with their students, writ large.

5. Writing reflectively to define oneself on selected issues:

Description:

Interns were assigned to write reflectively about 3 other assigned issues during the quarter: classroom management, assessment, and questioning in the classroom (together with some cataloguing and preliminary analysis of questions from an actual lesson they had taught or observed). From the syllabus:

> Criteria for these writings include going beyond careful description to analyze, synthesize, and personalize. "I would....because..." statements are encouraged. (3-5 double-spaced pages).

These writings were turned in as regular assignments, for instructor response. Grading criteria for the course indicated that evaluation of these writings would be conducted on the basis of the instructor's judgment on two criteria: addressing the prompt, and sufficient effort. The instructor wanted his responses to be substantial (issues-related) rather than evaluative (grade-related), and wanted the students to expect this kind of response.

Intern Responses:

In these writings, interns most clearly and deeply defined themselves in light of what they had experienced. Many indicated (in the course evaluations) that these writings were one of the most useful aspects of the course, helping them to figure out who they wanted to be in the classroom. In essence, many were able to move from the "they" stance to the "I" stance that the instructor valued. Excerpts from Mark's writing:

> "[School] has about a 50 percent attendance rate. Even though this is a terrible statistic, it actually helps manage classrooms. The students who cause the stereotypical problems aren't there...
>
> ...When I get my classroom I don't think I will have the advantage of authoritative size. I will have to establish my authority by my words and actions. I want to emulate my mentor teacher by not threatening the students.
>
> -Mark

In instances in which this was noted in their writing, the instructor made specific, explicit note of it, and coupled this with praise and encouragement. Several interns expressed a desire for "more written feedback" on their writings, even though the instructor was assiduous about comments, marginal notes, and inviting further inquiry and conversations on key issues.

Discussion and Extensions:

The instructor was very pleased with the degree to which these writings required and enabled students to place themselves in the role of the teacher, and to make defining statements that represented commitments to specific teaching philosophies, practices, and approaches. While responding to these writings was VERY time-consuming (there were 38 students in this cohort!), it is seen as essential to scaffolding interns into a comfort with making personal claims about what they valued in teaching. These claims were seen as the beginnings of what Schon (1987) called, "personal theories-in-use", the principles that guide teaching practice.

6. Course evaluations indicating interns' views of the course experience:

Description:

Interns were asked to respond to three prompts at the end of the course instructional sequence: 1) What were the most useful aspects of the course? 2) What suggestions could you give for improving the course? 3) Any other messages you may have for the instructor.

In accordance with procedures at the University, these evaluations were written in the absence of the instructor, and were delivered to clerical staff for word processing in anonymous form. The instructor received all responses for each prompt, randomly ordered, and with identifying marks removed. In addition to the written evaluations, a standardized 25-item Likert instrument evaluating the effectiveness of the course and various instructor attributes was administered.

Intern Responses:

In course evaluations: 18 out of 33 interns mentioned activities related to classroom management as one of the best aspects of the course, and of these, 5 mentioned the need for more time to be spent on this in future iterations of the course, and in successive teacher education coursework for this cohort. Some mentioned, as suggestions for improving the course, even more focus on issues related to management, and several mentioned that they would suggest including the Good & Brophy readings earlier in the program.

Discussion and Extensions:

The prominence of positive remarks about classroom management issues in the evaluations for this course are a strong indication that both the topics and the approaches were meaningful for the majority of students.

The instructor is considering further modifications to the course, specifically aimed at enhancing interaction around the reflective writing component. In effect, when the instructor's feedback is not seen as substantial enough, even though the instructor intentionally focused on writing good comments, there is a need for more interaction, more sense-making, around these writings. Perhaps the greatest value in these modifications will be creating situations in which students make and defend claims, analyze and evaluate situations in context, and come to personal decisions about their own priorities in these areas.

Summary and Discussion:

Teaching to support learning in a constructivist framework must proceed from some personal commitments made by the instructor, which mirror the commitments that the instructor was trying to promote in his students in the course examined above. While the data presented above is admittedly far from thoroughly and systematically analyzed, it does bear out the usefulness of several principles in this setting:

1. Teaching about complex issues related to practice (such as classroom management) should be structured over substantial periods of time, and across multiple settings and tasks.
2. Teaching about these complex issues should include observation of actual classroom teaching (either in person or via video segments), provision and use of some analytical tools, reflective writing and substantial response to it, and the requirement that interns define and defend personal positions related to each issue.

The course episodes and activities described above can be taken individually and fit into existing coursework. However, as a set, these activities seem to have had a substantial impact on the professional learning of this cohort of interns. Table 1 is provided as a brief summary of the set:

Activity	Pattern of Interaction
Interns write their expectations for field experience; they also write questions and concerns. Concerns were ranked.	Writings sorted by instructor and tallied; expectations and concerns tallies shared with interns. Questions reviewed by instructor, addressed individually or in group over time.
Interns read Good & Brophy, ch's 6&7, for information on management and teacher attributes	None planned; course reflected important distinction in proactive and reactive management techniques and approaches. Some interns used concepts and information later in course.
Teacher-intern role-play of heated verbal exchange, analyzed in terms of roles & responsibilities; journal assignment to analyze a difficult interaction they observe during quarter.	Role-play followed by group critique and analysis, led by instructor. Elucidation of method for capturing and analyzing interactions; connection to documenting same in teaching practice. Feedback given to interns individually, as comments on written records and analyses; some individual discussions.
Reflective writing on classroom management	Daily journal used as starting point for 3+ pg. writing that includes description, evaluation or analysis, and personal commitments in the area of classroom management.
Course evaluations addressing most and least useful aspects of course.	Instructor designed prompts; evaluation administered by an intern, delivered to clerical staff, typed to maintain anonymity. Responses then sorted and tallied by instructor, and recommendations catalogued for future iterations of course.

Table 1: Activities related to classroom management in a 10-week methods course.

Taken together, these activities over the span of 10 weeks of the course provided these interns opportunity and encouragement to look at their experiences in the schools from a different position, that of the teacher. In pushing the interns towards this stance, key elements of instruction included:

1. eliciting detailed statements of expectations, concerns, and questions at the outset of the course, in order to guide instructional design decisions
2. first-hand observation of classrooms using a provided tool (3-column format) coupled with reflective writing
3. formulating "teaching principles" in their own words in a collaborative setting
4. observing or taking part in role-playing, coupled with analysis, provision of a tool (rights & responsibilities format) and use of it
5. provision of rich textual resource of non-prescriptive information (Good & Brophy)
6. reflective writing on classroom management that included description and some analysis, synthesis, or personalization, and significant instructor responses
7. course evaluations which promoted student thinking about various aspects of the course, and the relative value of these in promoting professional growth in specific areas.

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MEZIROW'S THEORY OF TRANSFORMATIVE LEARNING WITH IMPLICATIONS FOR SCIENCE TEACHER EDUCATORS

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Teacher change is the precursor of reform in education. Without it, efforts intended to facilitate reform are thwarted and nullified leaving any apparent progress either incidental or superficial. Science educators therefore, must be adept at facilitating teacher change when answering the clarion call for reform in science education. For reform to come about, science educators must have an understanding of both the nature of teacher change and the manner by which such change is facilitated. The purpose of this article is to provide an overview of Mezirow's theory of transformative learning (1991) and its implications for science educators in fostering teacher change and learning.

Transformative Theory of Adult Learning

Mezirow's transformation theory (1991), a constructivist theory of adult learning, is a comprehensive, idealized, and universal model consisting of the generic structures, elements, and processes of adult learning and development. Transformation theory provides a theoretical basis for both teacher learning and teacher change. Teacher change is the process of altering, modifying or transforming the practices, attitudes, beliefs, and perceptions of teachers. Change is an individual learning process. For each teacher, change is a highly personal experience which entails learning and developmental growth.

Overview of Transformation Theory

Teachers, as adult learners, are caught in their own histories. No matter how good an adult is at making sense of their experiences, they all start with what they have been given and operate within horizons set by the ways of seeing and understanding they acquired through prior learning.

> This formative learning occurs in childhood both through socialization (informal or tacit learning of norms from parents, friends, and mentors that allows us to fit into society) and through our schooling. Approved ways

of seeing and understanding, shaped by our language, culture, and personal experience, collaborate to set limits to our future learning. (Mezirow, 1991, p.1)

Adults function in a changing world. "Contradictions generated by rapid dramatic change and a diversity of beliefs, values, and social practices are a hallmark of modern society" (Mezirow, 1991, p.2). Adults living in such a society must learn how to keep from being overwhelmed by these changes. The knowledge acquired from one's formative learning is no longer sufficient. Mezirow (1991) continued:

> Rather then merely adapting to changing circumstances by more diligently applying old ways of knowing, [adults] discover a need to acquire new perspectives [emphasis mine] in order to gain a more complete understanding of changing events and a higher degree of control in their lives. The formative learning of childhood becomes transformative learning in adulthood. (p.2)

Thus, adult learning can be defined as the process of using a prior interpretation to construe a new or revised interpretation of the meaning of one's experiences in order to guide future action. An individuals acquired frame of reference is central to this learning theory. It is through this frame of reference or personal paradigm that all meaning is construed and all learning takes place. Action in this context includes making decisions and associations, revising points of view, reframing or solving problems, modifying attitudes, or producing changes in behavior. For Mezirow (1991), "action in transformative theory is not only behavior, the effect of cause and effect, but rather 'praxis', the creative implementation of a purpose." (p. 12)

Adults construe meaning from both symbolic models or exemplars and habits of expectations. These habits of expectations are the meaning perspectives and meaning schemes which frame and organize these symbols into systems. The symbols that adults project onto their sense perceptions are filtered through these meaning perspectives and meaning schemes. As a result, symbols (and metaphors) take on new and enhanced meanings. Mezirow termed them loaded perceptions. Adult learning, development, and change come about when meaning perspectives and meaning schemes are transformed through reflection and critical discourse.

Meaning Perspectives and Meaning Schemes

Meaning perspectives are both a system for interpreting and evaluating the meaning of an experience and sets of habits of expectation which filter perception and cognition. Meaning perspectives and meaning schemes are structures of psycho-cultural assumptions within which new experiences are assimilated and transformed by past experiences (Mezirow, 1978, 1981, 1991). Mezirow, (1991) added that "meaning perspectives, or generalized sets of habitual expectation, act as perceptual and conceptual codes to form, limit, and distort how we think, believe, and feel and hope, what, when, and why we learn. They have cognitive, affective, and conative dimensions." (p. 34.) Meaning perspectives are more than a way of seeing. Meaning perspectives constitute an orientating frame of reference that serves as a tacit belief system. In this respect, they are similar to Polyani's (1966) perspectives, which were defined as systems of constructs involved in tacit knowing. Dewey (1933) wrote both on the importance of meaning perspectives and on one's normal unconsciousness of them.

Meaning perspectives serve as one of three sets of codes significantly shaping sensation and delimiting perception, feelings, and cognition. The sets of codes include the sociolinguistic, psychological, and epistemic (Mezirow, 1991, 1994). Sociolinguistic codes are those involved in dialogue or communicative action and allow individuals to relate to the world around them, to other people, and to their own feelings, intentions, and desires. Psychological codes are those which shape self-concept and epistemic codes pertain to the ways that individuals know and how they make use of that knowledge. Meaning perspectives are similar to what others have called personal frames or paradigms. Kuhn (1962) referred to a paradigm as a collection of ways of seeing, methods of inquiry, beliefs, ideas, values, and attitudes that influence the conduct of scientific inquiry.

Meaning schemes are the more specific dimensions of one's personal frame of reference or meaning perspective. Meaning schemes are "constellations of concepts, beliefs, judgments, and feelings which shape a particular interpretation" (Mezirow, 1994, p. 223). As such, they contain the specific beliefs, knowledge, feelings, and value judgments that become articulated in an interpretation (Mezirow, 1991, 1994).

Perspective Transformations

Perspective transformations are the most distinctive domain of adult learning. A perspective transformation involves what Habermas (1984, 1987) described as emancipatory action. Mezirow (1981) defines a perspective transformation as the "emancipatory process of becoming critically aware of how and why the structure of psycho-structural assumptions has come to constrain the way we see our relationships, reconstituting this structure to permit a more inclusive and discriminating integration of experience and acting upon these new understandings." (p. 6)

A transformation in meaning perspective can happen only through perspective taking, assimilating the perspectives of others (Mezirow, 1978). However, perspective taking is not role taking. Perspective taking implies a conscious recognition of the difference between one's old perception and the new one and a desire to appropriate the newer perspective because it is of more value. Conceptualizing one's self-concept in the process of perspective taking is developmentally a function of maturity (Mezirow, 1978).

A perception is the effect or product of becoming aware in one's mind. Individuals must draw upon their past knowledge to make interpretations that help them choose the dimensions of any new experience to which they will attend. Individuals also draw upon prior learning so that they may associate the new experience with existing ideas. "This tacit process of reviewing and making interpretations based on prior experience to delimit the slice of new experience to which we will attend is what we refer to as perception" (Mezirow, 1991, p. 16).

Adults rely on their frames of reference in order to interpret and give meaning to what they are experiencing. As people mature, they improve in their ability to anticipate reality by developing and refining their meaning perspectives and meaning schemes so that they may use them more effectively to integrate and differentiate experiences. When a preexisting meaning perspective or meaning scheme can no longer comfortably deal with anomalies in a new situation, a transformation can occur. "Adding of knowledge, skills, or increasing competencies within the present perspective is no longer functional: creative integration of a new experience into one's frame of reference no longer can resolve the conflict. One not only is made to react to one's own reactions, but to do so critically" (Mezirow, 1978, p. 104).

Perspective transformations are commonplace in an adult's life (Mezirow, 1978). As people mature, they make an intentional movement to resolve contradictions and to proceed to developmentally advanced conceptual structures. As such, adults are continually restructuring the reality of the past by reinterpreting it from successive vantagepoints. Perspective transformations, therefore, are critical to the process of adult learning and adult change.

Perspective transformations are precipitated by experiences that cannot be resolved by simply acquiring more information, enhancing problem solving skills, or adding to one's competencies. A perspective transformation can occur either through an accretion of transformation of meaning schemes resulting from a series of dilemmas, an epiphany, or in response to an externally imposed epochal dilemma (Mezirow, 1978, 1981, 1991). "However, any major challenge to an established perspective can result in a transformation" (Mezirow, 1991, p. 168). Once an individual has moved forward to a new meaning perspective they can never return to those in the past. However, after making a new meaning perspective the individual may require special support or assistance to maintain the will and determination to persevere.

"The process of perspective transformation has far reaching implications for the education of adults" (Mezirow, 1978, p. 107). The most significant behavior changes are functions of perspective transformations. A perspective transformation is often a precondition for meaningful changes in perception and behavior.

Adult Learning in Transformation Theory

Transformation theory includes four types of adult learning (Mezirow, 1991). They are described as follows:

1. Learning through meaning schemes. The adult further differentiates and elaborates previously acquired, taken for granted meaning schemes. Learning occurs within the

structure of the adult's acquired frame of reference.

2. Learning new meaning schemes. New meaning schemes are created. The new meaning schemes are consistent and compatible with existing meaning perspectives.
3. Learning through transformation of meaning schemes. Learning here involves reflection on assumptions. In this type of learning the adult finds that his/her specific points of view have become dysfunctional. This realization leaves the adult with a sense of how inadequate his/her old ways of seeing and understanding meaning are.
4. Learning through perspective transformation. The most significant kind of learning. This type of learning begins when the adult encounters experiences, often in an emotionally charged situation, that fail to fit his/her expectations and consequently lack meaning, or if he/she encounters an anomaly that cannot be given coherence either by learning within existing meaning schemes or by learning new meaning schemes. These are analogous to paradigm shifts as described by Kuhn.

<u>The Contexts of Learning</u>

Mezirow (1991) believes that learning involves five primary interacting contexts. These contexts are:

1. The meaning perspective or frame of reference in which the learning is embedded.
2. The conditions of communication: language mastery; the codes that delimit categories, constructs, and labels; and the ways in which problematic assertions are validated.
3. The line of action in which the learning occurs. This has to do with implementing the purpose and intentionality of the learner and involves the exercise of their conative powers.
4. The self-image of the learner. This context is concerned with how the learner feels, how things are going, and how he/she sees their situation. The meaning of this "felt sense is implicit; that is, it is never equal to specific cognitive units. We explain our felt sense by interpreting it and reflecting upon our interpretation, using it as a criterion for assessing the correctness of our interpretation of our situation"(p. 14).
5. The situation encountered. In other words, the external circumstances within which and

interpretation is made and remembered.

Fostering Transformational Learning

Mezirow (1991) identified a list of goals that anyone involved in the education of adults must fulfill in order to facilitate learning and foster transformational learning. They are as follows.

Progressively decrease the learner's dependency upon the educator.

Help the learner understand how to use learning resources, especially the experience of others, including the educator, and how to engage in reciprocal learning relationships.

1.Assist the learner to define his/her learning needs, both in terms of immediate awareness and in terms of understanding the cultural and psychological, assumptions influencing his/her perceptions of needs.

2.Assist the learner to assume increasing responsibility for the defining of learning objectives, planning his/her own learning program, and evaluating progress.

3.Help the learner organize what is to be learned in relationship to his/her current personal problems, concerns, and levels of understanding.

4.Foster learner decision making. Select learning experiences that require choosing, expanding the learner's range of options, and facilitating the learner's taking the perspective of others who have alternate ways of understanding.

5.Encourage the use of criteria for judging that are increasingly inclusive and differentiating in awareness, self-reflective, and integrative of experience.

6.Foster a self-corrective, reflexive approach to learning- to typifying and labeling, to perspective taking and choosing, and to habits of learning and learning relationships.

7.Facilitate posing and solving of problems, including problems associated with the implementation of individual and collective action, and the relationship between personal problems and public issues.

8.Reinforce the self-concept of the learner as a learner and doer by providing for progressive mastery and for a supportive climate with feedback to encourage provisional efforts to change and to take risks; by avoiding competitive judgment of performance; and by appropriate use of mutual support groups.

9.Emphasize experiential, participate, and projective instructional methods and use modeling and learning contracts where appropriate.

10.Make the moral distinction between helping the learner understand his/her full range of choices and ways to improve the quality of choosing and encouraging the learner to make a specific choice.

Fostering Transformative Learning in Teachers

Mezirow's transformation theory provides a theoretical framework for the processes of adult learning and development. As such, transformation theory also provides a theoretical basis for teacher learning and teacher change. Teacher learning is a precursor to teacher change. As such, the process of transformative learning has far reaching implications for facilitating teacher change. The most significant changes in a teacher's practices, attitudes, beliefs, and perceptions are functions of transformations of meaning perspectives and meaning schemes. Therefore, when planning learning experiences designed to facilitate science teacher change, science educators need to include those factors which foster transformational learning. These include the following. (adapted from Mezirow, 1981, 1991)

Progressively decrease the science teacher's dependency upon the educator. To facilitate this, the learning experience must take place in a non threatening and supportive climate.

Help the science teacher understand how to use learning resources and how to engage in reciprocal learning relationships. This can be accomplished if the learning experience provides for interaction, collaboration, and camaraderie.

1.Help the science teacher to define his/her learning needs. In order for this to happen, the learning experience must provide the teacher with the opportunity to become an active learner and to look through learner's eyes.

2.Help the science teacher to organize what is to be learned to his/her current views.

3.Foster science teacher decision making. Select learning experiences that require expanding the teacher's range of options and facilitate perspective taking.

4.Encourage the use of criteria for judging that are increasingly inclusive and differentiating in awareness, self-reflective, and integrative in experience.

5.Facilitate posing and solving problems.

6.Reinforce the self-concept and self-confidence of the science teacher. The teacher must leave the learning experience with increased self-confidence, self-esteem, and self-reliance.

7.Emphasize experiential and participative instructional methods and use modeling where appropriate.

8.Create opportunities for critical discourse. Again, this can be accomplished if the learning experience provides for interaction, collaboration, and camaraderie.

9.Provide opportunities for reflection.

10.Provide for an assessment of gains made as a result of transformative learning. The learning experience must provide the science teacher with the opportunity to assess the impact the implemented change is having on teaching and learning in the classroom.

11.Provide support for the science teacher who has made a transformation. This can be provided by others such as fellow members of a learning group, co-workers, students, administrators, or an educational mentor.

Conclusion

A great potential for improving science education lies with the classroom teacher. Therefore, programs directed at changing science teachers' behaviors are essential components in the process of improving science instruction (Abell & Pizzini, 1992). As such, efforts intended to bring about reform in science education are futile unless they facilitate science teacher change. However, science teacher change will only take place if accompanied by learning. Therefore, programs designed to alter, modify or transform the practices, attitudes, beliefs, and perceptions of science teachers must do so by facilitating learning. Mezirow's transformative theory, a constructivist theory of adult learning, is a comprehensive, idealized, and universal model consisting of the generic structures, elements, and processes of adult learning and development. As such, transformation theory provides the theoretical basis for both science teacher learning and science teacher change. Science educators need to be knowledgeable of the factors that facilitate adult learning, especially those which foster perspective transformations, and incorporate them when planning experiences designed to facilitate science teacher change.

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USING A WEB SITE IN AN ELEMENTARY SCIENCE METHODS CLASS: ARE WE OPENING A PANDORA'S BOX?

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Introduction

Since 1989, elementary science faculty at Florida International University (FIU) have worked with both undergraduate and graduate methods students to provide pre-service and in-service teachers with experiences in computer applications to science teaching with such tools as microcomputer-based laboratories (O'Brien, 1991; O'Brien & Peters, 1994) and telecommunications technology.

As a result of our interest in new technologies and their relevance for pre-service elementary teachers, we have been engaged in the construction of a web site and the utilization of web-based resources in our elementary methods courses at FIU. The current growth of the Internet -- which includes the establishment of lesson banks, links to informal and formal science settings, links to organizations that cater to teachers, and especially Internet science projects (see Cohen, 1997) -- makes the Internet an intriguing new gateway to such resources.

While university faculty are increasingly engaged in efforts to use the World Wide Web (WWW), there is as yet little research on the effectiveness of the WWW in the classroom. Technology literature suggests that using the WWW may alter the role of the teacher and the learning process itself (Owston, 1997). For example, Carey (1993) says that the teacher may become more of a facilitator rather than a disseminator of knowledge. The development of the WWW may even herald the replacement of a physical university with a virtual university (Barnard, 1997).

As the WWW increasingly becomes a part of our instruction, a number of questions can be raised about the way it is used including how it differs from other resources such as texts, how much prior knowledge is necessary for effective student utilization, and whether it does, indeed, change the way we are teaching.

We have likened the introduction of the WWW in our classrooms to the opening of Pandora's box. If you will recall from the Greek myth, Pandora is given custody of a box as part of her wedding dowry but is admonished not to open it. Driven by curiosity, she eventually succumbs and a variety of demons and evil spirits escape. Finally, there is a knock from the seemingly empty box and Hope appears to allay Pandora's fears and assure her that all is not lost for humankind. Like the myth of Pandora, we have opened up this box (the World Wide Web) we've been entrusted. Some would argue that a number of demons have come out of the opening of this box including access to materials that are confidential or not appropriate for minors. Some already bemoan the the impact of the Internet on the university. For example, in a newspaper editorial, Professor Tom Auxter (Auxter, 1997) opines that the virtual university student is "forced into a passive role, receiving canned materials and sending a reaction into cyberspace". Others look more hopefully at the use of the WWW, and see it as a way to open up new dimensions to learning and resources in a way not previously possible in schools.

As members of the science education community beginning to use the WWW in our own classrooms, we want to share with you some of our experiences in opening this box with our own undergraduate science methods students. We will describe our construction of an Elementary Science web site, a survey of students' use of the WWW at the beginning of the fall semester, 1997, and how we integrated the WWW into our science methods classes this past semester.

Part 1 -Constructing the Elementary Science Education Web Site

The initial development of a web site for pre-service teachers was pursued to investigate the potential benefits and limitations of this purpose. In addition, other reasons for creating a web site are presented.

Why Construct Your Own Web Site When There Are So Many Out There?

Why create a web site when there are so many interesting web sites available in science? For example, the Eisenhower National Clearinghouse (Web address: www.enc.org) has developed a site that caters to the audience of mathematics and science teachers nationally. We believe there are several reasons why it is worthwhile to develop one's own.

Catching The Wave

The growth of the web in recent years has been spectacular. The exponential growth of usage is well known. Recently, some universities such as UCLA have even been requiring that each course have a web page developed for it. The interest in the Internet as a medium provides motivation for its use by students as well as faculty. Increasing numbers of students are arriving in our classes having had experience with multimedia, and are comfortable using the computer medium.

The development of a web site also allows educators to engage in conversation with their colleagues about the value of this medium for the promotion of educational goals.

Locals Too

It may be critical for students to have access to local resources on such a site, both formal and informal. For example, if a student is researching a topic such as the Everglades, not only will a self-created web site with sufficient links and requisite search engines give the student general information about the topic, it could also provide information about contacts (scientists, science museums) in the local area that could give valuable advice about classroom projects.

Is It A Good Medium For Information About Curriculum, Lesson Plans, Etc.?

By taking on the task of creating a site, the instructor also has an opportunity to focus on examining existing sites and weighing their value for potential links.

How Is It Really Being Used?

Still another reason for developing a web site is to allow careful examination of ways in which students are really using the web site and the Internet. Do they spend time using the site in the manner anticipated, or do they use it in a different, more effective manner or do they use it in a way which is contrary to course goals? This issue is described further during a discussion of formative testing in the site development.

Development Processes

Given these reasons, the development of an Elementary Science Education Web Site was begun. In the course of the development, a number of design decisions were made.

Recruiting Site Developers

In order to begin this project, a pair of bright undergraduates who had completed the elementary science methods course the previous semester were recruited. Both students were experienced e-mail users and computer enthusiasts. One had even constructed a rudimentary web site as part of a class project.

Know The Code

Hypertext Markup Language (HTML) was used to create the site. While the growth of web site applications such as Claris Home Page or Netscape Navigagor currently allows the construction of sites without having to write programs, the authors felt that it was important to program in HTML in order to retain flexibilitity in adding features to the site.

Resources

The computer systems available included computer accounts and a UNIX server at the university. The designers worked at their own computers at home, uploading the HTML revisions as necessary.

Exploration - Discovering What Was Of Interest

This process, which is ongoing, is perhaps best characterized at this point as a series of steps.

Step 1- Initial Planning

During the first meetings, initial goals were discussed regarding the audience for the web site. It was decided to focus on researching two aspects of the Internet: desirable elements of site design (by examining a variety of web sites) and science education websites (for content links).

Step 2- Web Site Structure Planning

After the initial meetings and exploration, the designers decided to create a subject-related structure for the first web page prototype. A first page was planned with the subject headings of science subject index, informal science, teacher resources, kids' science, mailbox, and search engines. By selecting the science subject index, six science areas (biology, environmental science, chemistry and physics, earth science, astronomy, and meteorology) were displayed. By selecting one area, the user opens another page displaying in-depth links to that particular subject.

Step 3-First Formative Testing

The designers were anxious to get feedback from the students on the usefulness of the web site before proceeding too much further in the design, so several sessions were conducted to interview students as they utilized the web site. Pre-service student teachers met with the web team during half-hour sessions to review the site. Each was interviewed with respect to his or her experience in using the Internet and purpose for using the site. The students then proceeded to use the site to locate information. In this case, students were intent on gathering information related to preparation of particular science lessons for their teaching assignments. For example, one student teacher (Deborah) was planning a lesson about ants for a group of first grade students. In the course of observing and assisting Deborah's search efforts, the designers noted the levels of help they had to provide and the particular series of steps she took in her search. At that time, few links had been provided to biology sites, so that the student's efforts were redirected to using the search engine links. The student used these to locate a variety of ant-related sites such as E.O.Wilson's Ant Web Site. (Web address: www.dna.affrc.go.jp/htdocs/Ant.WWW/Harvard/ANT_MCZ.html)

Formative Issues

By that point in the development and interview process, a number of issues had been identified concerning the design of the site and the implications of the site for future use.

It was noted that a number of students needed some orientation to the particular browser being used and how to navigate back and forth on the web site itself. This implies that some rudimentary introduction to the use of browsers needed to be conducted, or at least a description of how they work, in order for students to be comfortable using the web site.

The designers found that it would be useful to include descriptors next to the links to indicate what that link contained before users jumped to the link itself.

Finally, it was apparent that pre-service teachers were concerned with locating lessons to utilize. A goal for future work with pre-service teachers was to find ways of addressing this concern within our own framework of critically evaluating such lessons with respect to their hands-on/minds-on relevance.

Part 2-A Survey of Student Usage of the WWW

Web Use Survey

To gather data about how science methods students might be using the WWW before and after the course in which they were expected to use the WWW, a survey was developed and administered at the beginning and end of the semester. (A copy of the survey may be found in the appendix). Elementary methods students' responses were compared to answers given by several other groups of students: undergraduates enrolled in other sections of science methods not attempting to integrate the WWW, graduate students having some course WWW integration, and graduate students having no WWW course integration. We will report here on the results of the pre course survey.

Pre Course Analysis

Prior Use of the WWW

Out of 210 students taking the pre course survey, 57% (119) had previously used the World Wide Web. Interestingly, there was a marked difference in the graduates and undergraduates experience: Only 39% (15) of the graduate students said that had previously used the WWW, while 60% (104) of the undergraduates had. Thus, undergraduates were more likely to have used the WWW.

Frequency of Usage

Five categories of usage frequency were developed - Non-users (0 times - students who answered that they had not used the WWW were placed in this category), One-time users (indicating they had used it 1-2 times in the last 6 months), Sometime users (indicating they had used it 3-5 times in the last 6 months), Frequent users (indicating they had used it 6-9 times in the last 6 months), and Regular users (indicating they had used it more than 10 times in the last 6 months).

The overall breakdown of each category by level was as follows:

Table 1
Frequency of Usage

	Non-Users	One-time users	Sometime users	Frequent users	Regular users
Everyone	43%	12%	10%	7%	28%
Grads	61%	5%	5%	3%	26%
Undergrads	40%	13%	11%	8%	28%

While both grads and undergraduates had a substantial group of frequent users, undergraduates were more likely to have used the world wide web on one-time or occasional basis. Because there were a substantial number of students who were regular users at both levels, there appears to be a disparity between "haves" and "have-nots".

Types of Usage

Seven categories of types of WWW usage were developed to help create a picture of why students use the WWW do so: 1 - School, 2- Job, 3- Personal, 4- School and Job, 5- School and Personal, 6- Job and Personal, 7 - School, Job, and Personal.

Table 2
Types of Usage

School	Job	Personal	S & J	S & P	J & P	S & J & P
19%	0%	34%	1%	35%	2%	9%

Students indicated that much of their work on the WWW was school related and personal related. Interestingly, very few reported use of the WWW at their job.

Comfort Level

Students indicated their comfort level using the WWW on a five point scale. Scores ranged from 1 (Not at all comfortable) to 5 (Very comfortable). The mean score for all students (N=119) using the WWW was a 3.1 (sd = 1.3), indicating students who had used the WWW upon entering the semester had a medium level of comfort using it.

Differences in Llife or Work

Students were asked if their work, school work, or life was any different since using the WWW. Of the students answering (N=80), 60% (48) said that it was different, many of them mentioning a change in research strategies.

Part 3- Course Integration of the WWW

First Attempt

The Elementary Science Web Site was introduced to an elementary science methods class during the first summer session in 1997. The class was taken to a university computer laboratory where all students had access to computers that had Internet connections. A number of students indicated that they had never used the World Wide Web. Thus students were given a brief introduction of how the computers were linked to the World Wide Web and how they would be using hyperlinks to "travel" from one site to another. Students were given a "scavenger hunt" assignment to work in teams to find as many sites from a list as possible. These sites included such items as Cockroach world, a science museum, and the Everglades digital library. It was hoped that an introduction in such an atmosphere would encourage students to utilize the web site and demonstrate the ease with which it was possible to "surf the net". In addition, students in this class were also expected to include references to specific WWW sites in their term project.

Fall, 1997

This past fall semester, 1997, we tied the use of the World Wide Web to course objectives in several ways. These included an introduction to the elementary education science web site, use of the GLOBE web site, use of a class web site, use of science standards web sites, and identification of web site resources as part of investigation assignments. As an illustration of our early attempts to integrate the WWW, course uses of the WWW by one of the instructors will be described in this section in some detail.

Introduction to the Elementary Science Web Site

Like the students in the first summer session, students were introduced to the Elementary Science Web Site on the first day of class and asked to conduct a scavenger hunt.

GLOBE Site Usage

One of us had the opportunity to take part in a GLOBE training session last summer. GLOBE is a program sponsored by NOAA and NSF to utilize a variety of protocols developed by scientists for use with K-12 schools which gather data and enter it into a database via web site. Participating schools are located in a number of countries and at numerous locations in the USA. The web site (Web address: www.globe.gov) contains tools such as graphs that allow the data to be displayed in various forms. Anyone using the WWW can enter the web site and view the data using the interfaces provided. Thus the GLOBE site provides an opportunity for student teachers to become acquainted with data gathering and analysis features. The GLOBE site provides a number of databases several of which (temperature, precipitation, cloud cover, and cloud type) related to our theme of studying patterns of weather. As another opportunity for students to utilize the WWW, students spent part of one class period in the computer lab looking at the GLOBE web site. Students were introduced to the web site and shown how to create graphs with selected data using the graphing interface. They were then given an assignment to display weather data from the GLOBE site using a variety of countries or locations. For example, they could have compared temperature at sites on the five continents for January through September, 1997. Students were expected to display their findings in hard copy form and discuss any patterns they found.

Course Web Page

A simple course web page (Web address: www.fiu.edu/~lewiss/weath.fall.97.htm) was developed using Netscape Navigator- Gold version. It included links to the elementary science page, lecture notes, and updated links to topical weather events such as El Niño and relevant weekly topics. Students were encouraged to search for information on these topics via the elementary science web site or a web search engine such as Yahoo, and then create the appropriate links to the class web site. They were also reminded by e-mail to check on the web site periodically to note updated links and information. For example, to supplement a discussion about the nature of science and the ways that new theories enter the accepted arena of science (See Duschl, 1990 for an extended description of this process), a web site was located (Web address: csep10.phys.utk.edu/astr161/lect/comets/smallcomets.html) discussing the new theory that small, water-laden comets are entering the atmosphere at a rate that may explain the development of the oceans. The site also contains an interesting description of the process by which the theory was developed. Thus students who viewed this site were able to get current information about the theory and its development via the World Wide Web.

Science Standards

Another goal of the course was to have the students become familiar with the National Science Standards and Florida Sunshine Standards in science. Using a web page developed for searching the Sunshine Standards (Web address: http://intech2000.miamisci.org/sss/sc/), students were required to locate the Sunshine Standards that pertained to their weather topic of study. The downloaded standards were then compared to the relevant National Standards.

Identification of Web Site Resources

A final project utilizing the Web had to do with one of the students' group projects. Students were required to pick a topic having to do with patterns of weather such as patterns of hurricane development. They then did extensive research in order to understand how the topic related to education. As part of this research, students were required to list at least two WWW addresses (URLs) that pertained to the topic.

Student Input into the Course Web Page

Students were not actively solicited to contribute to the web page, but two of them made contributions that led to the extension of the development of the web page. The first contribution was made indirectly by Susan, who had made a beautiful photographic collection of clouds. (Web address: www.fiu.edu/~lewiss/clouds1.jpg). After viewing these in class, it was suggested to her that the photos be digitized and that we could add these to the course web site. She had a friend scan them and digitize them, so we were able to incorporate these into the course web site.

The second student, Sean, found a science lesson web site (Web address: www.csun.edu/~vceed009/lesson.html) and reported this via e-mail. The site was examined and found to contain a variety of activities, a number of which had already been identified as consistent with the constructivist approach that guides the course.

As part of the class, students were to have an opportunity to examine lessons and to analyze them in various ways such as their relationship to the National Science Standards. The use of a digital bank of lessons offered an interesting way for students to find lessons to analyze which might also encourage them to use this source in the future. Therefore the lesson web site was added as a link to the course web page, and students were required to download a lesson for analysis. The development and utilization of science lesson banks on the Web is an area that bears further examination beyond the scope of this presentation.

As described, students had a number of in-class opportunities to use the WWW and several assignments that required them to use it outside of class.

PART 4-General Issues to Be Explored

These initial findings from the survey and observations from the early course use of the web sites raise several general issues about using the WWW in science methods courses.

Accessibility

A major issue is whether students can get sufficient access using the WWW. We have already seen from data on the pre-course survey that a large group of students are regular WWW users, while another large group never uses it. There have been recent developments that make it somewhat easier for Education students at FIU to access the Web through the addition of a computer lab with high speed Internet connections. In addition, a growing number of students have computers available at home or work. Nevertheless, many students may not be able to afford the computer hardware needed to successfully use the WWW. In addition, the university does not currently provide undergraduates with their own PPP accounts that allow WWW access via modem. Thus, unless students have sufficient computer hardware and software at home and their own Internet provider, using the WWW can be problematic and may lead to further disparities between the "haves" and "have nots".

Navigation Issues

Some students expressed difficulties in their understanding of how to navigate the WWW; they sometimes got lost. As Hill and Hannafin (1996) found, students who are disoriented in such an environment may not use optimal search strategies to locate relevant materials. Students were observed making ineffective searches or not carefully thinking about alternative ways of locating information through different types of searches. These students required a great deal of instructor assistance, a finding supported by Lyons et al (1996) who worked with middle and high school students using the WWW.

Additionally, the dynamic nature of links (which often change or are not accessible due to heavy traffic or servers being down) can sometimes make it frustrating to use. Students sometimes decided to use their own computers during off hours rather than wait for access.

The Dis-Information Age

While the number of sites and growth of the net are astounding, general questions are being raised regarding the quality and accuracy of the information available. Recent pranks involving the display of pseudo-data underscore the ease with which misinformation can be generated. This same issue surfaces with respect to the resources available for science education: how do we assess the quality of the information we are finding?

Inaccurate information also may be incorporated into the lesson that the pre-service student finds on the WWW. Similarly, the philosophical orientation of the lessons themselves -- which may be less than desirable from our own orientation -- may be hidden from the inexperienced teacher who is focused on creating some activity. Thus, there is a need to acquire a disciplined approach in facing the overwhelming sea of information available via the WWW. (Ryder & Wilson, 1996)

Accordingly, it may be important to promote the adoption of a critical framework for analyzing Web information like that suggested by Ryder & Hughes (1997). Their framework, which has been adapted from criticism of literary resources, addresses the following five points:

1. The purpose and audience (what is the intent of the information and why it is being communicated?)

2.Authority (What are the credentials of the individual(s) or group(s) presenting this information?)

3.Scope (What is the breadth, detail of the information provided?)

4. Format (How is this information presented? Can it easily be interpreted? Can it readily be acquired or reproduced?)

5. Acceptance of material (What is the opinion that others have of this material?)

The Uniqueness of Science Resources on the Internet

While there are a number of drawbacks in using the WWW, the use of the Internet provides unique opportunities for scientific study as described in the GLOBE project. Data sets are available for students to utilize in authentic studies. For example, students can access pictures from weather satellites and make their own forecasts. Scientists themselves can be engaged for discussion and advice. Students can rapidly find information about scientific developments.

Further Steps

We see the integration of the WWW in our science methods courses as a continuing cycle of experimentation and research. The post course survey will be analyzed with respect to changes in student use of and attitude toward the WWW. This should help shape further integration of the WWW in the science methods course, and lead to additional rounds of analysis and course development.

As K-12 and community use of the Internet expand, and as we move toward more use of the WWW in our post secondary science methods courses, the exploration of these benefits and drawbacks will become an increasingly important agenda item for the science education research community.

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Student Survey (Pre-Course)

Dear student,

We are surveying student use of the World Wide Web for information purposes as a follow-up to the first survey. Your answers will not affect your grade. Please provide the following information on both pages:

Student Name ______________ Date ______________ Course ______________

1. Have you used the World Wide Web?

Yes No

If you answer "No" to this question, please stop and turn in your survey, otherwise continue to answer the following questions:

2. How many times have you used it in the last 6 months?

1-2 3-5 6-9 More than 10 but not regularly Regularly

3. What do you use it for?

School work On the job Personal (including entertainment)

4. How comfortable are you using the World Wide Web?

Not at all comfortable	Somewhat comfortable	Medium comfortable	Somewhat more than medium comfortable	Very comfortable

5. Describe in detail how you are using it (especially in this or other classes).

6. Since you have started using the World Wide Web, is your work, school work, or life any different than before you started using it? Please describe why or why not in detail. (Use the back if necessary)

Post course survey additional questions below:

7. If you have been using the World Wide Web in this class or other classes this semester, has your attitude toward it changed? Circle one: Yes No

If yes, please describe how it has changed and why it has; if no, why not.

8. Any other comments you have on using the World Wide Web.

Thank you for your help in completing this survey!

A Project Designed to Engage K-8 Preservice and Inservice Teachers in Classroom Inquiry

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Teachers engaging in educational research is a topic addressed in the National Science Education Standards (1996) and is a prominent issue discussed in the educational literature (Butzow & Gabel, 1986; Elliot, 1991; Eiriksson, 1995; Goswami & Stillman, 1987; Hubbard & Power, 1993; Kyle & Shymansky, 1988). Educators argue that teachers who engage in classroom inquiry will use the information they gain from these endeavors to make careful reflections about their teaching and will experience an increase in confidence and professionalism (Smith, Layng, & Jones, 1996).

In 1984, the National Science Teachers Association (NSTA) established a program for K-12 teachers called "Every Teacher a Researcher" (Gabel, 1986). NSTA surveyed K-12 science teachers to find out their research interests and to start a research network of teachers. Once a sufficient network was developed, an invitation was extended to members of the network to join with colleagues of similar research interests and become partners in a research project.

In the same spirit as the Every Teacher a Researcher program, a project was organized to invite K-8 preservice and inservice teachers to participate in a national study. By participating in this project, teachers would not only gain information about how their students view science, but would also contribute data that would develop a national profile of students' views related to scientists and studying science. Although the initial purpose of this project was to engage teachers in classroom research, it was also an excellent vehicle to find out their views about the value of engaging in educational inquiry.

The remainder of this paper is divided into three main sections. The first section focuses on specific components and the results of the national study. The second part deals with the K-8 teachers' perceptions about participating in the study and examines their views of conducting future research. The third and final section discusses the educational implications of the results of the national study and the K-8 teachers' views regarding their participation in this study.

A National Study Involving K-8 Teachers

An Invitation to Teachers

In the fall of 1996, an article was published in Science & Chidren (S & C) which invited K-8 teachers to participate in a national study (Barman, 1996). In this article, the teachers were provided with an interview protocol developed by Barman and Ostlund (1996) which incorporates Chambers' (1983) Draw-A-Scientist Test (DAST) to examine their perceptions of scientists. In addition, this protocol investigates how students view the way they study science in school and their ideas about the relevance of science to their daily lives.

When using the protocol, the investigator works with each student individually in a personal interview setting. Although each student is asked a set of standard questions and given a standard set of directions, each interview session is informal enough to allow the investigator to gain additional information about the students' drawings and to clarify any of their responses. The responses are audio-taped and later transcribed for further analysis. The set of directions and questions included in this interview protocol are:

- Will you please draw a picture of a scientist doing science? When you are finished, will you please explain your drawing?
- On another piece of paper, will you please draw a picture of yourself doing science in school? When you are finished, will you please explain your drawing?
- Can you think of some ways you use what you learn in science outside of school?

The protocol also provides an opportunity for students to draw scientists from different ethnic backgrounds. Before the students are asked to draw their picture of a scientist, they are offered a set of colored pencils or crayons and told to feel free to color their drawing or any parts of their picture they would like to accentuate.

When developing the protocol, a concern was raised pertaining to asking students to make a "forced choice." If you ask students to draw a scientist, does this force them to make a choice between a male or a female? Or, if you asked students to draw two scientists, would this provide them with the freedom to depict both sexes? To answer this question, two groups of ten fifth grade students were randomly selected. Each group had an equal number of boys and girls. Group A was asked to draw two scientists doing science while group B was asked to draw one scientist doing science. In group A, 7 students drew two male scientists, 2 students drew a male and a female scientist, and 1 student drew 2 female scientists. In group B, 7 students drew a male scientist and 3 students drew a female scientist. Because the drawing of two scientists took each student twice as long to complete as the drawing of one scientist and because there appeared to be no major differences in the results of groups A and B, students were asked to draw only one scientist.

Data Collection

One hundred fifty-four elementary and middle school inservice and preservice teachers from twenty-three states and the District of Columbia participated in the data collection for this project. The S & C article (Barman, 1996) which invited the teacher participation also contained step-by-step directions about how to use the interview protocol developed for this investigation and it explained how to analyze and record the drawing and interview data so that the teachers could report their findings in a uniform format. To analyze each students' drawing of a scientist, the Draw-A-Scientist Checklist (DAST-C) was used (Finson, Beaver, and Crammond, 1995). Each item on the DAST-C resprsents a stereotypic characteristic derived from reviews of literature relating to students' images of scientists. During the analysis of a student's drawing, the more items "checked" on the DAST-C, the more stereotypes appear on the student's drawing. A similiar analysis technique was used for the students' drawings of themselves studying science in school and for their views about the relevance of science to their daily lives (Barman, 1996).

Teachers sent their drawings and analyses to the managing editor of S & C where they were organized and compiled according to specific grade levels (e.g. K-2, 3-5, and 6-8). These groupings provided a useful mechanism for making comparisons between different aged students and they made it possible to examine possible trends that may occur as children move from the primary grades to middle school.

Data were collected by the K-8 teachers for 1504 students. Half (50%) of these students were males and 50% were females. Of the total number of students interviewed, 235 were from grades K-2, 649 from grades 3-5, and 620 were from grades 6-8. The regions of the United States that were represented by these data were the East (7 states and the District of Columbia), the West (2 states), the Southwest (3 states), the Southeast (2 states), and the Midwest (9 states).

Analysis Techniques

The student's drawings of scientists were analyzed using the DAST-C. Each drawing was rated for specific stereotypic images and additional information obtained from the student interviews was compiled and reviewed (Table 1).

Table 1
Students' Images of a Scientist

Common Stereotypes N = 1504	Responses/Grade Level (frequency in %)		
	K-2	3-5	6-8
Scientist Wearing a Lab Coat	29	41	52
Scientist Wearing Eyeglasses	17	28	46
Scientist With Facial Hair	5	9	26
Symbols of Research Displayed (e.g. lab equipment, etc.)	72	94	84
Symbols of Knowledge (e.g. books, clipboards, pens in pockets, etc.)	19	35	37
Technology Represented (e.g. telephone, TV, computers, etc.	18	15	20
Relevant Captions (e.g. formulae, classification, "eureka", etc.)	2	13	19
Male Gender Only	58	73	75
Caucasian(s) Only	69	80	74
Scientist is Middle Aged/Elderly	13	32	38

Scientist has Mythic Stereotypes (Frankenstein creatures, etc.)	8	11	13
Indications of Secrecy (Warnings of "private," etc.)	1	3	11
Scientist is Working in Lab	86	88	71
Indications of Danger	10	18	22

The drawings of students doing science were grouped into two main categories: (1) those who pictured themselves as passive learners, such as reading about science or taking notes at a desk, and (2) those who saw themselves as active learners (Table 2). Additional information obtained from interviews was also compiled and analyzed.

Table 2
Students' Perceptions of "Doing Science" in School

Activity Represented N = 1504	Responses/Grade Level (frequency in %) K-2	3-5	6-8
Seated at Desk Reading a Book	9	6	5
Seated as Desk Taking Notes	6	10	7
Participating in Activity	85	84	88

Data related to students' perceptions about using science outside of school were gathered from the interview transcripts. These data were categorized into four main groups: (1) students who think they can use science outside of school, (2) students who only see themselves using science by repeating activities from school, (3) students who could generalize the use of science knowledge and processes to everyday situations, and (4) students who did not see any use of science outside of school (Table 3).

Table 3
Student Perceptions of Using Science

Category N = 1504	Responses/Grade Level (in %) K-2	 3-5	 6-8
Students Who Don't See a Use for Science Outside of School	41	16	13
Students Who Think They Can Use Science Outside of School	59	84	87
Students Who See Themselves Only Repeating School Assignments	27	32	28
Students That Could Generalize Use of Skills and Knowledge of Science to Everyday Situations (e.g solving problems, making obserations, predicting weather and care for plants and pets)	32	52	59

Results

Students' Perceptions of Scientists

As shown in table 1, the students in this study had similiar images of scientists to those revealed in previous studies (Chambers 1983; Fort & Varney 1989; Finson, Beaver, & Crammond 1995; Huber & Burton 1995). Most of the scientists were depicted as white males. The primary students represented females in their drawings more often (42%) than the students in grades 3-5 (27%) and grades 6-8 (25%). In the case of ethnic background, 69% of the K-2 students, 80% of the 3-5 students, and 74% of the 6-8 students depicted their scientist as a Caucasian.

The students in each grade category drew scientists with several types of stereotypic features. However, there is an tendency for students in grades 3-5 and 6-8 to include more of these features in their drawings. For example, a greater percentage of the older students included things like lab coats, eyeglasses, and facial hair in their drawings. Most students in grades K-2 and 3-5 (86% and 88% respectively) depicted their scientist working indoors, whereas 29% of the middle grade students drew their scientist in some other type of environment. In addition, the majority of students in all three groups pictured their scientist working in surroundings that were not secretive or dangerous.

The mythical stereotype, such as Frankenstein creatures or Mad Scientists, was not a predominant feature represented in most of the drawings from all three groups (8%, 11%, and 13% respectively). This indicates that the majority of the students tend to have images of scientists as regular people and that the view of scientist as a "crazed person" was a minority view among the students interviewed in this project. In addition, all three groups of students tended to see scientists as young adults rather than middle-aged or elderly.

Students' Perceptions of School Science

According to the students interviewed in this project, it appears the emphasis placed on activity-oriented science over the last few decades has made a difference in how students are studying science. In each category, the majority of students pictured themselves studying science by doing some type of activity (85%, 84%, 88% respectively) instead of taking notes or reading a book (Table 2).

Students' Perceptions About Using Science Outside of School

As shown in table 3, more students see a use for science outside of school than those who do not. As these students become older, they have an increasing tendency to recognize this relationship. In addition, more than half of the K-2 students (32%) who fall into this category are able to generalize the use of science knowledge and skills to everyday situations other than just repeating the activities they do in school. This same trend is shown in the data for students in grades 3-5 (52%) and 6-8 (59%).

K-8 Teachers' Perceptions About Participating in the National Study

When the teachers submitted their data and analyses to the managing editor or S & C, they were asked to also include their names and mailing addresses. Of the 154 teachers who submitted data, 50 current addresses for preservice teachers and 77 addresses for inservice teachers were received. A survey instrument was developed and sent to those 127 teachers. Responses were obtained from 31 (62%) of the preservice teachers and 60 (78%) of the inservice teachers surveyed. In addition to specific demographic information, the survey instrument asked the following questions:

- Why did you participate in the S & C study?
- How did you learn about the study?
- Do you think this study had or will have an impact on your teaching?
- Did you share your data with any of your peers? If so, what were their reactions to this information?
- In the future, do you think you will conduct your own classroom research? Why or why not?

Survey Results

Demographic Data

As indicated in table 4, the majority of inservice (83%) and preservice teachers (84%) that participated in the study were females. This is not surprising because the focus group for this study was K-8 teachers. Of the inservice teachers who responded to the survey, the greatest number were those who taught for 1-5 years (34%) or 10-15 years (23%). The inservice respondents were primarily undergraduate seniors (65%). There was a fairly even distribution of inservice teachers from the five different school district categories listed on the survey. In relation to teaching assignment, it appears responses were obtained from fewer teachers from grades K-2 (14%) than teachers from grades 3-5 (32%) and grades 6-8 (24%). However, these data may be a bit deceiving because 22% of the respondents listed multiple grade levels for their teaching assignment and there was no way of determining whether these teachers taught one or more primary grades or a combination of upper level grades.

Table 4
Demographic Information About Respondents

Inservice Teachers: N = 60

Males - 17%
Females - 83%

Number of Years Teaching:
1-5 yrs. - 35%
6-10 yrs. - 13%
10-15 yrs. - 23%
15-20 yrs. - 14%
20+ yrs. - 15%

Teaching Assignment:
K - 3%
1 - 3%
2 - 8%
3 - 5%
4 - 12%
5 - 15%
6 - 17%
7 - 5%
8 - 2%
Multiple Grades - 22%
Science Coordinator - 8%

Setting of School District in Which Respondent Taught:

Rural District - 17%
Small City (1-10,000 people) - 15%
Medium City (10-50,000 people) - 28%
Large City (50-100,000+) - 22%
Inner City School - 18%

Preservice Teachers: N = 31

Males - 16%
Females - 84%

Year in School:
Freshman - 0
Sophomore - 0
Junior - 0
Senior - 65%
Graduate Student - 35%

Teachers' Answers to Survey Questions

When asked why they participated in the study, the majority of inservice teachers indicated that they were interested in learning more about the way their students perceived scientists. Several inservice teachers also indicated that by contributing to this project, they would be helping construct a national profile of how elementary and middle school students view scientists and studying science. These teachers said they were anxious to see how their students compared to other students in the United States. Most of the preservice teachers responded to this question by saying participation in this study was either a requirement of a science education class or their instructor strongly encouraged them to take part in this project.

The majority of inservice teachers (65%) indicated that they learned about this study by reading S & C (Table 5). A smaller percentage (10%) heard about of the study through a college class and 25% indicated that they had been told of the study from a professional colleague. On the other hand, most of the preservice teachers (90%) said they learned about the study from a college class and only 10% indicated that they were informed of this study by reading S & C.

Table 5
Inservice & Preservice Teachers' Responses

Survey Questions	Responses		
	Reading S & C	College Class	Other Source
How did you learn about the S & C Study?			
Inservice Teachers	65%	10%	25%
Preservice Teachers	10%	90%	0
	Yes	No	Unsure
Do you think participating in this study has had an impact on your teaching or will impact you as a future teacher?			
Inservice Teachers	75%	25%	0
Preservice Teachers	77%	10%	13%
Do you plan to conduct further research?			
Inservice Teachers	70%	13%	17%
Preservice Teachers	71%	13%	16%
Did you share your results with peers?			
Inservice Teachers	85%	15%	-
Preservice Teachers	74%	26%	-

Inservice Teachers N = 60
Preservice Teachers N = 31

A large percentage of the inservice teachers (75%) felt participating in this study did have an impact on their teaching and 77% of the preservice teachers felt their participation would impact them as a future teacher. Several inservice teachers said the results of this study have caused them to pause and self-evaluate their teaching practices. These teachers indicated that they plan to invite scientists (especially women) to their class to talk about their work. Other teachers stated that they were planning to intergrate more science in language arts. For example, in their language arts classes they plan to have their students read a biography of a famous scientist who is a woman or from some other minority group. In addition, several inservice teachers said that they were surprised by the results of this study. They would have never predicted that their students would have included so many stereotypical features in their drawings of scientists.

Several preservice teachers stated they were glad they participated in the study because the strategies they used in the interview protocol could also be employed in other areas to identify prior knowledge of their students. They also indicated that they now know that they will have to make a deliberate attempt to show their students how science is used in their everyday lives.

When asked if they planned to conduct further classroom research, 70% of the inservice and 71% of the preservice teachers said yes. Several of the inservice teachers indicated that they are interested in doing more classroom research but felt in order to do so they needed the type of guidance provided in the S & C article (Barman, 1996). Others stated that they have already started to think of additional ways they can collect information about their students and their teaching. A few of the preservice teachers stated that they believed research would be an integral part of their teaching. They felt that by continuing to do classroom research they would validate their teaching practices.

A large number of the inservice (85%) and the preservice (74%) teachers indicated that they shared the results of their research with peers. Several inservice teachers reported that the results were discussed at faculty meetings and that their peers were interested in the information. One middle school teacher stated that she shared the information from this study with some high school teachers. The high school teachers, however, were not very interested in the information and didn't see any relevance in asking high school students about their ideas of scientists and studying science.

Several preservice teachers stated that they discussed the results of their research in their science education classes. In these classes, they tried to identify ways they could help students examine their ideas about scientists and science. Interestingly, one preservice teacher indicated that when she shared her results with peers, some of them said if they had been asked to draw a scientist they would have included some the same stereotypical features respresented by most of her elementary school students.

Educational Implications of Project

Implications for Science Teaching

The data from this study show some positive trends in K-8 student views about scientists and studying science. The majority of the students depicted scientists as realistic people and not mythical creatures like they are generally pictured in cartoons. They also had a tendency to exclude indications of secrecy and danger in their pictures, which may indicate they see scientists as engaging in projects that are beneficial and not harmful.

In relation to students' perceptions about studying science in school and using science outside of school, the data also provides a reason for optimism. Many students saw themselves doing activity-oriented science in school and, even at an early age, they recognize a use outside of school for the knowledge and skills they learn in science.

An obvious concern raised by the data is related to the students' perceptions about gender and ethnic origin. Previous studies have shown students view scientists as primarily white males (Krause 1977; Chambers 1983; Schibeci & Sorenson 1983; Fort & Varney 1989; Huber & Burton 1995) and the results from this study indicate this trend has not changed. It appears a greater emphasis needs to be placed on highlighting women and minorities in school science, starting with the primary grades and continuing through middle school.

Although most of the students did not represent their scientist as a mythical or "mad" person, several did include other stereotypes, such as eyeglasses, facial hair, and lab coats. In addition, many students also drew their scientist indoors in a laboratory. This suggests a need in the elementary and middle school science curriculum to create opportunities for students to see scientists in a variety of settings and roles. For example, science units could include videotapes featuring expeditions and investigations which present scientists outside of the laboratory in a variety of surroundings. Videotapes of scientists who are from different ethnic backgrounds and female scientists could also help students broaden their views about the type of indviduals who can become scientists. Resources, like Dragonfly (Project Dragonfly 1996), could help teachers present students with an inclusive image of science and scientists. Dragonfly is a publication in which students interview scientists. Through these interviews, the readers not only learn about their scientific work but also are given insight into the scientists' personal interests. Science classes could also incorporate live communications with scientists. Internet connections or live telecasts can involve classes in discussions with scientists from around the world.

Although many students did see a use for science outside of school, several students did not fall into this category. In addition, some who did see a use for science outside of school could only see their application as repeating an activity they had done in school. To help students make better connections between school science and what they do outside of school, it is important to engage students in discussions about what they did in class and how it could apply to their everyday occurences. For example, when the students are taking specific measurements or doing some type of classification exercise, it would be helpful to demonstrate how these same skills are used at home by the students and their families. Or, if the students are studying types of fungi, such as yeast and mushrooms, activities like baking bread and mushroom tasting may help the students see a connection between these organisms and their everyday experiences.

Implications for Teacher Education

This project has also revealed some important information related to K-8 teachers and their perceptions about the value of engaging in classroom inquiry. First, the fact that over half of the inservice teachers learned about the study by reading S & C, demonstrates the important role educational journals play in providing a network for educators to share ideas. An important lesson can also be learned from the fact that 90% of the preservice teachers were informed about the study via a college class. College instructors involved in methods classes can provide an important service for students by introducing them to these journals and by directing their attention to special projects like the national study. By so doing, their students will hopefully see the professional benefit of reading these journals on a regular basis.

Second, most of the inservice and preservice teachers surveyed felt that participating in the national study either did have or would have a positive impact on their teaching. They also viewed engaging in research as beneficial to them and their students in improving instruction. Only 13% of both the inservice and preservice teachers said they did not plan to engage in further research. The rest of the teachers surveyed either said they planned to do additional research (70% and 71%) or they were not sure if they would conduct further research (17% and 16%). Several of the inservice teachers felt that for them to engage in more classroom research they needed the type of guidance provided in S & C (Barman, 1996). For these teachers, it appears it was important for them to have a set procedure to follow in gathering and analyzing the data. This demonstrates another important role science educators can play in the professional development of teachers. Through university courses and inservice workshops, science educators can provide the support, guidance, and information teachers need to engage in classroom inquiry.

Finally, according to one preservice teacher, some of her peers stated that their drawings would have included the same stereotypic features that appeared in the K-8 students' pictures. As science educators, it is critical to be aware of the perceptions our preservice teachers have about scientists. Their perceptions could very likely perpetuate further misconceptions about science and scientists among their students. Therefore, excercises, like Draw-A-Scientist, followed by a classroom discussion about the drawings is an appropriate activity for science methods classes. In addition, including examples of activities that allow students to observe male and female scientists in multiple roles as well as from different ethnic backgrounds can provide opportunities that will help preservice teachers identify ways to expose their own students to similiar experiences and, hopefully, help their students develop realistic ideas of scientists and the scientific enterprise.

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STIMULATING PROFESSIONAL GROWTH OF TEACHERS THROUGH ACTION RESEARCH

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Introduction

This paper describes how teachers in an Eisenhower professional development project were encouraged to engage in systematic reflection and inquiry in order to make changes in their classroom practices. Ensuring the implementation of innovative practices in the classroom has always been a problem for teacher educators. This Eisenhower project was designed to address the issue of how current science education reform efforts can be translated from good ideas and suggestions in various reform documents into actual practices implemented in the classroom by teachers. The purpose of the project was threefold. The first was to provide opportunities for teachers to synthesize the information in the reform documents so as to enable them to develop a vision for the teaching and learning standards contained in them. The second was to provide opportunities for teachers to acquire the knowledge and skills that will enable them to implement the standards described in the reform documents in their classrooms. The third was to provide opportunities for teachers to develop the knowledge and skills needed to become reflective practitioners and change agents in their school communities. The target group in the project was grades K-8 teachers of science in rural schools.

Background

In the past fifty years, educational reform has moved from a public control ideology to decentralization, teacher autonomy, and professionalization of teaching (Hollinsworth & Sockett, 1994). Within the control paradigm, university researchers used the classroom for "scientific" research which generated theories, techniques, and strategies for effective teaching and learning. Curriculum materials were also developed based on research findings. These techniques and materials were passed on to teachers in professional development workshops or through courses taught in masters programs. Knowledge about effective teaching and learning was generated from above and handed down to teachers. Teachers then became very dependent on teacher educators and were forever searching for little tricks and fads that would work wonders in their classrooms. On the other hand, many teachers went through these workshops, returned to their classrooms and continued with their old practices, because their beliefs about effective teaching and learning did not change. They believed some of the techniques and strategies learned or the new curriculum materials received were not relevant to or appropriate for their local setting. Thus, the control paradigm feeds a bureaucratic mentality in which the researcher generates knowledge that is to be transmitted to the practitioners. A professional development model based on such a paradigm was never very effective in producing teacher change.

Teacher autonomy and professionalization of teaching are closely linked. Professionals contribute to the knowledge base of the profession. They also make informed decisions based on information generated from research. As opposed to the control paradigm in which knowledge is generated and channeled from above, the autonomy and professionalism movement encourages teachers to become researchers (Stenhouse, 1975; Posch, 1992). Teachers can engage in classroom or school research and contribute to the generation of knowledge through various forms of collaborative partnership with university researchers (Connelly & Ben-Peretz, 1980; Schön, 1983; Sagor, 1992). A teacher should not be a technician constantly striving to learn new skills and techniques, but rather a reflective practitioner that engages in inquiry and reflection in an effort to improve professional practices. Professionalism demands continued professional growth and development.

Teacher collaboration is an important aspect of professional development. Holly (1991) describes action research as the missing link in teacher collaboration discussions. Action research has emerged as an ideal vehicle for inquiry and reflection by teachers and an excellent medium for collaboration among teachers and between researchers and practitioners. Traditional research was seen by teachers as something done by external experts to teachers, but action research is done by teachers in collaboration with colleagues (Sagor, 1992).

Action research helps teachers to think critically about the changes they make in their classrooms and schools (Willis, 1995). Through action research, teachers have the opportunity to take ownership of the change process that occurs during educational reform. As Fullan (1985) pointed out, educational change is dependent on change in individual teachers in individual classrooms. Thus, teachers involved in action research as part of a professional development project are more likely to become change agents than teachers involved in traditional professional development programs that emphasizes the transmission of knowledge and skills from teacher educators to practitioners.

One of the four assumptions in the *National Science Education Standards*, about the nature of professional development activities for teachers of science, is that it is a continuous, lifelong process. Another assumption is that the professional development opportunities are clearly connected to teachers' work in the context of the school. Encouraging teachers to engage in action research not only makes it possible for both of the assumptions above to be met but also specifically addresses Professional Development Standard C. This standard includes the statement that professional development activities should provide opportunities for teachers to learn and use the skills of research to generate new knowledge about the teaching and learning of science. Teachers involved in a professional development project of that nature are given the opportunity to become producers of knowledge and facilitators of change.

Overview of the Project

Participants in the project attended five weekend workshops during the academic year. A total of sixty hours of instruction was provided through the workshops. Topics covered in the workshops included action research, inquiry in science teaching, constructivism, the learning cycle, integration of the sciences and integration of science with other subjects, problem solving and critical thinking, diversity issues in science teaching and learning, and alternative and authentic assessment including concept mapping. Participants were engaged in a variety of activities in the hope of empowering them to make decisions about what they teach, when they teach it, how they teach it, and why they teach it. At each workshop the participants developed sample lessons or unit in which they incorporated the knowledge, skills and techniques learned in the workshop. They later taught and self evaluated the lessons or unit and gave a report at the following workshop.

All of the participating teachers in the professional development project were required to do an action research project on a topic of their choice during the year. As Willis (1995) pointed out, action research can be embarked on at three levels.

> An individual teacher may examine something in his or her own classroom. A group of teachers may collaborate in researching a shared interest. Or an entire school might research an issue together. (p. 4)

Participants designed research projects at the first two levels. Some teachers worked individually on a specific problem they wanted to address in their classroom. Others from the same school or district collaborated by either working on different aspects of the same problem or embarking in a study that spanned several grade levels.

The participants were given basic instruction about action research and the different ways in which it could be done. The teachers were then asked to think of possible topics and to discuss the topic with one of the project instructors before embarking on the project. Thus, they received guidance in finding and framing their research problems and questions. They were then required to prepare a plan of how the study will be conducted, what data will be collected and how the information gathered will be analyzed. Throughout the project each instructor served as a critical friend to different groups of action researchers.

The project staff made school visits and observed science lessons taught by the participants. After each classroom observation, time was spent reviewing the lesson with the teacher as well as discussing any problems he or she may be having in implementing any of the new ideas presented in the workshops. The school visits also provided an opportunity for discussing the progress of the action research project the teacher was working on.

Results

At the beginning of the project, most of the participants were very apprehensive about the idea of them working on a research project. Some of them documented in their journals the struggles they went through during that phase of the project. They did not know what questions to ask or how to identify a researchable problem. After receiving the necessary instruction, the participants used their reflective journal writing assignment to reflect on their classroom practices for a few weeks. Through continued guidance and discussions with the instructors, all of the participants were eventually able to formulate a research question.

The topics selected varied from case studies of individual students to studies involving large numbers of students. Some studies centered around curricular materials that were being used and others focused on the use of a teaching strategy or techniques introduced at the workshops. The participants selected questions they had some perceived ideas about or questions that addressed a problem or dilemma they were faced with in their classrooms.

One of the participants did a case study in which she tried to find out what she could do to help a learning disabled student learn science. Her school district had adopted an inclusion policy, and she decided to do the study because she felt she was totally unsuccessful in teaching science to the special needs students in her class. She tried several approaches and finally found a strategy that worked reasonably well in including that student in the science activities done in the classroom. The student did not only learn science, but her self-esteem improved and she became more motivated to learn. She developed a special bond with the students in her group and became much more a part of the class. The teacher reported that she learned a lot as she analyzed several pedagogical practices during the project. She commented that as she focused on developing a meaningful learning experience for the student she ended up participating in a unique learning experience she will never forget. The change she experienced was just as dramatic as the change she observed in the student.

A couple of teachers from a small rural school district were discouraged about the lack of interest of their third and fifth grade students in science. They decided to try out a 'science buddy' technique. Fifth grade students planned and prepared science lessons that were presented to the third grade students. Later fifth and third grade students worked in groups on small science projects. Thus, the science buddies were created. Teachers were amazed at the results that they observed. Not only did interest in science improve but the behavior of students in class, in the lunch room, and the playground improved as well. Science buddies became friends and older kids were helping younger kids instead of pushing them around as they were prone to doing before. In addition, fourth and sixth grade students were asking their teachers if they could have science buddies too.

A group of teachers from a school that had just adopted two new science programs for upper and lower elementary grades decided to take a critical look at the programs. They developed criteria for evaluating the programs based on national and state science education standards. They collected different forms of data which served as strong evidence for convincing school administrators about the effectiveness of the programs.

All of the projects yielded interesting and valuable results. Some of the teachers were surprised that, in several cases, their results supported research findings in the literature. Results from other projects provided valuable information and insights on specific issues that were addressed by the individual teacher, a group of teachers, or the school as a whole. In a few cases, they had solid evidence to support some hunches they already had. Some of the studies led to follow-up questions that are currently being addressed and in one case the participants have embarked on a school wide project involving external funding. In every case the participants reported that engaging in action research was a very valuable learning experience for them.

The Eisenhower project was evaluated in several ways. Several of the teachers reported in the project evaluation that the action research experience was a very effective learning process which helped them to reflect on and improve their practices. Several of them also stated that they intend to extend their study or continue with follow-up questions or generate new questions to investigate. Some of the teachers have succeeded in initiating large scale action research projects involving all of the teachers in their school.

Conclusion

As Holly (1991) puts it, action research constitutes participative learning for teachers. It is conducted by teachers to inform their own practices. As was the case in this project, action research enables teachers to focus on real classroom or school problems and to generate their own solutions. The learning experience was unique in each case because teachers studied issues that were of particular interest to them. They generated solutions, acted upon those solutions and evaluated the effects. Thus, the changes that resulted from these studies came from the teachers themselves. Action research provided an opportunity for teachers to collaborate with each other to take a critical look at the teaching and learning situations in their schools. Action research was a major professional development activity in this project. It served as a very effective vehicle for pedagogical analysis, reflection, and change.

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USING THE SCIENCE MISCONCEPTIONS RESEARCH TO ADDRESS SCIENCE TEACHING MISCONCEPTIONS

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One of the most frustrating experiences for me as a science educator has been trying to persuade preservice teachers to use inductive, problem-solving science teaching strategies. I teach science methods to 90-120 elementary and middle school preservice teachers each semester, and to 15-25 secondary biology, chemistry, earth science, and physics preservice teachers each spring. The majority of the elementary and middle school preservice teachers start the semester disliking science. Only about 10% are science majors. Their first reflective writing assignment, a science autobiography (Koch, 1990), consistently reveals that most of their K-12 science instruction has been traditional direct instruction, which many characterize as boring and generally ineffective.

Unlike the elementary and middle school preservice teachers, the secondary science education majors LIKED traditional school science. Their science autobiographies reveal that they learned from lectures; they enjoyed cookbook labs; they did well on multiple choice exams on science vocabulary. Despite these difference in attitudes towards science as traditionally taught, both elementary and secondary preservice teachers are generally enthusiastic about and eager to implement the more effective "backwards" (inductive) learning cycle lessons that are modeled in class. The paradox is that too many individuals from both groups fall back on "explain-first-then-confirm-with-a-cool-demo-or-activity" (direct instruction) when planning and teaching their own science lessons during the last half of the semester.

Science educators are all familiar with the adage that "teacher teach as they were taught." After 2,340 days of traditional K-12 science instruction, it certainly is not surprising that preservice teachers are not readily able to master these new teaching strategies. However, I have begun to take this difficult challenge personally. If the goals of the National Science Education Standards (National Research Council, 1996) are going to be widely implemented, I need to start doing a better job with these preservice teachers. And I have to be able to do it in one methods course.

The purpose of the study reported here was threefold: (1) describe how the lesson plans of preservice teachers differed from the inductive learning cycle planning model, (2) relate these differences to persistent naive conceptions about effective science pedagogy held by these preservice teachers, and (3) suggest strategies, based on the science misconceptions literature, that methods instructors can use to encourage the understanding and use of inductive learning cycle instruction by beginning teachers.

Analysis of Errors in Planning Inductive Instruction

Both the elementary/middle school methods course and the secondary methods course at SUNY Oswego are structured as a semester-long learning cycle as described by Rubba (1992), Barman and Shedd (1992), and Weber (1994). In both courses, the semester begins with opportunities for students to explore model inductive learning cycle lesson sequences focusing on the nature of science and how children learn science. In the second phase of the course, the theoretical basis for constructivist, inductive science teaching strategies is derived from the exploration activities and explained. The last half of the course is devoted to giving students opportunities to apply/elaborate learning cycle strategies as they design week-long "mini-units" on a science topic and teach one or more lessons in their practicum classrooms.

Students are expected to plan an inductive learning cycle "mini-unit" which begins with a hands-on, problem-solving activity; this is followed by a more teacher- or text-centered explanation and ends with other concrete elaboration activities connecting across the curriculum (Biological Sciences Curriculum Study, 1989). An assessment plan which evaluates content, attitudes, and skill objectives using a continuous, diverse embedded approach is also required (Hein, 1994). The rubric for the elementary and middle school units lists the specific evaluation criteria (Table 1). The secondary rubric is similar, but more extensive since it accommodates laboratory experiences and the more frequent appropriate use of direct instruction with high school students.

As units are graded each semester, extensive comments and suggestions are made throughout the materials submitted by the students. The scoring rubrics are annotated to help students understand the specific strengths and weaknesses of their plans before the lesson(s) are taught. In this study, copies of the scoring rubrics for 459 elementary and middle school mini-units over seven semesters were analyzed to determine the most frequent areas of poor fit between the requirements of the inductive learning cycle model and the actual units created by 593 students (328 individuals, 128 pairs and 3 trios). An "error" was scored in a particular category if the item was defective or missing entirely. Thus, the results emphasize the pattern of mistakes of both commission or omission, rather than the pattern of partial or complete success.

Table 1
Scoring Rubric for Elementary and Middle School Learning Cycle Units

MINI-UNIT INDIVIDUAL SCORE (80 POINTS)			
Engagement/Exploration			
Activity reveals children's initial ideas (link)	0	2	4
Activity is likely to be interesting to kids (hook)	0	2	4
Activity is hands-on, concrete, problem-solving	0	4	8
Main idea is clearly understandable from activity	0	2	4
Activity is developmentally appropriate	0	2	4
Activity includes emphasis on skills and/or attitudes	0	2	4
Explanation			
Children discuss results, focus question (activity closure)	0	2	4
Materials clearly & concisely explain the main idea	0	4	6
Materials are developmentally appropriate	0	4	6
Elaboration/Reinforcement/Curriculum Connections			
Includes hands-on, concrete, problem-solving activity	0	4	6
Materials are directly related to main idea	0	2	4
Materials are developmentally appropriate	0	2	4
Materials appeal to diverse learning styles	0	2	4
Includes related math activity, children's tradebook	0	2	4
Evaluation			
Directly related to main content/attitude/skill ideas	0	2	4
Uses diverse strategies & learning modalities	0	2	4
General			
Syllabus references are appropriate	0	0	2
Generalization clear, cover sheet complete	0	0	2
Variety resources used, learning cycle labels correct	0	0	2

Table 2 shows that preservice teachers had the most difficulty with those portions of the exploration portion of the mini-unit which were not typically part of a direct instruction lesson. For example, their lessons often failed to adequately elicit student ideas before the initial activity was conducted. In contrast, preservice teachers were generally attentive to the need to plan an motivating, hands-on, concrete, developmentally-appropriate activity at the beginning of the sequence and as elaboration after the explanation. However, some preservice teachers chose "cute" activities instead of activities related to the main idea of the unit, and in nearly one third of the units, these same activities did not provide a genuine problem-solving opportunity for children. In fact, about 10-15% of the students every semester simply ignored the idea of providing an initial exploratory experience of any description; these traditional direct instruction units began with a teacher-centered explanation instead.

Table 2
Inductive Planning Errors Made By Elementary and Middle School Preservice Teachers

		Percent of Preservice Teachers Making Error								
		Total		By Semester						
	Planning Criteria	M	SD	F93	S94	F94	S96	F96	S97	F97
Exploration	Initial Student Concepts	36	10	31	47	19	33	44	43	36
	Motivating Activity	16	6	14	14	19	12	21	26	8
	Problem-Solving Activity	29	8	20	39	18	38	28	30	33
	Hands On Activity	15	5	13	10	12	10	18	24	18
	Concrete Activity	12	4	11	10	8	12	15	17	8
	Concept Clarity	26	7	21	33	14	24	29	28	32
	Developmental Level	10	7	2	11	5	10	16	22	7
Explanation	Activity Discussion	38	10	42	54	28	47	37	35	25
	Concept Clarity	24	12	23	49	15	12	26	28	17
	Development Level	26	6	26	36	18	28	23	26	24
Elaboration	Problem-Solving Activity	23	9	10	20	14	29	25	35	31
	Hands On Activity	6	3	7	3	5	9	9	9	3
	Concrete Activity	5	3	6	2	7	9	9	0	3
	Concept Clarity	8	5	14	13	5	2	9	4	11
	Developmental Level	9	4	7	12	5	12	14	7	5
Overall	Traditional Direct Instruction	12	3	13	11	7	12	13	17	8
	Proficient Inductive Instruction	31	9	39	20	45	29	26	37	25
	n	593		107	92	85	58	117	46	88

In the explanation phase of the learning cycle, student often ignored the importance of beginning with children's own explanations of the science concept underlying the activity. Other kinds of difficulties preservice teachers had in providing teacher or text-centered explanation to enhance student explanations seem to result from ignorance or overzealousness, rather than a misunderstanding of the teaching model. Preservice teachers routinely overestimated the cognitive development and reading abilities of children at particular grade levels. The most common mistakes were the use of above-grade-level text selections, often with the developmentally unrealistic notation that the "teacher will read and explain the text to the students."

Common Misconceptions Inherent in Inductive Planning Errors

I have begun to think about the problem of preservice teacher preference for direct instruction as a "pedagogical misconception." Like science content misconceptions, my students' pedagogical preference for direct instruction is implicit, based on everyday experience, robust, and resistant to change. Based on this analysis of my student's culminating units and the work of others (Appleton & Asoko, 1996; Gee, Boberg, & Gabel, 1996; Gee & Gabel, 1996; Hampton, Odom &Settlage, 1995), Table 3 juxtaposes the apparent underlying naive conceptions – myths about science teaching – with the related inductive learning cycle planning "errors" from Table 2.

Table 3
Relationship between Inductive Planning Errors and Naive Conceptions of Science Teaching

Naive Conceptions about Teaching Science	Related Inductive Planning Errors	
Teachers need to provide background information in order for students to understand the science concept of an activity. ("DIRECT INSTRUCTION IS MOST EFFECTIVE" MYTH)	Traditional Direct Instruction Problem-Solving (Explore)	12% 29%
Students with mistaken ideas about a science concept will readily change their ideas if they do hands-on activities OR if the teacher carefully explains the science concept. ("IDEAS LEARNED OUTSIDE THE CLASSROOM ARE NOT IMPORTANT" & "DIRECT INSTRUCTION IS MOST EFFECTIVE" MYTHS)	Student Initial Ideas Traditional Direct Instruction	36% 12%
The most important factor in promoting understanding of a science concept is how much fun the activity is. ("HANDS-ON IS ENOUGH" MYTH)	Problem-Solving Motivating Activity Hands-On Activity Concrete Activity	23-29% 16% 5-15% 6-12%
Science activities need to be teacher-centered in order to keep students under control and on task. ("NOISE AND MESS ARE INCOMPATIBLE WITH LEARNING" MYTH)	Traditional Direct Instruction	12%
To promote student understanding of a science concept, teachers should plan hands-on activities instead of reading a textbook. ("TEXTBOOKS ARE BAD" MYTH)	Concept Clarity (Explain)	24%
Students can understand text/concepts suitable for older students as long as the teacher reads or carefully explains it to them. ("CHILDREN UNDERSTAND COMPLEX IDEAS SPOKEN SLOWLY" MYTH)	Concept Clarity(Explain) Developmental Level (Explain)	24% 26%
Teachers cannot do hands-on, problem-solving science activities because the state/school district/ principal/ next year's teacher/SATs expect students to cover all the textbook topics. ("MEMORIZING VOCABULARY IS UNDERSTANDING" & "I CAN'T HELP IT" MYTHS)	Traditional Direct Instruction	12%

Strategies Which Support Conceptual Change About Pedagogy

It seems likely that conceptual change about pedagogy needs the same conditions as conceptual change about science concepts: (1) students must be dissatisfied with their existing ideas and (2) the new idea must be plausible, attractive, and more useful than the old concept (Posner, Strike, Hewson & Gertzog, 1982).

Since ordinary instructional approaches are not effective in altering science content misconceptions, researchers have investigated a variety of alternative strategies (Pfundt & Duit, 1987, 1991). A meta-analysis of the reading education and science education research (Guzzetti, Snyder, Glass, & Gamas, 1993) identified four effective interventions for science content misconceptions: (1) discrepant events, (2) bridging analogies, (3) refutational text, and (4) Learning Cycle instructional sequencing. It is these four strategies that I have consciously begun to use to persuade preservice teachers to substitute an inductive, constructivist pedagogy for the less effective direct instructional strategies with which they are most comfortable.

Discrepant (Pedagogical) Events

I have both my elementary and secondary students write a "Science Autobiography" (Koch, 1990) which helps them identify the experiences that influence their initial negative or positive attitudes toward science and science teaching. The discrepancy for the elementary students involves recognizing that while they might have hated traditional high school science, they are actually enjoying doing the model learning cycle lessons in their methods class. With the secondary science majors (who liked traditional high school science), I do a class activity which involves comparing their own biographies with a representative selection from my elementary methods students. This discrepancy begins a serious discussion on effective and ineffective science pedagogy which we revisit all semester.

Refutational Text (About Pedagogy)

Guzzetti and her colleagues (1993) point out that simply having students read a scientific explanation does not modify students' misconceptions about a science topic. Only refutational text – which presents the scientific explanation and explicitly refutes the common misconceptions – was effective in altering student science content misconceptions. It seems likely that the same principle applies to preservice teachers as they read descriptions of pedagogical models of teaching in a typical science methods textbook. Students do not really attend to the distinctive differences between direct instruction and inductive learning cycle planning frameworks because the text does not directly address their tendency to confuse the two strategies. I have not rewritten the textbook, but I do provide a written advanced organizer which points out the problem before they read. After the reading assignment, we explicitly discuss the possible confusion as we review the material in preparation for using both models in the next activity.

Bridging Analogies (for Pedagogy)

The use of bridging analogies – linking a situation in which a scientific concept is correctly understood to a new situation likely to be misconstrued – was another strategy identified as effective in changing science content misconceptions (Guzzetti, Snyder, Glass, & Gamas, 1993). After modeling an inductive science lesson, I have students in small groups outline the instructional sequence. A consistent minority will reconstruct the lesson as direct instruction, even though they experienced it as an inductive "backwards" learning cycle sequence. We explore this discrepancy as we achieve consensus on what really happened. Then I have them deliberately rewrite the lesson as a direct instruction sequence, a pattern which they understand very well, using only the activities in the original lesson. In a side-by-side comparison, I try to help these students build a mental bridge between the direct instruction they understand, back to the inductive, problem-solving approach that I want them to adopt. Being clear about how the two strategies are related is critical before students attempt to create their own instructional units later in the semester.

Learning Cycle Strategies (for Teaching Pedagogy)

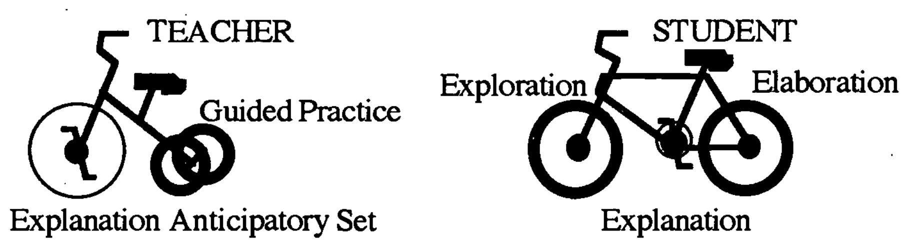
Finally, Guzzetti and her colleagues (1993) concluded that learning cycle and related conceptual change instructional sequences were effective in altering student science content misconceptions. I think the reason is that these instructional models tend to incorporate discrepant events, refutational explanation, and bridging analogies in a sequence that (1) causes students to question their old ideas and (2) presents new ideas as plausible, attractive, and useful (Posner et al., 1982). The instructional sequence I described above for changing student pedagogical notions – science autobiography comparison and model inductive lessons as discrepant events, refutational text/discussion, and the inductive/direct lesson writing bridging analogy activity – also fall into the inductive learning cycle pattern of engagement/exploration, explanation/invention, and elaboration/application.

A Metaphor for Preservice Teachers Naive Conceptions about Effective Science Pedagogy

Learning to teach is sometimes compared to learning to ride a bike. However, this simple comparison fails to describe the complexity of what our preservice students need to do in order to learn to teach science from a constructivist perspective.

Preservice teachers have spent many years watching their own science teachers ride a direct teaching tricycle (Figure 1). In fact, many have already mentally purchased their own tricycles before they even enter a science methods class, and they are expecting to be taught how to ride it. However, the direct teaching tricycle depends mainly on abstract teacher-directed explanation, supported by an anticipatory set to motivate students and guided practice to reinforce student understanding of the new ideas presented by the teacher.

Figure 1
The Direct Teaching Tricycle and the Inductive Learning Bicycle



When we ask preservice teachers to implement inductive teaching strategies, we require them to deconstruct their mental direct teaching tricycles and rearrange the parts into an inductive learning bicycle – expand the tiny anticipatory set wheel into a full-size problem-solving exploration wheel, retool the explanation wheel into a drive shaft linking exploration to application, and transform the guided practice wheel into the much larger application/elaboration wheel. Even more difficult, we ask preservice teachers to relinquish control of the vehicle, putting students rather that the teacher in control of the bicycle. There is no doubt that it would be far easier for everyone involved just to stick to tricycles!

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SHIFTING FROM ACTIVITY MANIA TO INQUIRY SCIENCE -- WHAT DO WE (SCIENCE EDUCATORS) NEED TO DO?

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We live in a period of dramatic changes in science education. Research results published in professional journals and books, as well as national documents, call for science to be taught in the same way it builds -- using inquiry. *The National Science Education Standards* express it very clearly: "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (NRC, 1996, p. 31). The document goes beyond general statements and defines the role of the students as the ones who:

> formulate the question and devise ways to answer them, they collect data and decide how to represent it, they organize data to generate knowledge, and they test the reliability of the knowledge they have generated. As they proceed, students explain and justify their work to themselves and to one another, learn to cope with problems such as the limitation of equipment, and react to challenges posed by the teacher and by classmates. Students assess the efficacy of their efforts - they evaluate the data they have collected, re-examining or collecting more if necessary, and making statements about the generalizability of their findings. They plan and make presentations to the rest of the class about their work and accept and react to the constructive criticism of others. (p. 33).

From this paragraph it is evident that inquiry science also provides a natural avenue for integration. Mathematical knowledge (e.g., data collection and representation, testing reliability) and language arts knowledge (e.g., written and verbal communication) add to the quality of the experience.

The teacher's rôle also requires a move away from the traditional presenter of science. During students' inquiries, teachers are supposed to "guide, focus, challenge, and encourage student learning" (NRC, 1996, p. 33). Teachers need to provide help to individual students according to their needs (something that reminds us of the concept of "scaffolding" used by Vygotsky), and promote inquiry by asking questions rather than providing answers.

So, What is the Problem?

I surveyed the degree of comfort expressed by prospective elementary teachers in using inquiry techniques when they teach science. Sixty-six students enrolled in three sections of the Elementary Science Methods course at a university in the northwest United States responded. The general perception expressed by these prospective elementary teachers was that they were unable to use techniques consistent with inquiry science as they were never involved as students in such processes. During their schooling as well as their studies at the university prospective elementary teachers did not feel they encountered such teaching. They also feared that their perceived weak background in science did not support such techniques. If they were going to teach science, they felt more comfortable with a series of disconnected activities or what was called activity mania by Moscovici and Nelson (1998).

Barr (1994) confirms this in her exploration of four main barriers to inquiry science implementation at the elementary level. Her findings show that most teacher preparation programs are inconsistent with inquiry science.

Surveys of practicing elementary teachers uncovered a similar pattern. Samples from two different districts in the Pacific Northwest (Moscovici & Nelson, 1998) show that elementary teachers (N=24) use methods that are consistent with inquiry science only for 22% of their time, and in most cases (based on analysis of descriptions provided by the teachers on the surveys) it was the teacher who went through inquiry rather than the students. In the same surveys, elementary teachers expressed their wish to involve their students in inquiry science at a much higher level and suggested modeling, workshops/courses for inquiry science, and inquiry science support groups as avenues necessary in order to achieve this goal.

Czerniak (1990), found that highly efficacious teachers (teachers who believe that effective teaching will have a positive effect on students' learning) tended to use more inquiry and student-centered teaching strategies while teachers with a low sense of efficacy tended to use more teacher-centered strategies, such as lectures and readings from the textbook. Huinker and Madison's (1997) work suggested that two methods courses (one in science and one in mathematics) that showed consistency in terms of developing efficacious elementary teachers proved successful. The two courses which combined content and fieldwork encouraged the prospective elementary teachers to explore science and mathematics as both learners and teachers. Their results support Barr's (1994) findings mentioned previously and advocate for teacher preparation programs that show consistence with inquiry science.

In this paper I will concentrate on what we (science educators) can do in order to support the shift toward inquiry science in the elementary classroom. We all teach at least one course - the elementary methods in science course - and there are ways to involve prospective teachers in genuine inquiry.

The Science Methods Courses -- Goals

Anderson & Mitchener (1994) described the role of the science methods courses in the following way:

> Science methods courses act as the bridge between many areas of the teacher education curriculum, as well as between education and studies in the science departments. Methods courses help prospective teachers integrate knowledge and gain experience in applying this integrated learning in actual school settings with real students or in simulated environments with peers (p. 17)

During science methods courses, prospective elementary teachers have the opportunity to make their knowledge regarding content and pedagogy explicit, be able to describe their personal teaching philosophy, and become what Schoen called "reflective practitioners" (Schoen, 1987). It is not to say that prospective elementary teachers do not engage in reflection on their experiences as students in science and education classes prior to the science methods course(s). It just says that during the science methods courses reflection is a recommended tool (Nichols, Tippins, and Wieseman, 1997; Abell and Bryan, 1997) to help prospective teachers develop content knowledge, pedagogical content knowledge, and curricular knowledge in a variety of forms as suggested by Shulman (1986).

Inquiry Science as a Central Part of the Methods Courses

The suggestion to have prospective teachers involved in scientific inquiry is not new. I studied more than twenty syllabi for methods courses for elementary teachers in use in different parts of the United States, as well as on different continents. Most of them used elements from the student's role in inquiry science (e.g., collecting data, displaying data, looking for resources), but unfortunately, in a rather disconnected way. I could not find any syllabi that requested students to fulfill all the requirements and go through a full inquiry science unit and have to communicate their findings to peers and/or students.

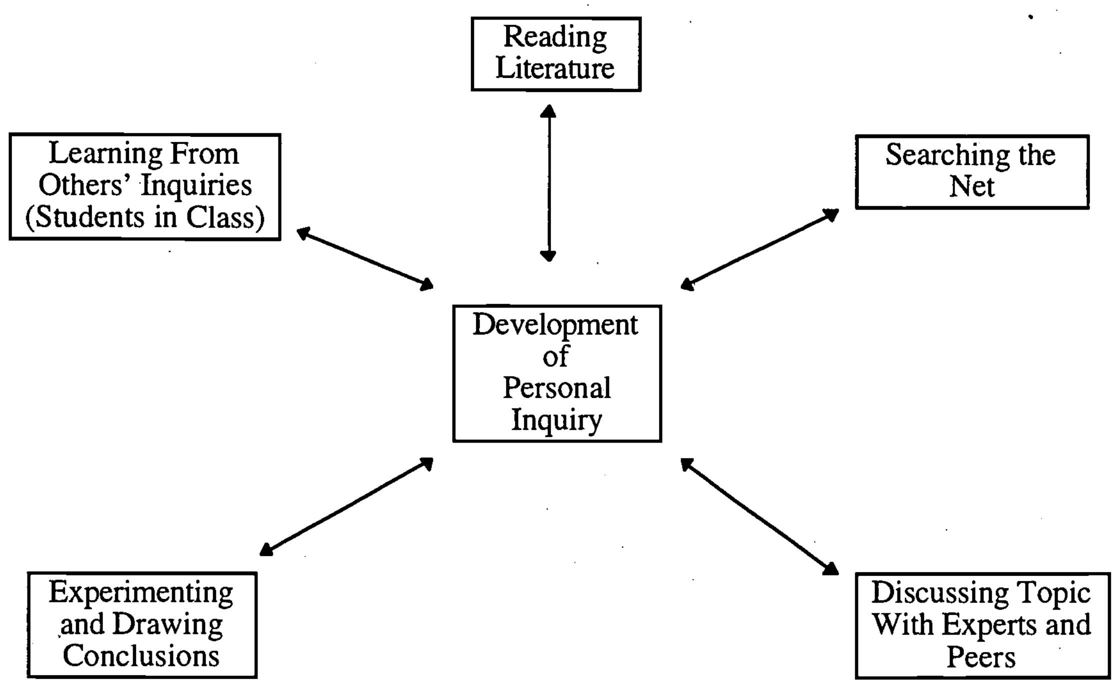
In the following sections, I will differentiate between two stages in scientific inquiry from the standpoint of the prospective or practicing teacher. One relates to the scientific inquiry that the prospective teacher undergoes as a student in the science methods course (personal inquiry). The other inquiry refers to the scientific explorations performed by students in a classroom where the teacher assumes the role of facilitator helping students with their inquiries.

Personal inquiry

This stage of inquiry (see Figure 1) is necessary and it answers to the need expressed by various prospective and practicing teachers: "How can I teach using scientific inquiry if I was never involved in such a process as a student?" It engages the prospective elementary teachers in all the various levels of scientific inquiry stated in the National Science Education Standards in the section regarding the role of the student (NRC, 1996). In many ways this process is the same as the one experienced by every scientist in the research laboratory. From the formulation of the question, to planning and performing experiments, to the formulation and representation of knowledge produced and to the reliability tests, prospective teachers explore personal interests. During their investigations, participants investigate pertinent literature, use educational technology (e.g., Internet, CD-ROMs, video clips) and various experts. Prospective teachers generate knowledge, test for reliability, and justify their results to themselves and to others. Peer presentations and constructive criticism enhance the quality of their inquiries and provide new avenues for research.

Prospective elementary teachers need to reflect during their inquiries and express their feelings during the different stages of inquiry. Such follow-up will prove very valuable when students become teachers trying to involve their own pupils in scientific inquiry.

Figure 1
Essential Elements for the Development of Personal Inquiries



From Personal Inquiry to Involving Students in Inquiry

When the prospective elementary teacher (the student) becomes the teacher, it is important to act as a facilitator, a guide, a provider of scaffolding according to student needs, a follower during students' investigations (NRC, 1996). The shift in roles (from student to teacher, see Table 1) needs to be a reflective one, and the teacher needs to be able to assume a secondary role during student investigations. It is not to say that the teacher cannot use any of their various sources of knowledge (Shulman, 1986) and their experience gathered during personal investigations. Just the opposite. Such situations are excellent integrative experiences in the life of teachers. What I am saying is that they should use their knowledge carefully, only when required for scaffolding. They must not forget that personal scientific inquiry knowledge remains personal, and that it is connected to the person's individual question, experiences, scientific methodology, and theoretical frameworks.

It is not enough for the teacher to have experience as a student in inquiry science in order to have teachers who are going to involve their students in inquiry science. In order to illustrate this statement, I will use the science faculty teaching science courses at the university. Almost all science courses at the university level are taught by scientists with experience as researchers. Their Master of Science, as well as their Ph.D. degrees required scientific research. The problem as I see it is that these researchers teach their personal inquiries (or other researchers' personal inquiries) as "the science that knows" (Latour, 1987, p. 7). It is presented as an established and unquestionable fact that lost its inquiry flavor. Students in these courses do not engage in scientific inquiries and are unable to bring inquiry science into their own classrooms.

The argument brought up in this section reminds me of an argument we had during a session on inquiry science at NARST, 1997. A person in the audience asked "How much science knowledge does a person need to have in order to involve his/her students in inquiry science?" and the answer of the presenter was "None!." I do not think we should go to such an extreme. The teacher must be knowledgeable in various areas of science, education, and curriculum (Shulman, 1986). In addition, he/she must be able to involve students in inquiry science and avoid imposing personal knowledge or other aspects of knowledge of the kind of "the science that knows" (Latour, 1987, p. 7) on the students.

Table 1
Relationships between the kind of experience and roles assumed by the student and teacher.

KIND OF EXPERIENCE	ROLE OF THE STUDENT	ROLE OF THE TEACHER
EXERCISE/ ACTIVITY/ IMPOSED INQUIRY	TECHNICIAN	EXPERT/ CONTROLLER
INQUIRY (NRC, 1996)	DEVELOPS PERSONAL INQUIRIES (RESEARCHER)	FACILITATOR TO CO-LEARNER

Summary

In this paper I raised the argument that as science educators we have the responsibility to accelerate the shift toward inquiry science in the elementary classroom. We have both the knowledge and the support from the *National Science Education Standards* (NRC, 1996) to ensure this kind of shift. While engaged in such a process, prospective elementary teachers have the opportunity to integrate knowledge gained in their science courses with that gained in education courses (Anderson & Mitchener, 1994). They are challenged to interrelate content knowledge (both facts and processes), with pedagogical content knowledge, and with curricular knowledge (Shulman ,1986). They are also encouraged to integrate their knowledge in various subjects, such as mathematics, art, and language arts.

During the elementary science methods courses, science educators are encouraged to engage their students in scientific inquiry much in the same way in which science researchers experience science in their research laboratories. Prospective teachers should become research scientists and experience the various stages of scientific inquiry from the formulation of the research question, to planning and experimenting, testing for reliability and deciding on ways to organize and present their knowledge, to acting according to constructive criticism. This process helps them understand that scientific inquiry is not finite, and that every answer brings more questions and more avenues for research.

Prospective elementary teachers undergoing scientific inquiry need to understand the difference between their personal inquiry process and the experience they need to provide to their students and peers. Through reflection they find ways to avoid transforming their personal inquiry into the "science that knows" (Latour, 1987, p. 7). Inquiry implies helping students find answers to their own questions using principles of scientific inquiry, the "science that does not know yet" (Latour, 1987, p. 7). "The science that does not know yet" (Latour, 1987, p. 7), requires the application of the principles of scientific inquiry to the search for answers to student-generated questions.

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HOW MUCH IS ENOUGH? PREPARING ELEMENTARY SCIENCE TEACHERS THROUGH SCIENCE PRACTICA

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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. Stefanich and Kelsey (1989) who found that less time is spent on science instruction in elementary schools than any other subject have corroborated these results. 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 practica 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 their 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, Toohey, and Hughes (1996) 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.

This research investigated the influence of an extended elementary science teaching practicum upon preservice elementary teachers' science self-efficacy. An "extended practicum" was defined as 12 weeks long comprising 12 hours per week placement at a local elementary school where the preservice teacher was assigned to teach primarily elementary school science. Various research projects have investigated science self-efficacy 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 self-efficacy throughout a preservice teacher's preparation. This in-depth study explored both quantitatively and qualitatively the progression of teacher efficacy and outcome expectancy of preservice elementary education majors as well as the influence of a science methods course before, during or after a practicum experience.

Methodology

Quantitative Design

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 10 weeks, totaling 120 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. Quantitative Research Design

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).

Quantitative Instrumentation

The STEBI B (preservice version) (Enochs & Riggs, 1990) was administered to the preservice practicum teachers on a weekly basis. 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.

Clearly, test sensitivity was a major threat to internal validity. In an attempt to lessen this threat, the SciLOC I and SciLOC II instruments were administered 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 0.73 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 positive 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 an additional facet of relationship between the STEBI B and SciLOC instruments.

Qualitative Research Design

The qualitative parameters of this study included pre and post interviews given the first and last week of practicum, supervisor and cooperating teacher observation notes (participant observations), 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). For further investigation of the differences in the STEBI B 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 (See Table 1). This resulted in a sizeable amount of thick and rich data that helped define the statistical analyses.

Table 1
Selected Participants & 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

Results

Quantitative Results

Descriptive results of the STEBI B and SciLOC administrations can be found in Tables 2 and 3. Figures 1 and 2 show the line plots of the STEBI B subscale scores. Table 4 reports the descriptive statistics of the SciLOC I & II administrations. Table 5 reveals a statistically significant difference in PSTEB scores between weeks 1 and 12.

Table 2
Descriptive statistics 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)

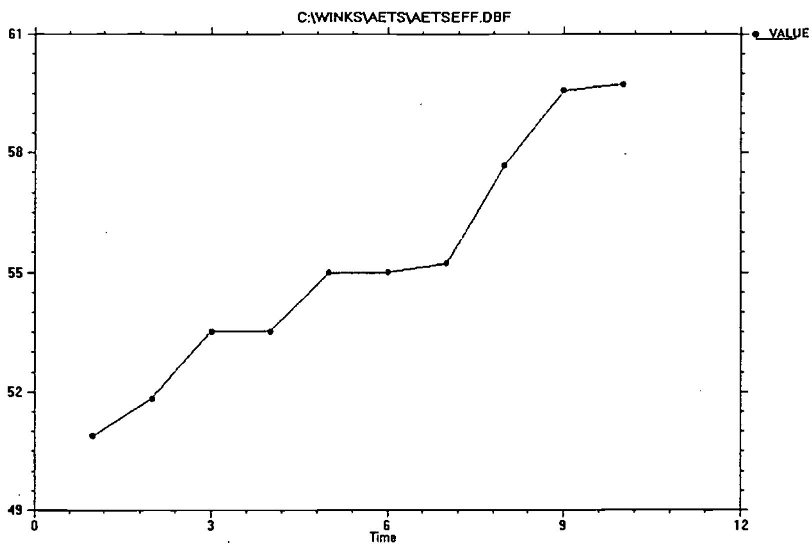

Figure 1. Line plot of Personal Science Teaching Efficacy Beliefs Scores (PST EB) scores for weeks 1 - 7, and 10 - 11.

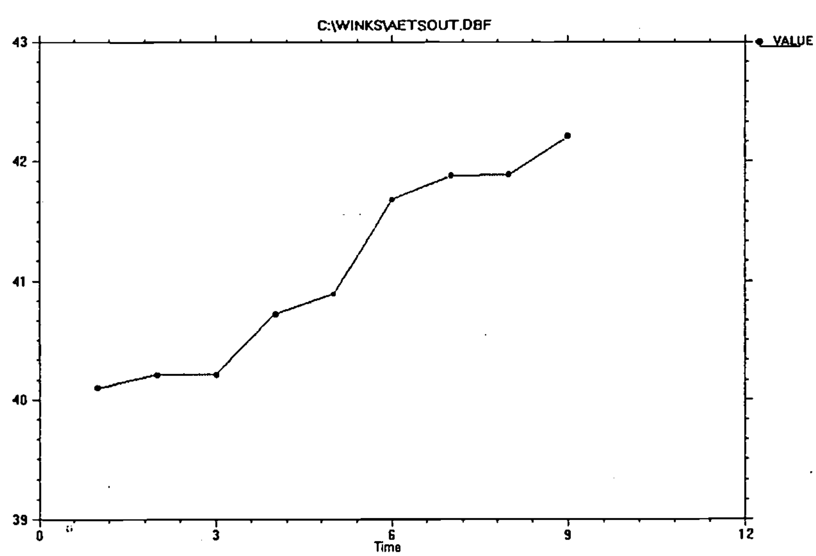

Figure 2. Line plot of Science Teaching Outcome Expectancy Scores (STOE) scores for weeks 1 - 7, and 10 - 12.

Table 3
Descriptive statistics of SciLOC I and II scores for practicum weeks 8 & 9

FIELD	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 4
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 5
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)

Qualitative Analysis

Self-efficacy

Quantitative analyses from the STEBI B show that there is a significant improvement over the course of study in self- efficacy, but the outcome expectancy, although positive, gained only 2 points for all 19 participants. This is a common pattern found in STEBI research. In order to find out more about why this pattern emerges, six questions from the STEBI B (question numbers 5, 12, and 22 for self- efficacy and question numbers 1, 9, and 16 for outcome expectancy) were used in addition to two other questions, "What does the word science mean to you" and "What anxieties do you have pertaining to the teaching of elementary science" in a pre / post interview format for six purposefully selected participants (See Table 1). Some very interesting conversations emerged which help to explain the quantitative results of the STEBI B and also the elementary science practicum and the relationship of a science methods experience.

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, that 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 and is referred to as outcome expectancy.

The six participants all had different levels of self-efficacy, especially in the pre interviews, but by the end of the semester all of the participants believed in their ability to perform and that this ability would have desirable outcomes.

More specifically, the first question asked in order to try to understand this efficacy gain was question number 5 from the STEBI B (Enochs & Riggs, 1990). Question five states "I know the steps necessary to teach science concepts effectively." The participants that had not taken science methods and were not concurrently enrolled in science methods (participants 003 & 006) both had major reservations in the pre interview. Participant 003 stated, "right now, I know a little about the steps, but I have TONS of room for improvement." Participant 006 stated, "I don't know how science is taught in the school - I will need to see it."

Participants 001 & 005, who were concurrently enrolled in science methods, also had reservations in the pre interview. Participant 001 stated, "I'm in the process of learning the steps." Participant 005 stated, "right now I don't feel very confident in knowing the steps to teach science." Both of these participants made reference to the methods class and that between both classes they would know the steps by the end of the semester.

Participants 002 & 004, who had previously taken science methods prior to the practicum experience, felt a little more confident about the steps to teaching science in the pre interview. Participant 002 stated, "I feel more confident because of my methods class, but in reality, you can read a book and study it all you want, but until you actually get out and do it - it never really sinks in." Participant 004 stated, "It depends on the concept - some I feel prepared to teach and others I will need to research." The statement by the second participant here was supported by her journal that in the beginning she still had a lot of anxiety about the science content that she was supposed to teach and thus was missing the point about the process or steps in teaching science.

The science methods course under study taught the 5 E model of the learning cycle as outlined by Biological Sciences Curriculum Study (BSCS) (Bybee, 1990). Students go through various exercises in writing lesson plans and teaching lessons using the model. Because this methods course is held primarily on campus, the majority of these lessons are peer taught, but the planning process is basically the same for both the methods instruction and the practicum. In the first week of the practicum, one full day was spent on the 5 E model and how to develop lessons in that format. At the end of the practicum all of the participants strongly agreed with the statement of knowing the steps to teach science effectively, but a qualitative difference occurred.

Participants 003 and 006, who had not taken science methods or who weren't concurrently enrolled in methods, could not recite the steps of teaching science, or more specifically the 5 E's, when pushed in the post interview. Participant 003 stated. "Yes, I think I know the steps - I have a basic knowledge of how to teach science, but I could learn more."

When pushed for the steps 003 said, "Motivation is important and using a hands-on approach." Participant 006 said, "I think that I have learned to write a lesson plan." When she was pushed for the steps she stated, "I think I know the steps - first you engage them and then you bring closure to the lesson." Participant 006 was on the right track, but information from her journal and through observations further clarified that she really did not know or use a consistent planning model for science instruction.

The participants that were concurrently enrolled in the methods course also could not list the 5 E's when pushed; however, they were able to tell the steps of lesson planning using different terms in the post interview. Participant 005 stated, "Compared from the beginning to now - I didn't know the steps, but now as I have been teaching science I now have confidence and I know the steps." When 005 was pushed for the steps she gave the scientific method and intertwined her words of the 5 E's. Participant 001 said "I know the steps, but I am still working on them - the first 5 weeks weren't as good as the last 5 weeks. I learned to plan and how to execute the plan." When 001 was pushed for the 5 E's she gave a narrative version, "Get the kids excited and interested, bring in previous knowledge, let them do the activity, regroup, then fill in the gaps."

The participants who had previously taken science methods were both able to explain the steps to teaching science effectively and were able to recite the 5 E's from memory in the post interview. Participant 002 responded, "Yes I know the steps and it is so more ingrained now - especially the engagement and how important that is." Participant 002 recited the 5 E's perfectly when asked. Participant 004 also knew the steps. She stated, "I think I do - after the methods and now the practicum I feel more confident than I ever have." When pushed for the steps she said, "you mean the 5 E's" then she recited them with explanation for each of the stages of planning.

Overall, the difference in knowing the steps to teach science effectively came in understanding the lesson design. Each participant felt that he/she could teach the lessons, but in practice the more experience they had had prior to the practicum in lesson design, methodologies, philosophies, and steps in planning hands-on type lessons seemed pertinent to both the teaching success of the practicum students and their ability to communicate those steps in the interview.

Similar patterns emerged in the narrative and interviews of the participants in question 12 from the STEBI B, "I understand science concepts well enough to be effective in teaching elementary science" and question #22, "When teaching science, I will usually welcome student questions."

Generally speaking for self- efficacy, we found for these six participants that taking the science methods course before having the practicum proved beneficial for the students and enabled them to communicate their efficacy gain better. The participants who did not have the methods or who were concurrently enrolled said to have gained in self- efficacy, but could not communicate that in the interviews. This is significant in that many students respond on tests with what they think is correct or what they would want to do "ideally" in teaching. Having the students communicate in an interview situation really clarified what the students believed to be their gain in self- efficacy. Interestingly, this was similar for those with the same amount of preparation, but for those without the science methods course it was completely different -- even though the scores were similar on the STEBI B instrument. The interview was also a way to blow away the smoke from the less prepared students and gain insight to what they thought was a gain in self- efficacy which to a small degree was for them, but not in comparison to the students with more preparation in methodology.

Outcome expectancy

In terms of teaching, outcome expectancy is defined as "a teacher's belief that student learning can be influenced by effective teaching" (Ramey- Gassert, 1990). Outcome expectancies as measured by the STEBI have some interesting results. Ramey-Gassert (1990) reported that, "Behavior is enacted when people not only expect certain behaviors to produce desirable outcomes [outcome expectancy], but they also believe in their own ability to perform the behaviors [self-efficacy]." Bandura (1977) speculated that people with a high sense of self-efficacy and outcome expectancy would act in a confident, determined manner. A mixture of the two behaviors might cause individuals to momentarily increase their labors, but in the end, this increase will lead to frustration. However, the outcome expectancy began and ended with only a two-point gain, which showed significance for this 12-week period for all 19 participants.

This result was anticipated based upon prior research on both practicing teachers and preservice teachers done by the authors. In order to understand more about outcome expectancies of preservice teachers, the effect of the duration of the practicum, and the amount of prior preparation via the science methods course, questions 1, 9, and 16 from the STEBI B (Enochs & Riggs, 1990) were used in a pre / post interview format with the six participants selected for the qualitative portion of this study (See Table 1).

Question 9 from the STEBI B (Enochs & Riggs, 1990) states, "The inadequacy of a student's science background can be overcome by good teaching." We asked the participants how they felt about this question and then pushed them for explanation of what good teaching meant to them.

Participants 003 & 006, the students who had not had science methods nor were they concurrently enrolled in science methods, had some interesting comments in the pre interview. Participant 003 stated, "I strongly agree -- science is not a big thing for most families and good teaching, whatever way, makes the students learn the most." Participant 003, in the pre interview, defined good teaching as "Whatever way makes the students learn the most." Participant 006 responded similarly in the pre interview, "I agree. I think it is important that the teacher does a good job trying to explain things to the kids. If a kid does well it is because the teacher explained it well." Participant 006 defined good teaching as "having each student succeed."

The participants who were concurrently enrolled in the science methods course also responded similarly to the non-methods participants in the pre interview. Participant 001 stated, "Yea, I agree - I mean you know where your kids are and what they are learning - so... I mean if a kid doesn't know what an atom is you can't go on and explain the positive and negative charges - this goes for all subjects." Participant 001 defined good teaching in the pre interview as the amount of knowledge (content) that the teacher posses. Participant 005 responded in the pre interview to the question as, "Yes, I agree 100%. Because there is always a time when a teacher teaches something that is not appropriate (to the level) of the students and she knows it. . . . you can then adjust and go from there." Participant 005 defined good teaching as, "planning ahead - a lot of planning ahead and making lesson plans." Both Participants really didn't address the question of the inadequacy of a student's background, but rather focused on the teaching aspect.

The participants who had previously taken the methods course responded with more depth than the previous four participants in the pre interview did. Participant 002 responded, "If the teachers are not teaching science then the students are not doing science and have no thoughts towards it. If a teacher teaches hands-on science the kids will see how much fun it is and then get into it and talk about it more." Participant 002 defined good teaching as "doing your homework outside of class (planning), researching and then doing ongoing evaluations of your own teaching." Participant 004, in the pre interview, stated, "I think that is true, if a child feels inadequate and the teacher can show the child that he can do it - then the child will feel much better about that." Participant 002 defined good teaching as, "A hands-on approach - kids really respond to that."

The interesting aspect of the comments in the pre interview was in the depth of the responses and in the participants who had the science methods courses reflecting the hands-on approach. Although the outcome expectancy scores were similar in numeric value from the STEBI B analysis, the qualitative analyses reveal the subtle differences at the beginning of the semester. At the end of the semester, the participants all had the same amount of time in the classroom, one would expect that the outcome expectancies might change. Although the quantitative results were minimal, there were more noticeable differences qualitatively from pre to post in all of the participants.

The participants who had not taken science methods, or who were not concurrently enrolled in methods, responded in the post interview with more depth than they did in the pre interview. Participant 003 stated, "I agree. You can overcome kids problems by being a good teacher." It may be important to note that 003 was employed in a school for drop out high school students during this practicum. He wrote in his journal often about how many kids left school because of poor teaching. Participant 003 defined good teaching at the end of the semester as, "whatever it takes to get the kids interested. There is no formula - just whatever you can do within your own power to make the kids more excited and willing to learn." Participant 006 didn't change much from the beginning of the semester with her definition. She stated in the post interview that, "I think good teaching is important because just reading out of the book they don't understand it, but if you know how to teach it the correct way (hands-on) - they get more out of it." Participant 006 defined good teaching at the end of the semester as, "Teaching to where the kids understand the concepts."

The participants who were concurrently enrolled in the science methods course also responded with more depth at the end of the practicum experience. Participant 001 stated, "I agree to a point. It is hard when there are people in your class on different levels . . . although the kids learned a lot compared from the beginning to the end." Participant 001 was placed in a classroom that had three main streamed special education students, one of which was severely handicapped and learning disabled, the other two classified as very attention deficit (ADD). Participant 001 defined good teaching at the end of the experience as, "Extra effort - working as long as necessary until the student either looses interest or until the concept is learned. This may include going back and researching a new way to teach it and explain things." Participant 005 responded at the end of the practicum and stated, "I strongly agree because good teaching is followed by good learning. Good clear explanations and observing while they are learning - you can know if they have learned." Participant 005 defined good teaching as, "Every student can learn - planning lessons to accommodate all learners."

The participants who had previously taken methods also were able to add more rich explanations to their prior comments concerning the question, "inadequacy of students background can be overcome by good teaching." Participant 002 stated, "Definitely, the inadequacy in any child is that they haven't been involved to their developmental level or been engaged in work which is fun. Kids turn off to reading and answering the questions in any subject." Participant 002 defined good teaching at the end of the practicum experience as, "Getting the kids involved - it is doing engagements, which capture their attention, it is fun, it is getting kids to work on projects in groups. Get them involved in their learning. I had kids crawling up on their desks making observations (of plants growing on their desks in 2 liter pop bottles) and just talking about that stuff to each other - what other subject could allow them to do that?" Participant 004 responded to the question as, "Yes, I think that the inadequacy of any child's background can be overcome by good teaching if the teacher can get the child interested and wanting to learn." Participant 004 defined good teaching at the end of the practicum experience as, "Someone who can make a child understand without standing in front of the class and lecturing. Be able to get down with the child one on one and then evaluate their own teaching and how the kids learned. To know what went right and what went wrong in a lesson - all of that is good teaching."

It is very interesting to note that after the practicum experience all of the participants explained good teaching as involving the children in their learning. They found that active involvement and hands-on approaches worked much better than more traditional lecture and reading approaches. Also it is interesting to note the level of dialogue that occurred in the post interviews. Although there was no major changes in the STEBI B data, all participants were able to communicate their outcome expectancies much better after the experience, based upon events they encountered during the practicum and in their teaching. They now understood why they responded the way that they did rather than just making an unsubstantiated statement.

Did their outcome expectancies then really improve over the semester? Quantitatively minimally, but qualitatively more so. The students now had experiences by which they were able to substantiate their outcome expectancy responses and beliefs. The responses from the other interview questions followed a very similar pattern as the one narrated above. The narratives became richer and the participants based their responses upon their experiences. The participants' conclusions tended to align with research saying that good teaching can impact student learning. Gibson and Dembo (1984) concluded from their studies on teacher beliefs that "student learning can be influenced by effective teaching." Gibson and Dembo (1984) 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" (p. 37).

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.

The qualitative data doesn't really address the ideal time of the practicum, as these students have only had this one experience. However, the comments from the participants strongly support that the time in the classroom was just right. In an exit interview with all (19) 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.

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 fieldwork or practica experiences.

What is the most ideal amount of practica experiences? The results of this study reveal that during a 12-week practicum experience, PSTEB scores continued to rise, 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.

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 120 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.

Conclusion

Westerback and Long (1990) investigated the impact of self-confidence 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 significant 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. Additionally, this study found that the time of 10 weeks actually teaching in the classroom was a good experience for the participants involved. Over the course of the practicum there were significant gains in self- efficacy both quantitatively and qualitatively and although there were minimal gains quantitatively on outcome expectancy, there was sufficient evidence to support a qualitative difference amongst the participants from week 1 to week 12.

There are some great limitations to this study. Repeating the same instrument on a weekly basis 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. And finally, there was no real measure to compare the time frame of the practicum experience to other practica of other lengths.

For further study, we are changing the practicum to only three hours one day a week instead of the 12 hours (4 hours 3 days a week) that this study explored. Cannon (1997) bases this upon the research where a minimal statistical difference in self-efficacy was found from a 150-hour practicum experience and a 3-hour practicum experience during a semester. Although there is no substitute for experience, the quest for the ideal practicum time still remains. And although Cannon's (1997) research states that there is minimal statistical difference in his study, the qualitative results from this study encourage the researchers that perhaps there is a qualitative difference and that it is worthy of spending valuable research time exploring.

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USING NEGOTIATED CRITERIA AND PEER-EVALUATION IN UNDERGRADUATE ELEMENTARY SCHOOL SCIENCE EDUCATION PROGRAMS

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Introduction

This paper reports on an on-going action research study of the elementary school science education courses at the University of Victoria. The Department of Social and Natural Sciences requires that professors evaluate their teaching effectiveness annually using a variety of methods—student evaluations, peer observations, course outline analyses, and other methods approved by the department chair. This requirement provides an excellent opportunity to conduct action research to document teaching, to reflect on teaching, to improve practice, and to revise course outlines based on multiple sources of data. The negotiated criteria, peer-evaluation, and student-led workshop components of Ed-E 445A: Science Instruction in the Elementary School are the foci of this paper.

Background

Elementary science teacher education has lacked a consistent focus and direction over the last 10-15 years. A quick inspection of 1980s national and regional conferences on science teaching and science teacher education reveals a loose collection of interesting ideas and effective programs without a central, clear, philosophical, psychological, pedagogical framework. The *National Science Education Standards* (NRC, 1996) explicitly addressed this lack of clarity by including teaching, assessment, content, program, and professional development standards. The science standards, taken in conjunction with the *National Board for Professional Teaching Standards* (NBPTS, 1994) and the Report of the *National Commission on Teaching and America's Future* (NCTAF, Darling-Hammond, 1996), reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on student's thinking, academic achievement, emotional disposition, and science literacy and have renewed the emphasis on teaching and teacher education research. These documents provide both generalist and science-specific frameworks on which elementary school science education and teacher education programs can be judged.

Shulman (1987) encouraged designers of teacher education programs to articulate and coordinate the content knowledge, pedagogical knowledge, and content-pedagogical knowledge components of a program. Surveys of elementary teachers indicate that practicing teachers believe they lack appropriate science content knowledge. The surveys also indicate that practicing teachers do not value their preservice science education courses. These reflections indicate that science and science education components of elementary teacher education programs are not effective in that they do not address the perceived needs of classroom teachers, do not reflect reasonable expectations and current conditions of classrooms, do not provide depth of understanding, and do not convince preservice teachers of their value. In part, this situation is due to the disconnected internal relations within the university but it is also due to the disconnected nature of the program's campus-based and field-based components (Roth & Pipho, 1990; Yager & Penick, 1990).

The 1960s science education reform produced a series of false dichotomies, process/product, child-centered/subject-centered, structured/unstructured, basics/higher-order thinking, etc. Contemporary perspectives must address these false propositions—all teaching must "merge commitment to students with allegiance to knowledge at all grade levels" (NBPTS, 1994, p. 10); integrate knowledge, inquiry skills, habits-of-mind and critical thinking (NRC, 1996); and balance appropriately content structure, teacher structure and students' self-regulation to enhance learning (Yore, 1984; 1986). The NCTAF report states "students are entitled to teachers who know their subjects, understand their students and what they need, and have mastered the professional skill required to make learning come alive" (Darling-Hammond, 1996, p. 6). The report goes on to recommend that American education get serious about standards for teachers and students, teacher education and professional development be reinvented, teacher recruitment be overhauled, teaching knowledge and skills be encouraged and rewarded, and schools be reorganized as places for teaching and learning.

General Standards for Teaching

The NBPTS (1994) described a vision of effective teaching generally that contains five core propositions and developed a national teacher certification program based on standards for these propositions (abstracted from pp. 6-8):

1. Teachers are Committed to Students and Their Learning

   Board-certified teachers are dedicated to making knowledge accessible to "all" students. They act on the belief that "all" students can learn. They treat students equitably, recognizing individual differences and taking account of these differences in their practice. They adjust their practices as appropriate, based on observation and knowledge of their students' interests, abilities, skills, knowledge, family circumstances, peer relationships, and culture.

2. Teachers Know the Subjects they Teach and How to Teach those Subjects to Students

   Board-certified teachers have a rich understanding of the subject(s) they teach and appreciate how knowledge in their subject is created, organized, linked to other disciplines, and applied to real-world settings. While faithfully representing the collective wisdom of our culture and upholding the value of disciplinary knowledge, they also develop the critical and analytical capacities of their students. They are aware of the preconceptions and background knowledge that students typically bring to each subject and of strategies and instructional materials that can be of assistance. They understand where difficulties are likely to arise and modify their practice accordingly.

3. Teachers are Responsible for Managing and Monitoring Student Learning

Board-certified teachers create, enrich, maintain, and alter instructional settings to capture and sustain the interest of their students and to make the most effective use of time. They also are adept at engaging students and adults to assist their teaching and at enlisting their colleagues' knowledge and expertise to complement their own. Accomplished teachers command a range of generic instructional techniques, know when each is appropriate, and can implement them as needed. They know how to engage groups of students to ensure a disciplined learning environment and how to organize instruction to allow the schools' goals for students to be met. They employ multiple methods for measuring student growth and understanding and can clearly explain student performance to parents.

4. Teachers Think Systematically about their Practice and Learn from Experience

Board-certified teachers are models of educated persons, exemplifying the virtues they seek to inspire in students—curiosity, tolerance, honesty, fairness, respect for diversity, appreciation of cultural differences—and the capacities that are prerequisites for intellectual growth: the ability to reason and take multiple perspectives, to be creative and take risks, to adopt an experimental and problem-solving orientation. Accomplished teachers draw on their knowledge of human development, subject matter and instruction and on their understanding of their students to make principled judgments about sound practice. Striving to strengthen their teaching, Board-certified teachers critically examine their practice, seek to expand their repertoire, deepen their knowledge, sharpen their judgment, and adapt their teaching to new findings, ideas, and theories.

5. Teachers are Members of Learning Communities

Board-certified teachers contribute to the effectiveness of the school by working collaboratively with other professionals on instructional policy, curriculum development, and staff development. They can evaluate school progress and the allocation of school resources in light of their understanding of state and local educational objectives. They are knowledgeable about specialized school and community resources that can be engaged for their students' benefit and are skilled at employing such resources as needed.

Science Education Standards

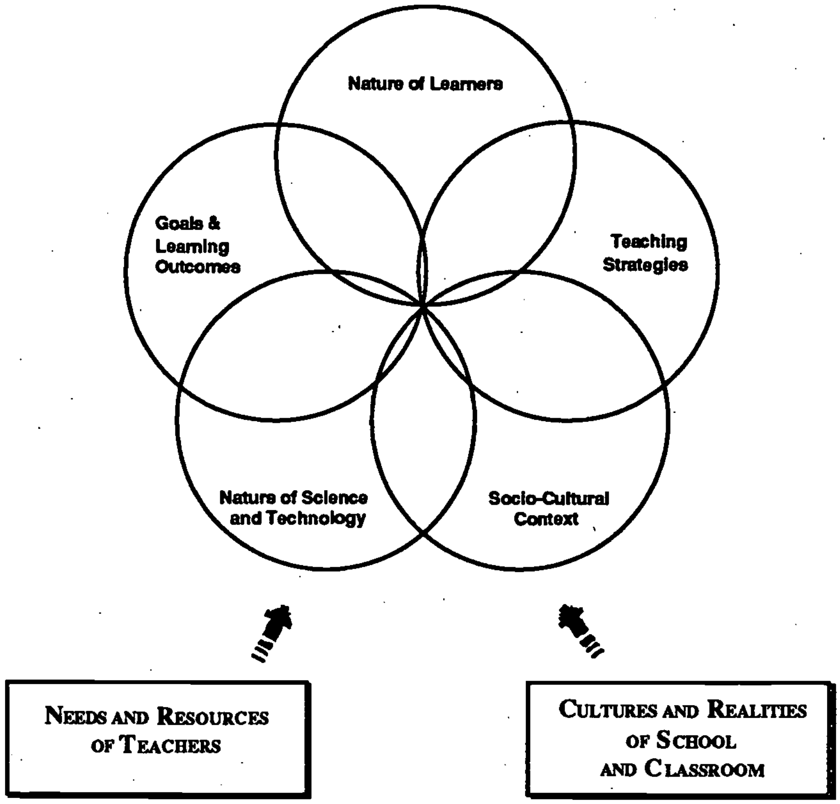
The *National Science Education Standards* (NRC, 1996) apply these general assumptions about commitment to all students, effective teaching, authentic assessment, organizational abilities, reflective practice, leadership and professionalism to science teaching, science learning, and science teachers. The science standards describe the collective content-pedagogical knowledge, grade-appropriate goals, and actions needed for effective science teaching. The teaching standards address: (1) planning inquiry science programs, (2) actions required to guide and facilitate learning, (3) assessments of teaching and learning, (4) environments that promote learning, (5) communities of learners to support learning , and (6) planning and development of school-wide science programs. The assessment standards recognize the importance of how evaluation drives teaching and learning and the need to have goals, teaching, and evaluation aligned. The standards address: (1) the consistency of assessment information and educational decisions, (2) consideration of both achievement and opportunity, (3) the match between technical quality and consequences, (4) the fairness of assessment practices, and (5) the soundness of inferences modeled from assessment data. The professional development standards envision true professionalism and a seamless professional education system for science teachers that includes preservice, induction (early years of teaching), and continued professional education. The standards address: (1) learning science content through inquiry, (2) integrating content knowledge and pedagogical knowledge into learner/topic appropriate content-pedagogical knowledge, (3) lifelong learning, and (4) coherence and integration of professional development programs.

Teaching All Students Science

Teaching is a complex endeavor involving a balancing act while juggling numerous factors. "The education challenge ... is not that its schools are not as good as they once were, it is that schools must help the vast majority of young people reach levels of skills and competencies once thought within the reach of a few. To help diverse learners master much more challenging content, teachers must go far beyond dispensing information, giving a test, and giving a grade" (Darling-Hammond, 1996, p. 8). The constructivist teaching envisioned by contemporary reforms is much more demanding on teachers requiring thousands of decisions and adjustments during each lesson (reflection-in-action) and analysis of teaching effectiveness after the lesson (reflection-on-action). Teaching is too complex to understand in its totality; deconstructing teaching into separate components is dangerous, but it is necessary to explore the interacting parts to better understand the holistic process (Figure 1).

The inclusive nature of the science standards, the multicultural nature of North American schools, and the humanistic nature of school policies involving mainstreaming special needs students have placed increased importance on the nature of the learners. The composition of many elementary school classes produces a rich mosaic of cultures, languages, and belief systems that provide a challenge to science teachers and need consideration during instructional planning and teaching (Lee, 1997). Likewise, the inclusion of special needs students in most classrooms changes the delivery mode, pace, and organization of most science teaching.

Figure 1
Compatibility Model for Science Teaching and Learning



The science teaching standards imply that science teaching should utilize a constructivist approach without specifying the exact nature of teaching strategies. Constructivism has many interpretations (faces) in education (Good, Wandersee & St. Julien, 1993; Phillips, 1995). The faces of constructivism provide a "range of accounts of the processes by which knowledge construction takes place. Some clarification of these distinct perspectives and how they may interrelate" is needed as this epistemic theory is used to construct compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). The individual faces have some common assumptions (basics) and important differences (world view, view of scientific knowledge, locus of mental activity, locus of structure/control, discourse, etc.).

Basics of Constructivism. Accounts of the various interpretations of constructivism agree that understanding is actively made out of, invented from, or imposed on personal experiences.

The construction process and the resulting constructs are influenced by the learners' prior knowledge, memory, cognitive abilities, metacognition, interpretative framework, and sociocultural context. Each interpretation encourages meaningful learning of integrated knowledge networks through active deliberation, resolution, debate, and reflection of cognitive conflicts; and each has discounted rote learning, isolated skills, and drill-practice. Furthermore, each interpretation agrees that people have misconceptions within their prior knowledge and that these misconceptions are not indications of stupidity; are found across age groupings, content areas, cultures, and national boundaries; and are resistant to change. Replacement of misconceptions with more scientifically acceptable conceptions requires that the new concept be sensible, rational, usable, and powerful.

The Different Faces of Constructivism. The constructivist theory is based on a collection of philosophical and psychological theories, models and ideas–cognitive equilibrium, zone of proximal development, semiotic interactions, capacity of working memory, etc. (Fosnot, 1996). The different faces of constructivism recognize the basic assumptions but appear to emphasize specific aspects to greater or lesser degrees. Henriques (1997) established a comparative framework for four faces of constructivist approaches: information processing, interactive-constructive, social constructivist, and radical constructivist. Yore and Shymansky (1997) analyzed these four faces and their embedded philosophical, psychological, and epistemic assumptions. Information processing utilizes a computer metaphor to illustrate learning in which a series of sub-routines or micro-processes generates ideas and analyzes errors that lead to closer and closer approximations of a knowledge network, the right answer, and causality (Fisher & Lipson, 1985; McCarthy & Raphael, 1992). The interactive-constructive model utilizes a hybrid ecological metaphor (organism, environment, machine) to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence of Nature and privately integrated (assimilated or accommodated) into the person's knowledge network within the limited capacity of working memory and stored in long-term memory (Shymansky, Yore, Treagust, Thiele, Harrison, Stocklmayer, & Venville, 1997). Social constructivism utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are resolved by social negotiations resulting in consensus and common understanding at the group level (McCarthy & Raphael, 1992). Radical constructivism utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency (Airasian & Walsh, 1997; Phillips, 1995; von Glaserfeld, 1987).

These four faces of constructivism have unique philosophical, psychological, epistemic, and pedagogical profiles (Table 1, Yore & Shymansky, 1997). World view involves ways of thinking about how the world works–mechanistic, organistic, contextualistic, and hybrid (Prawat & Floden, 1994). Mechanistic views stress the important role of antecedent events as influence on behavior. Contextualistic views stress the importance of situation and environment. The meaning of an act may undergo changes as it unfolds in a dynamic environment, and the pattern of events in a sociocultural context have low predictability. Organistic views stress the importance of the organism as a whole. Reality is only what the organism subjectively perceives; knowing is an individualistic event. Hybrid views stress the importance of interactions with the physical world (natural and people-built) as well as the sociocultural context, recognize that interpretations reflect lived experience and cultural beliefs of the knowers, but require all interpretations to be judged against evidence grounded in Nature. Epistemic view of science (Hofer & Pintrick, 1997; Kuhn, 1993) represents the structure of knowledge and ways of knowing–absolutist (a single right answer is proven), evaluatist (multiple interpretations are tested and supported or disconfirmed), and relativist (multiple interpretations are equally valid). Locus of mental activity represents the beliefs about where understanding is created–privately deep within the mind and brain of the individual (activity flows from periphery to core where irrelevant stimuli are discarded, leaving abstract representations of critical and essential information or activity focused on subjective experiences, extracting internal coherence and where rightness is seen as the fit with personally established order); publicly within the dynamics of the group (activity is on the interface between the individual and the environment where the collective wisdom of the group and craft knowledge of the community construct understanding); and publicly and privately in which possibilities are surfaced, clarified, and narrowed by group negotiations but actual meaning is made privately by individuals reflecting on these possibilities (Hennessey, 1994; Prawat & Floden, 1994). Locus of structure/control represents an epistemic influence, a pedagogical feature and the pragmatics of classroom teaching dealing with who sets the agenda for study within a specific discipline–teachers, students, or shared. The nature of the science discipline being studied (physical sciences, biological sciences, earth-space sciences) centered contributes to the contextual structure of inquiry-oriented lessons (Yore, 1984, 1986). The content structure complements the teacher structure and the students' self-direction. Discourse represents the combined psychological-pedagogical feature of type and purpose of interpersonal and intrapersonal communications in the classroom–one-way communications of expert to novice, one-way communications of person to self (inner speech the language tool of thinking and spontaneous conception) and two-way communications among people to negotiate clarity or consensus (Fosnot, 1996; Prawat & Floden, 1994).

Science Assessment

The science assessment standards identify "essential characteristics of exemplary assessment practices, the standards serve as guides for developing assessment tasks, practices, and policies, ... (and they) can be applied equally to the assessment of students, teachers, and programs; to summative and formative assessment practices; and to classroom assessments as well as large-scale, external assessments" (NRC, 1996, p. 75). Contemporary interpretations of assessment recognize that assessment drives teaching and learning and that learning outcomes, teaching strategies, and assessment techniques must be aligned. Shymansky (1994) suggested that contemporary assessment has moved toward informing instruction and empowering learning and away from simply grouping and ranking students based on isolated fragments. Constructivist teachers focus on finding out what (a) students already know and utilize this information to plan instruction and to teach, (b) how students learn something, and (c) how they feel about their learning. Ultimately, assessment should move from control by the teacher, to shared control of teacher and student, to the executive control of the student (self-regulated learning).

Table 1
Philosophical, Psychological, Epistemic and Pedagogical Features of Information Processing, Interactive-Constructivist, Social Constructivist and Radical Constructivist Approaches (Yore & Shymansky, 1997)

Feature	Information Processing	Interactive-Constructivist	Social Constructivist	Radical Constructivist
World View	Mechanistic	Hybrid	Contextualistic	Organistic
Epistemic View of Science	Absolutist (Traditional) Nature as Judge	Evaluative (Modern) Nature as Judge	Evaluative (Postmodern) Social Agreement as Judge	Relativist (Postmodern) Self as Judge
Locus of Mental Activity	Private	Public and Private	Public	Private
Locus of Structure/Control	Teacher	Shared: Teacher and Individuals	Group	Individual
Discourse	One-Way: Teacher to Student	Two-Way: Negotiations to Surface Alternatives and to Clarify	Two-Way: Negotiations Leading to Consensus	One-Way: Individual to Self (Inner Speech)

The underlying assumptions of constructivist-oriented assessment is to collect accurate, consistent information of authentic learning in a realistic context that closely parallels and is embedded in the instruction (Yore, Williams, Shymansky, Chidsey, Henriques, & Craig, 1995). Furthermore, the assessment needs to reflect the intended use and the risk involved. Assessment needs to move away from behavioral–based, fragmented objective testing toward more authentic, holistic performance and depth of understanding approaches. Several approaches have promise: two-part objective items, confidence weighting, concept mapping, observational checklists, interviews, and performance tasks. Each approach requires clearly articulated targets and sound scoring rubrics (Luft, 1997; Nott, Peave & Reeve, 1992).

Practicing teachers report that negotiating clarity of the desired outcome and establishing scoring procedures are among the most meaningful professional development activity available. This mediation process involves groups of informed teachers that clarify the desired performance and establish mutually exclusive, exhaustive, and ordered categories of performance. The scoring rubric can describe a holistic performance or establish analytical components believed to comprise the performance. The ordered set of categories within either of these rubrics represents increased quantity of performance and qualitative shifts in performance. Frequently, more of the same type of performances are inter-mixed with the onset of new types of performance.

Negotiating criteria has been used with students to clarify language arts tasks and to establish metacognitive awareness of tasks (Anthony, Johnson, Heckelson & Preece, 1991). Repeated use of negotiated criteria with novices helps the students more completely understand the standards expected of expert performance and puts the novices in a position to monitor and regulate their performance. They claim that negotiated criteria establishes ownership, improves performance, and increases students' satisfaction with their evaluations.

Professional Development.

The standards for professional development describe a seamless experience leading preservice teachers into an induction year and to certified status. Clearly this vision requires elementary school science education programs that provide authentic problem-centered learning experiences and that produce elementary science teachers within the teaching profession willing to assume the roles of change agent, mentor, and model. Many good innovations and educational changes are not fully implemented because leadership is not provided at the target level (classrooms, teachers, students) or transferred from the innovators to the grassroots change agents. Leadership must be a central goal of science education programs; therefore, leadership training needs to be a part of undergraduate coursework. Leadership envisioned here is illustrated by teachers taking on responsibility for curriculum committees, ordering equipment, providing mentorships for new teachers, active membership in science teacher organizations, writing professional articles, giving conference presentations, and conducting professional development workshops.

Cascading leadership addresses the traditional distinctions between advocates, sponsors, change agents, and targets. "The challenge of professional development for teachers of science is to create optional collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers" (NRC, 1996, p. 58). Furthermore, local resource people are needed to support teachers' continued professional growth when external expertise is used to initiate inservice. Frequently these resource people are among the most recent teachers to join the school staff (Henriques, 1997). Providing teachers with opportunities to conduct workshops allows them to not only share and demonstrate their expertise but also opportunities to reflect, compare, contrast, and revise their exemplary practice (NRC, 1996).

The University of Victoria's Elementary School Teacher Education Program

The University of Victoria is authorized by the British Columbia College of Teachers to offer elementary education programs that meet its standards. The regular program leads to a B.Ed. degree in five years. Most students enter after either one or two years of general-liberal academic courses in the Faculty of Arts and Sciences of a college or university. The third year is a pre-professional year with content, general pedagogical and limited methods (physical education, music, drama, and art) coursework, and a two-week clinical experience at the end of the year. The fourth year is the professional year with further foundations and methods courses and two six-week practica, which leads to certification. The fifth year may be done after teaching has begun and is designed to give teachers a concentration in a specific curricular area of their interest. Currently, most students stay onto complete the fifth year, since it provides a higher salary and teaching positions are presently in short supply.

Science Education

The science education component of the elementary teacher education program at the time of this study (1996-97) ranges from the basic core to two levels of specialization: a concentration and a teaching area (Figure 2).

Laboratory Science Requirements

The core science education requirements are 3 to 4.5 units (1.5 units = 3 semester hours or 4.5 quarter hours) of laboratory science and 2 units of science methods. The most popular electives to fulfill the laboratory science requirements are SNSC 145A, SNSC 145B, and SNSC 145C. These content courses were designed by the Department of Social and Natural Sciences to provide a non-calculus, conceptual, hands-on/minds-on orientation to understanding physical science, earth-space science, and biological science concepts. These courses focus on specific content knowledge embedded in the provincial elementary school science curriculum (K-7) and the professors attempt to demonstrate the desired constructivist pedagogical strategies in their teaching but do not explicitly stress the pedagogical aspect.

Science Methods

The required elementary school science methods course (ED-E 745) meets 50-54 hours during 19 weeks spread over two semesters or concentrated during six weeks depending on the specific program. Student teaching experiences (practica) are embedded in the last six weeks (November-December) of the first semester and in the final six weeks (April-May) of the second semester during the regular program or the science methods course is embedded midway (November-December) during a year-long internship program. The philosophy of science

Figure 2
Science Education Component of the Elementary B.Ed. Program

ELEMENTARY SCIENCE EDUCATION PROGRAMS
University of Victoria

	Core	Concentration	Teaching Area
Year 1/2	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science

* If Grade 11/12 Science, requirement reduced. Most frequent courses SNSC 145A (1.5) - Physical Science, SNSC 145B (1.5) - Earth Science, SNSC 145C (1.5) - Biological Science

	Core	Concentration	Teaching Area
Year 3	None	**SNSC 345B (1.5)** Science-Technology-Society Issues in Science Education	**SNSC 345B (1.5)** Science-Technology-Society Issues in Science Education
		SNSC 373 (1.5) Environmental Education	**SNSC 373 (1.5)** Environmental Education
		SNSC 345A (1.5) Selected Topics in General Science	**SNSC 345A (1.5)** Selected Topics in General Science
Year 4	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science
Year 5	None	**ED-E 438A (1.5)** Computer Applications in the Instruction of Elementary Math, Science and Social Studies	**ED-E 438A (1.5)** Computer Applications in the Instruction of Elementary Math, Science and Social Studies
		ED-E 445A (1.5) Science Instruction in the Elementary School	**ED-E 445A (1.5)** Science Instruction in the Elementary School
		ED-E 445B (1.5) Contemporary Issues in Elementary Science Curriculum	**ED-E 445B (1.5)** Contemporary Issues in Elementary Science Curriculum
		ED-E 473 (1.5) Environmental Issues in Education	**ED-E 473 (1.5)** Environmental Issues in Education
	Core = 5 - 6.5 units	Other Sciences	Other Sciences
TOTAL		Core + 9 units	Core + 15 units

1.5 units equals 3 semester hours or 4.5 quarter hours

education methods is heavily influenced by the contemporary science education reforms and applied cognitive science, and curriculum and instruction are linked to an interactive-constructive perspective of teaching and learning (Shymansky, et al., 1997). ED-E 745 attempts to develop content-pedagogical knowledge and teaching strategies regarding the philosophical and psychological foundation of the science curriculum and instruction, the goals of the curriculum, inquiry skills, and authentic assessment. Contemporary articles from professional journals (*BC Catalyst, Science Scope, Science and Children*, etc.) and provincial curriculum documents (*Integrated Resource Package: Science K-7*, etc.) are used to elaborate classroom activities and discourse. Most often the educational idea under consideration is used to demonstrate the idea itself. Therefore, activities from the provincially recommended curriculum materials that are interesting and challenging to adult learners are used to illustrate the attributes of the inquiry-oriented curriculum; and instructional strategies are modeled prior to being discussed. Considerable planning takes place to ensure that students have had concrete experience with an idea before the idea is formally discussed and potential classroom applications and associated teaching strategies are described. The practica provide authentic context to apply these ideas.

Science Education Specialization

The "concentration" in science requires a further 9 units (6 courses) of science content and science content-pedagogical courses over and above the core requirements. The "teaching area" in science requires a further 15 units (10 courses) of science content and science content-pedagogical courses over and above the core requirements. Students may elect from a variety of content courses in Earth and Ocean Sciences, Environmental Studies, Chemistry, Physics, Biology, and Biochemistry. Students must complete upper-level STS, technology applications, advanced instruction, and advanced curriculum courses.

The Action Research Focus

Course Content

ED-E 445A: Science Instruction in the Elementary Schools is a 1.5 unit course focused on advanced science instruction (teaching and assessment) in kindergarten to grade 7. The course meets 3 hours per week during spring term and normally serves as the keystone course in the science concentration and teaching area for 10-15 students per year. ED-E 445A is designed to provide science education students with:

1. awareness of provincial, national and international trends in science education and science literacy.
2. knowledge and sensitivity to factors influencing the selection of instructional strategies, i.e., nature of science, nature of learner, desired outcomes, available resources, classroom and school environments, others.
3. knowledge about and skills related to specific instructional strategies.
4. ability to select, develop, implement and justify the use of specific instructional strategies.
5. leadership skills related to improving science instruction.

The seminar nature of the course allows the professor to personalize the course and to utilize a variety of human and instructional resources. Recently the *National Science Education Standards* (NRC, 1996), reprints from *Science and Children, Science Scope* and other professional journals, and reference articles and textbooks (placed on reserve in the Curriculum Library) have served as the print supplements for the course. The following topic outline and assignments were used in 1997:

<u>Topics</u>

I The Private Universe and *Times-Colonist* Article on Adult Science Literacy
Making a Difference as a Science Teacher
Nature of Science, Technology and Social Studies; Science Literacy; and Multiculturalism

II Science Education in North America and B.C.
a. NSTA Scope, Sequence and Coordination
b. AAAS Science for All Americans and Benchmarks for Science Literacy
c. NRC Standards (pp. 1 - 26)
d. BC Science Integrated Resource Package for Science (K-7)
e. Pan Canadian Framework for Science (1996 Working Draft)

III The Many Faces of Constructivist Teaching/Learning (NRC, 1996, pp. 27 - 54)
a. Information Processing
b. Teacher-Guided Inquiry
c. Conceptual Change
d. Interactive-Constructive
e. Social Constructivist
f. Radical Constructivist

IV Assessment Alternatives (NRC, 1996, pp. 75 - 103)
a. Performance Tasks and Scoring Rubrics
b. Concept Mapping and Scoring Procedures
c. Think Alouds
d. Negotiated Criteria

V Content Standards (NRC, 1996, pp. 103 - 172)
a. K - 4 Content Standards
b. 5 - 8 Content Standards
c. Analysis of B.C. Science Integrated Resource Package for Science (K - 7)
d. Exploring New Curriculum Resources (FOSS, AIMS, STC, Insights)

VI Basic Inquiry Teaching and Learning Approaches
a. Generative Approach
b. Learning Cycle
c. Conceptual Change
d. Promoting Social Discourse
e. 4-part Teaching Strategy

VII Science Instruction Utilizing Alternative Approaches (Student-Presented Workshops)
a. Guided Imagery
b. Role Playing
c. Games
d. Simulations
e. Models, Analogues and Metaphors
f. Peer Teaching and Learning
g. Cooperative Learning
h. Structured Controversy
i. Case Studies
j. InterNet
k. Computer Assisted, Microcomputer-Based Laboratory, etc.
l. Projects
m. Science Camps: Science Venture, CRD Parks, Swan Lake
n. Science Fairs
o. Problem Solving: Science Odyssey, Invention Conventions, Science Olympics
p. Others

VIII Reading-to-Learn: Explicit Content Reading Instruction in Science
a. General Plans
b. Teaching Sequence: Do First, Read Later
c. Strategy Development Embedded in Authentic Inquiry

IX Writing-to-Learn: Content Writing Activities in Science

<u>Assignments</u>

1. Term Paper
A ten-page position paper on an assigned topic. The paper will include 10-15 references. Your expert-group composed of students with the same topic will share ideas and resources, while the other expert-groups will provide reactions and editorial feedback on drafts #1 and #2 of your paper. The instructor will grade draft #3. A draft #4 will be allowed for those students wishing to improve their grade.

Topics:

A. Nature of science, social studies, mathematics and technology. How should they influence what we teach and how we teach Elementary School science.
B. Multi-culturalism. How should it influence what we teach and how we teach Elementary School science.
C. Cross-curricular aspects of literacy and a conceptual framework for science literacy. (30 points)

2. Class Presentation
A 30-minute workshop on an instructional strategy (see topic VII). A substantive class hand-out that provides description, research support and application of the strategy is required. (20 points)

3. Teaching Internship in Science
A three-week science teaching project at an elementary school (TBA). Two students will work with a classroom teacher to identify, develop and deliver a science unit consisting of 6-10 hours of instruction and evaluation. (30 points)

4. Examination
Two (2) hour comprehensive examinations. A pool of questions will be provided in advance and the examination will be selected from these questions. (20 points)

Assessment and Workshop Components

ED-E 445A attempts to develop science education in five ways: knowledge about science education reforms, curricula, instruction, and assessment; communication skills (oral and written); workshop experience; collaborative planning; and reflective practice. The specific foci of this action research were the assessment and workshop activities.

Students in this course hold or could hold a Standard Teaching Certificate (Level 4) since they have successfully completed their student teaching and four years of post-secondary education. In fact, many of the students are serving as teacher-on-call (TOC) in local school districts while completing their year five course work. This means that they are well informed about science education in local schools and are somewhat more self-confident, futuristic and risk-takers than most preservice students. They realize that not everything addressed in the course will be usable the next day and that some of the benefits of the course will be realized as they become practicing teachers.

With such students several activities are possible that may not be appropriate with other students—collaborative essay writing negotiated criteria for and peer-evaluation of student-led workshops and science teaching internships. The collaborative writing, task has enhanced the students' writing ability and their willingness to publicize their ideas (Yore, 1996). The internship was developed as a platform to enhance preservice teachers' science teaching experience and to promote school science leadership (Yore, 1997).

The focus of this study was the use of negotiating criteria for an elementary school science workshop and the use of these criteria in the peer-evaluation of a student-led workshop. The eleven students in this course had experienced professional development workshops during their university courses and student teaching experiences. They had reasonably well-articulated expectations of effective and ineffective workshops.

The professional development standards were used to provide a rationale for the workshop assignment, and the changing emphasis in professional development was used to crystalize the discussion (NRC, 1996, p. 72). Small groups of 3 or 4 students were asked to develop a list of attributes of an effective elementary school science workshop and to develop a rationale for why the attributes were important. Large- group discussion integrated the small-group results with the NRC standards to provide greater clarity and a local context. During these negotiations three general dimensions were identified for effective workshops:

1. Practical ideas based in exemplary practice, current curriculum, and contemporary theory: experiences, illustrations, and examples.
2. The presentation should demonstrate effective teaching practice and should help participants enhance their practice: multimedia, constructivist, concrete hands-on/minds-on, and focused.
3. Handouts should provide participants with a permanent record of the experience, reinforcement and enrichment of their understanding, and link the workshop to other resources: print copy of ideas, explicit connections to theory, references to science journals, and instructional resources.

Further discussion of these dimensions indicated that they were not all of equal importance. The group decided to weight the scoring procedures to more accurately reflect each dimension's importance. The decision was made to assign 40% of the total score to the first dimension and 30% of the total score to each of the second and third dimensions and that the holistic rating would be the composite of the three dimensions scores.

A draft rating chart was developed by the professor based on the group decision and submitted to the class at the next meeting for their approval. At this meeting a few minor changes were made to clarify the three dimensions. It was decided to adjust the grading procedure to anticipate that not all students would rate each student-led workshop since some students might be absent and it would be unreasonable to expect students presenting a workshop on a given day to rate other workshops given that day. The class decided to base the course grade on the average composite rating of five randomly selected peer-evaluations and the professor's evaluation. With the established criteria the student-led workshops were prepared over the next three weeks. The eleven workshops addressed a variety of science teaching ideas:

- Science beyond the classroom
- Cooperative learning approaches
- Peer teaching
- Case studies
- World wide web
- Guided imagery
- Problem solving
- Role plays
- Science fairs
- Analogues, metaphors and models
- Mad Science ® Canadian company

Not every topic was equally easy to explore in a 30-minute workshop. Therefore, a variety of workshops was presented.

Results

The effectiveness of the negotiated criteria and peer-evaluation of the student-led workshop was documented with instructional artifacts produced by the students (class hand-outs), professor's journal notes, observations, peer-evaluations, professor's evaluations, and students' course evaluation comments. Qualitative (constant comparison) and quantitative (descriptive statistics, correlations, and T-tests) analyses of these data sources were used to explore the students-professor inter-rater reliability and assertions regarding the value and improvement of the activities.

Seven to nine students and the professor rated each student-led workshop on the three dimensions negotiated earlier (Table 2). A composite rating was determined by summation of the analytical dimensions. The 92 peer-evaluations were compared with the professor's evaluations to establish inter-rater agreement and reliability. Agreement of ± 0.5 for the analytical dimension ratings was achieved for 60% of the ratings in the first dimension, 53% of the ratings in the second dimension, and 70% of the ratings in the third dimension. Only 55% of the composite ratings were within ± 1.0 agreement. When the comparison was limited to the 7 to 9 peer-evaluations and the professor's evaluations for an individual student-led workshop, the ± 0.5 agreement ranged between 29% to 100% of the ratings in specific dimensions and 29% to 78% agreement (± 1.0) for the composite rating. Greatest agreement was found for demonstrating effective practice and enhancing participants' practice (dimension 2), closely followed by agreement on the quality of the print resources provided (dimension 3). The least agreement was found for the composite ratings. Complete agreement of all dimensions and the composite was reached on 4 workshops, 75% agreement was reached on 2 workshops, and 50% agreement was reached on 5 workshops. Inspection of these groups of workshops revealed no common characteristics in quality since the composite ratings appeared to be distributed across the range of values.

Individual students' ratings were generally higher than the professor's rating (57% for the first dimension, 48% for the second dimension, 59% for the third dimension, and 70% for the composite). About a quarter of peer evaluations exactly matched the professor's rating for the analytical dimensions (25%, 23%, 24%) while only 3% of the composite ratings matched exactly. Between 17% and 29% of the students' ratings were lower than the professor's rating. Analyses of the average ratings for the analytical dimensions and the composite and the professor's ratings indicated ± 0.5 agreement for 64% of the ratings in the first dimension, 91% of the ratings in the second dimension, and 82% of the ratings in the third dimension, while only 36% of the composite ratings agreed within ± 1.0.

Correlations of the students' ratings and professor's ratings across all workshops for specific dimensions and composite ratings revealed significant ($p \leq 0.05$) correlation coefficiencies for two analytical dimensions (dimension 1 = 0.42, dimension 3 = 0.44) and the composite (0.49). T-tests of the differences between peer-evaluations and professor's evaluations for the 11 workshops revealed that 4 differences for dimension 1 were significant ($p \leq 0.05$), 3 differences for dimension 2 and 3 were significant, and 5 differences for the composite were significant. These results indicate that a substantial majority of the peer-evaluations were similar to the professor's evaluations.

Qualitative comments were provided by the students after the completion of the course according to departmental procedures. These qualitative data were examined to identify general patterns for the negotiated criteria, student-led workshop, and peer-evaluation components of the course. The following assertions were revealed from the student comments.

Negotiated criteria for the student-led workshop as learning experience was worthwhile and practical.

- *Worthwhile and a good example of how you can include students in their own evaluation. Let us know what was expected in workshop.*
- *I thought this was an excellent idea. We all knew what was expected and how each part of the workshop was weighted markwise.*

Table 2
Average, Range, and Number of Peer Ratings and Professor Ratings of Student-Led Workshops

Student ID Number		Dimension 1	Dimension 2	Dimension 3	Composite
001	Peers	7.4, 6.5-8.0 (9)	5.5, 5.0-6.0 (9)	5.7, 5.0-6.0 (9)	18.7, 16.5-20.0 (9)
	Professor	7.5	5.0	5.0	17.5
002	Peers	7.2, 6.5-8.0 (9)	5.1, 4.0-6.0 (9)	5.7, 5.0-6.0 (9)	17.9, 16.4-20.0 (9)
	Professor	7.0	4.8	5.0	16.8
003	Peers	7.1, 6.0-8.0 (7)	5.3, 4.0-6.0 (7)	5.7, 5.0-6.0 (7)	18.1, 16.0-20.0 (7)
	Professor	6.0	4.8	5.5	16.3
004	Peers	6.6, 5.0-7.5 (9)	4.9, 4.0-6.0 (9)	5.1, 5-6.0 (9)	16.6, 13.5-20.0 (9)
	Professors	5.5	5.0	5.0	15.5
005	Peers	7.0, 6.0-8.0 (8)	5.2, 4.7-6.0 (8)	5.0, 4.5-5.5 (8)	17.2, 16.0-19.0 (8)
	Professor	6.5	5.0	4.8	16.3
006	Peers	6.5, 6.0-7.5 (8)	5.1, 5.0-5.5 (8)	5.1, 4.5-6.0 (8)	16.8, 16.0-19.0 (8)
	Professor	5.5	5.5	4.8	15.8
007	Peers	7.2, 6.5-8.0 (8)	5.3, 5.0-6.0 (8)	5.7, 5.0-6.0 (8)	18.1, 17.0-19.5 (8)
	Professor	7.0	5.0	5.5	17.5
008	Peers	6.8, 6.0-7.5 (8)	5.1, 4.0-6.5 (8)	5.2, 4.5-6.0 (8)	17.0, 15.0-19.5 (8)
	Professor	6.0	4.8	4.8	15.6
009	Peers	6.8, 5.5-7.0 (9)	5.3, 4.5-6.0 (9)	5.0, 4.5-6.0 (9)	17.0, 15.5-20.0 (9)
	Professor	6.5	5.0	5.0	16.5
010	Peers	5.6, 4.0-6.0 (8)	4.4, 4.0-5.0 (8)	4.8, 4.0-6.0 (8)	14.8, 13.0-17.0 (8)
	Professor	6.0	4.8	4.8	15.6
011	Peers	7.3, 6.5-8.0 (9)	5.3, 4.0-6.0 (9)	5.5, 5.0-6.0 (9)	18.1, 16.0-20.0 (9)
	Professor	7.0	5.0	5.0	17.0

- *Good—made it very clear to us what was expected since we created the criteria.*
- *Good idea. Criteria were clear and reasonable.*
- *The negotiated criteria worked well—I knew what I had to do and how to mark.*
- *Good to be precise on what will be evaluated.*

Suggested changes to the negotiated criteria experience: Reinforce accountability and consider diversity of workshop topics.

- *Good experience—needs accountability on the part of peer evaluation to be built in somehow.*
- *Good idea, however, keep in mind that different topics lend themselves to different criteria, i.e. not all topics can be multi-media or hands-on.*
- *It would be helpful to revisit these after the workshops because some sounded good when we talked about them in the abstract but they did not translate as easily to the real thing.*

Workshop as learning experience was useful.

- *Very useful, lots of good ideas for teaching science in a nontraditional method.*
- *Very useful. I would refine the product if I was to give the workshop again.*
- *Useful experience in setting up and delivering the information.*
- *Great learning experience. Continue (it as an assignment).*

Workshop as leadership experience improved self-confidence and presentation skills.

- *Very useful. I definitely feel capable of putting on a workshop for my peers.*
- *I enjoyed running a workshop for my peers. It added to my teaching experience.*

Suggested changes to the workshop assignment: Broaden range of topics and more time for workshop.

- *Excellent, more input as to what workshop would be about. I would have liked to have chosen my own topic.*
- *Useful, but some topics were things I had seen many times before. Perhaps a broader range of topics and push for things less familiar.*

- *It is always useful to be a part of peer workshops. I would have liked these to start earlier and maybe have only 1 or 2 each day. Otherwise, it can be overwhelming.*
- *I think this worked well. More time to present the workshop would deepen the knowledge gained but it was a good 'taste.'*

Reflections

The results of this study must be considered in the context of the size and attributes of the students involved and the unique characteristics of the course and program explored. The 11 students were highly motivated, above average ability, mature, experienced, and self-directed. There was little variation in their performance and academic achievement (B+ to A). The seminar nature of this year 5 course allowed a great deal of input from students with rich and diverse backgrounds and allowed the professor flexibility to respond to their input. The specialized nature of the program provided a common focus for the students—a desire to be an elementary school science teacher.

The overall reaction to the results were positive in that reasonably valid and reliable evaluation data were produced within a generally effective learning experience. Clearly these activities addressed many of the science teaching, assessment, and professional development standards (NBPTS, 1994; NRC, 1996). I am satisfied that these experiences provided authentic learning experiences for these preservice teachers and that these experiences were reasonable models of contemporary assessment and professional development. Negotiating criteria for the workshop illustrated how an interactive-constructive teacher can utilize student ideas in a shared-control context. Students' ideas were explicitly valued and their ideas made an explicit difference in the grades awarded for the student-led workshop. I believe the addition of the negotiated criteria and peer-evaluation have made this course a more accurate example of the science teaching described in the *National Standards of Science Education* (NRC, 1996).

It was not surprising that peer-evaluations were higher than the professor's evaluations due to the raters' vested interests and their compassion for their fellow students. I had anticipated the deviations would be distributed somewhat more evenly above and below my ratings and that the deviations would cancel one another in the average rating. The mechanism to use the average of 5 peer-evaluations selected randomly from those submitted for each student-led workshop and the professor's evaluation to calculate the composite rating for grading purposes was fortunate. Limiting the number of peer-evaluations maximized the weighting given the professor's rating (1 of 6 rather than 1 of 8, 1 of 9 or 1 of 10) and thereby controlled the magnitude of the deviation between the averages and the professor's ratings. This procedure resulted in much higher agreement than using all the peer-evaluations to calculate the assignment grade.

Only one student expressed concern about the composite score for the student-led workshop assignment. One out-lying set of ratings selected appeared to indicate a less than complete evaluation by the peer. The appeal was considered, and a new random set of 5 peer-ratings was selected to calculate this student's grade. The procedure eliminated the out-lying set of ratings but only minimally increased the composite score. This result addressed the student's concern without totally disregarding the negotiated procedures.

The benefits of using negotiated criteria and peer-evaluation out-weighed the disadvantages. The use of constraints to minimize the deviations and the limitation of peer-evaluation to a single assignment placed the professor in reasonable compliance with the university's grading policy. The full benefits of negotiated criteria were not achieved in this limited use. In the future, peer-evaluation could be increased to include one more assignment—the collaborative writing assignment.

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EXTENDING OUR NETWORKING AND PROFESSIONAL DEVELOPMENT AS SCIENCE TEACHER EDUCATORS AND RESEARCHERS: A FORUM BY AND FOR GRADUATE STUDENTS

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Origins and Evolution of the Idea for A Graduate Students' Forum

At one of the evening receptions of the 1997 annual meeting of the Association for the Education of Teachers of Science (AETS) several graduate students from the University of Southern California (USC) and the University of Georgia (UGA) compared their program experiences. Their stories revealed great differences in their preparation for assuming the roles associated with being a science teacher educator and researcher. They asked themselves, "Who else attending the conference was a graduate student? How did graduate students network and engage in professional development opportunities, especially students who were "shy," in smaller scale doctoral programs or at institutions where the faculty did not "take students under their wing" and introduce them to other science teacher educator/researchers?

When the conversation ended, the idea for a forum by and for graduate students with the aim of establishing a formal structure for networking, professional development, and learning, had been conceived. From June through December of 1997 the conversation grew to include students at Oregon State University, Purdue University and Pennsylvania State University, as well as other students at UGA.

Each year's conference provides an opportune time to gather and share experiences in an environment which transects institutional boundaries. To the best of our knowledge, putting together a forum such as this is a first in AETS history. There has not been an attempt to formalize a structure for graduate students' networking and professional development – to bring issues, dilemmas, challenges and questions to the fore about what it means to become and be a science teacher educator/researcher. We hope that sponsoring this session marks the birth of a tradition within AETS and that graduate students assume leadership roles for planning a session at future years' annual meetings of AETS.

The Forum of 1998: Extending our Networking and Professional Development as Science Teacher Educators and Researchers

Two former and four current doctoral students sponsored this year's session. We highlighted three broad dimensions of the professional life of science teacher educators/researchers. Each of these dimensions was addressed from two individuals' perspectives:

1. Transitioning from other worlds into the professional world of science teacher education: Two multicultural perspectives (by B. Rascoe and H. A. Wang)
2. Resolving dilemmas encountered in undergraduate teaching and student teacher supervision (by A. Kemp and K. Wieseman)
3. Challenges of negotiating roles as educational researchers (by L. Bryan and V. Dickinson)

Metamorphosis of a Gray Female with Reflection Syndrome (by Barbara Rascoe)

My journey began on a small farm in North Carolina where I behaved differently or so I was told. My actions were termed different or weird because of my daily scavenger hunts. I knew at the age of four that the study of science was to be my destiny. The pursuit of my destiny has entailed a journey that has led me to the Science Education Doctoral Program at the University of Georgia. Using physical science and biological concepts, I shall attempt to explicate my experiences at UGA. These analogies or, if you must, metaphors will not be complete, but will hopefully provide enough information to give readers the essence of empathy.

In biology, the term metamorphosis is used to describe the lifestyle of animals that live in very different habitats or environments during their life span. The metamorphic animal undergoes a resurgence of development that transforms the animal so as to have different mouth parts. For in each new habitat, the diet is different. Reflecting, I shall explain the differences between my previous habitat and diet and my present habitat here at UGA and diet. The main purpose, however, of this endeavor is to use the process of metamorphosis to help me express personal feelings and reactions that ensued in the change from high school biology teacher to that of a graduate student in a doctoral program.

The process of metamorphosis involves the resurgence of development that transforms one stage of an animal into a different stage. The morphological appearance of the animal in the second stage may or may not be different. For this discourse, my first stage begins with that of a high school biology teacher. The habitat or setting was a high school in a very small town and the menu consisted of other teachers, students, science courses, and science competition. Reflection occurred on a daily basis because of the need to change or alter lesson plans on the spot or over the course of the summer so as to align teaching with new objectives. The high school experience, at times, forced me to negotiate some changes in my conceptual frameworks of epistemology and pedagogy.

Presently, my new habitat in situated in a university setting and the menu consists of people and graduate courses. The people on this university menu are advisors, other graduate students, as well as a host of undergraduate students aspiring to become future teachers. The graduate courses on the menu vary and list dishes such as research, statistics, scientific literacy, and science. I am not morphologically different in terms of color, but the resurgence of my development has provided modified mouth parts to help ingest the graduate courses on the menu. One of the main courses here at UGA is the study of research relevant to the teaching of science. My reactions to this meal will be analogous to the processes of digestion (biology) and reflection (physical science).

The process of digestion requires a system with a large surface area on which enzymes can break down food ingested which, in my case, is the study of research relevant to the teaching of science. The process of reflection requires looking back (with mirrors) to analyze my perceptions of the sizes of each "bite" of the study of research relevant to the teaching of science. In reflection, some of the mirrors are concave and my perception is a virtual image of a bite that appears smaller that the actual bite. Other mirrors are convex and my perception is a virtual image of a bite that is larger than the actual bite. My perceptions of these images or bites that appear either smaller or larger than life do not digest very well. If these exaggerated images of the new ideas and new concepts ingested during the study of research relevant to the teaching of science are digested, the process takes much, much longer. Prolonged digestion sometimes causes me to experience "reflection syndrome." I shall attempt to explain what occurs during prolonged digestion and list some of the symptoms experienced during reflection syndrome.

During prolonged digestion, enzymes are attempting to break down each exaggerated bite so that it fits into my conceptual framework of "how to teach science." Breaking down new ideas and concepts represented by these exaggerated, virtual images results in reflection syndrome. Some of the symptoms of reflection syndrome are disbelief, awe, headaches, and arrhythmia. In the course of prolonged digestion, some new concepts are broken down to the extent that they can be absorbed or assimilated into my present conceptual frameworks. New concepts that do not fit into my conceptual frameworks are eliminated. But elimination of new concepts and ideas that were not initially digested does not preempt future absorption or assimilation into my conceptual frameworks. So what changes have to occur to elicit future digestion of the eliminated ideas and concepts?

My digestive system is presently adapting to the extent that it will absorb more and/or eliminate less of the new ideas or concepts presented in my graduate program. This adaptation process will also mean that I, as an organism, will have molted or metamorphosed into a different sage with slightly different mouth parts, modified conceptual frameworks, and new frameworks, but still gray in color. In any given habitat, and especially in a new habitat, organisms frequently react to other organisms that are different. My gray color does elicit reactions.

Gray is how I should appear phenotypically because I am a mixture of Caucasian (White) and African American (Black) ethnic groups. I have chosen not to experience racial discrimination. I have chosen not to see that I am sometimes eliminated from group discussion with eye contact and body language. I have chosen not to see that my suggestions are sometimes shrugged off as irrelevant only to become a great idea later if broached by a nongray person. As my journey progresses and my metamorphosis is incomplete, I await each new molt. On the road to becoming an effective teacher of science and science teachers, each new molt will result in the emergence of a new stage replete with a new habitat, new menus, and new reactions, and maybe reflection syndrome as I continually negotiate changes in my conceptual frameworks of epistemology and pedagogy.

On Becoming a Science Educator in the United States:
Reflective Thoughts from an Oriental Voice (by HsingChi Wang)

The "Puzzle Place" is a public broadcasting television show for children with messages showing young learners how to appreciate the diverse cultures in which we live. However, for me, what the show considers multicultural is merely multiethnic. Multicultural issues go beyond the color of the skin, race, gender, nonverbal behaviors, or even socioeconomic status. They encompass all of the factors of a multicultural classroom, including individual learning traits.

Culture describes what can exist on the level of an individual to what is shared by a group, that is from individual personality or characteristics to family and organizational culture. A classroom is an example of organizational culture. In every classroom individuals hail from different family cultures and project diverse learning traits. Whether teaching in an all-Asian, all-Caucasian, or a "puzzle place" classroom, a teacher must recognize that each child brings a different learning style and behavior, and problems and issues.

I question my personal understanding of multicultural education. I would like to know what "ingredients" or "glue" are needed to put "puzzle pieces" together. And, I would like to find out what we teacher educators need to do in professional development for teachers to further our understanding of what multicultural means. I hate to see the advocacy of the Puzzle Place television program's concept of multicultural becoming a popular and unquestionably accepted fad in educational reform.

Expectations in Classrooms

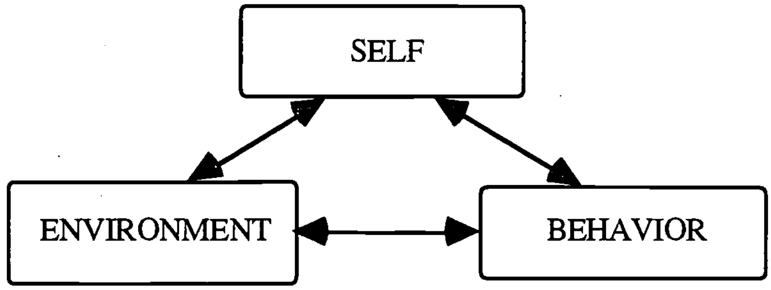
Increasingly, race, gender, nonverbal behaviors, and socioeconomic status, as they pertain to teacher expectations, are the focus of discussion in teacher education communities (Saunders, 1997). One form of teacher expectations is called the "Pygmalion Effect" (Rosenthal, 1991), commonly referred to as the "self-fulfilling prophecy." This construct describes how teacher expectations of students are closely associated with students' learning outcomes – that student performance will match teacher expectation of performance. Sanders (1997) pointed out that gender inequity in classrooms is partly linked to a self-fulfilling prophecy resulting from gender-biased attitudes. Didham (1990) found that the teachers are generally correct in their judgements of what a student needs, however, unconscious bias or treatment of particular children could lead to self-fulfilling prophecies.

Both Sanders and Didham argued that the role of self-fulfilling prophecies were easily ignored within interactions in the classroom setting. These authors proposed that this phenomenon should be addressed in education courses prior to student teaching. Furthermore, although teacher education textbooks address the topic of self-fulfilling prophecy, the controversy concerning the topic is not conveyed (Fetsco and Clark, 1990). I suggest that oversimplification in textbooks could be dealt with by having student teachers conduct classroom observations about the phenomenon, and generate appropriate strategies to rectify these issues. I also raise the issue that self-fulfilling prophecies potentially play a significant role in the academic success of Asian students in American schools and universities.

A Social Cognitive Model for Multicultural Education

Bandura's (1986) social cognitive theory on self-regulation provides a different view of teacher/student interactions in the classroom and offers insight into what can happen in multicultural classrooms. The social cognitive theory on self-regulation identifies three dyadic sets of reciprocal relationships among three factors, "Self Perception," "Behavior," and "Environment," as the influences on teacher-student communication and responses to each other. The Triadix Analysis of Self-Regulated Functioning Model (see Figure 1) can provide educators with a better understanding of interacting factors which produce students' ultimate learning behaviors.

Figure 1
A Triadix Analysis of Self-regulated Functioning Model



Each student comes from a different environment. The student's environment influences and is influenced by his or her perception of self. In turn, the student's learning behavior is defined by these images of self which have been formed in diverse environments. Eventually, a student's behavior sends messages to the teacher who, interpreting these messages, reciprocates via interactive behaviors directed toward the student. This cycle of interactions can sometimes be the source of misunderstanding and confusion, especially when teacher and student's cultures are vastly different, such as what can happen when "east meets west."

East Meets West

Teachers in classrooms everywhere (e.g., the United States, Europe, or Taiwan) may find that there are students who barely open up and participate in classroom discussions. The teacher may invite such students to see her or him as a friend, yet, these students continue to keep their distance. Many times these are Oriental students. An explanation offered in the research literature is that Oriental students are shy, thus they will not speak aloud in front of others and rarely participate in teacher-initiated activities outside the classroom. I present an alternative view – an Oriental view to explain this phenomenon – and draw from Cleary's (1991) translation of Confucius' thoughts. About his foremost disciple Confucius once said,

> I can talk to him all day, and he doesn't contradict me, as if he were ignorant. From what I observe of his private life after he has gone home, however, I found he has the ability to apply what he's learnt. He is no ignoramus. (p. 55)

This quote portrays an image of a student who is obedient and respectful. Respectfulness is highly valued in Chinese culture. In fact it is one of the five virtues highly esteemed by Asians.

As a teacher is one of the five figures toward whom one must pay ceaseless respect, Orientals are taught to listen to their teacher's knowledge when in his or her presence. The attitude toward the teacher is respect and, more or less, "fear." The idea of a teacher as our learning facilitator/partner is quite alien to us. After class a student is expected to digest the knowledge and work hard to present their best work to their teachers. The more a student cares what the teacher thinks of her or him, the more critical that student is about her or his learning outcomes, and the longer the student waits before presenting his or her ideas. To others who do not understand this dynamic, it appears that the Oriental student is slow in generating the work, nor cares to talk to the teacher outside the classroom.

While tradition exists, so with the passage of time have there been changes. Today's Oriental students may have different attitudes about teacher/student roles and establish different relationships with their teachers. A teacher may have Oriental students who are quite outgoing and actively participate in their classes. Like students from other cultures, they might pose questions regarding their teachers' lectures.

I hope that by sharing Cleary's translation of Confucius' thinking and its meaning from an Oriental perspective, I heighten awareness of multiple explanations for a shy and quiet type of student behavior, particularly if the student involved is Oriental. Furthermore, I share the following personal story to illustrate the power of tradition and the relevance of multiple explanations for student behavior.

<u>I Arrive and Attempt to Adapt to American Models of Teacher-Student Interactional Patterns</u>

When I first arrived in the United States, I found it difficult to consider teachers as friends, regardless of their openness for this type of relationship. My respect of them held me back. I waited and waited before talking with them about my work, as I was concerned that they would think less of me if I bungled the tasks which I had been given to accomplish. My professors had to repeatedly ask me to report my progress. At the same time, my viewpoint was that I had just one more item on which to improve before presenting my work to them.Though, I have gradually become attuned to American teacher-student interactional patterns, the idea of "teacher as a friend" still perplexes me.

Krashen (1992) reported that a person's consciousness about outcomes of performance inhibited Second Language students' language performance. I am tangible and vivid evidence of such a conclusion. While I feel very comfortable speaking to my friends, whenever I have to talk to my professors, I am embarrassed. A feeling of lack of adeptness in my English language skills has been a barrier.

By sharing my story, my intent is not to find excuses for Oriental students' interactional patterns with their teachers or their approach toward completing assignments. Instead, I hope to contribute to our understanding of why some students might appear to show indifference or disinterest in developing friendly relationships with their teachers. It may be that such behavior signals a time to have a heart-to-heart conversation with the student to find out about and ease any possible anxiety.

Significance of Collegial Support and Teaching Experience During Culture Shock

As an international student, I found that the cultural shock of being in America, as well as all the intellectual conflict from shifting into social science with only a science background, was almost too much to bear. As a consequence, after completing my master's degree in one year, I thought about leaving the United States. During this time, I went to speak with my adviser about the idea of continuing my studies at the doctoral level. He told me, "Without teaching experiences and not being educated in the K-12 educational system of the United States, I would not recommend that you continue your studies." It was difficult for me to hear this statement and to look at where I stood in my career path. However, I also felt challenged.

I believed that diligence could make up for any weakness! This belief, what I also thought of as naïvete, led me to new difficulties and challenges. I found that I was having to choose topics for class projects in my doctoral courses that had no connection between my course of study and the field (i.e., classrooms). The topics were "more philosophical," or, using teacher jargon, "useless" to practitioners. Connections to the field and everyday practice is really important. I needed to make concrete connections to the field so things would make sense. I asked myself, "How can I become a teacher educator if I don't have any teaching experience?"And, I wondered what others did about this issue!

At this time in my program two colleagues encouraged me to present my research in conferences. "Me?," I thought, "They must be joking!" I could not even make myself clear to my adviser. How could I make a speech in front of an audience of English speakers? But, my colleagues continued their tremendous encouragement and support and I began making presentations at various conferences. Attending a presentation I made on the Third International Mathematics and Science Survey (TIMSS) and Science Standards was a teacher from the Los Angeles Unified School Distric (LAUSD). Subsequently she invited me to talk to a group of LAUSD teachers. From this opportunity I developed my first connections with real school settings. I will never forget my friends' confidence in me. I also know I can never thank them enough.

As a researcher, I read reports on the absence of peer support among classroom teachers. Perhaps this is because we, teacher educators, did not provide enough venues, vehicles or models to encourage and help student teachers cultivate such behaviors. How might we approach this tendency? At the University of Southern California, our student teachers are paired up to co-teach. They invite their partner to observe a specific teaching behavior – questioning style, for example – and then debrief after the observation about the observed behavior. They discuss strategies they might adopt for future instruction.

As graduate students, my two wonderful colleagues, Joanne Olson and Amy Cox, have also paired up to co-teach their courses. By listening to their conversations, I came to realize that it was the continual communication and information exchange that was so valuable to their teaching. Through these interactions they built a foundation of mutual trust that enabled them to give feedback to each other. Lastly, in the California Science Project (CSP), of which I am now a leadership cohort member, our professional development programs make sure that the teachers we work with have sufficient time to talk to each other and co-plan their lessons. Giving teachers this time during the in-service workshop is an intentional and critical component.

Conclusion

To conclude my report, I pose several issues for discussion:

1. What are the types of discussions we should be having in our teacher education communities about the interaction of culture, instructional materials, teaching strategies, and ways to develop intercultural awareness in students and faculty, to facilitate application in real classroom settings?

2. Should teacher education institutions admit international students to teacher education program? And, if so, what assistance should be provided?

3. What strategies need to be built into teacher education programs to strengthen student teachers' communication skills? What are effective peer support strategies that benefit student teachers?

The Roles of Student Teacher Supervisors (by Andy Kemp)

As graduate students, we find ourselves in new roles. One of these, in my case, has been as a university supervisor for secondary science student teachers. A university supervisor has several roles in dealing with student teachers. Like any teacher, the supervisor must instruct, support, and evaluate the student. These roles are not always complementary. Which supervisory role deserves priority – instruction, support, or evaluation? I feel that in the case of supervision, it is the evaluation side, not the teaching or support sides, which has priority--and for a good reason. We cannot allow these students to fail or to muddle through. I would be interested in hearing whether a case can be made for instruction or support as the more important roles.

Another question I have is how much authority is (or should be) invested in a graduate supervisor? I have been fortunate enough not to have any particularly bad student teachers. But I often wonder what I would do if I had a particularly weak (wobbly) student teacher. How can we justify our evaluations so that they will hold up in case we need to pull the student teacher out?

Should a person receive formal training before supervising student teachers? I think a person should receive training before being asked to supervise student teacher. Such training would address questions such as what knowledge, skills, and values can a beginning teacher legitimately be expected to possess before teaching? What should they be able to do (at a minimum) by the end of their student teaching experience? Also important is the related question of how can you assess whether or not they possess or acquire these bits of knowledge, abilities, and values during their internship?

Training would reduce anxiety for a supervisor, and increase the support the supervisor can give. Training would protect the student teacher's right to have the best possible education/learning situation. Training would result in better science instruction and therefore would improve student achievement. What sorts of training for graduate supervisors exist, and how adequate is the instruction? I do not know about other graduate students, but I did not receive very much training for this role. I believe that like anything else, you have to learn how to supervise. There is the school of hard knocks, and then there is the formal path to learning. I think the latter is preferable, but I wonder how prevalent it is. Could a lack of formal supervisory training lead to less well-qualified science teachers as a result of mediocre student teaching experiences?

What methods are used in universities for conducting student teaching and practicums? At the University of Georgia, we assign one supervisor per student teacher, and place the student teachers in separate rooms and schools under the direction of their own personal cooperating teachers for 10 weeks. (We do not have very much control over the assignment of a student to a school or teacher.) About every two weeks, we (university supervisors, student teachers and interested cooperating teachers) hold a seminar for our entire group of student teachers at the university. I would be interested in hearing about the models used at other universities, and discussing their strengths and weaknesses.

In conclusion, I have a particular interest in disussing the following questions:

1. Which supervisory role deserves priority instruction, support, or evaluation?

2. How much authority is (or should be) invested in a graduate supervisor?

3. Should a person receive formal training before supervising student?

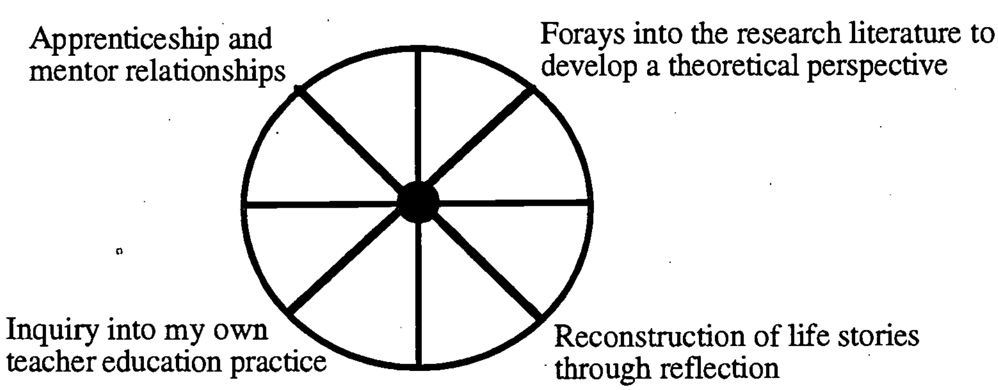
4. What sorts of training for graduate supervisors exist, and how adequate is the instruction?

5. What methods are used at your university for conducting student teaching and practicums?

<u>A Journey of Becoming a Science Teacher Educator:
Learning to Teach and Teaching to Learn (by Katherine Wieseman)</u>

My journey of becoming a science teacher educator overall may be characterized as a process of learning to teach and teaching to learn. A meaningful way to represent this journey is through use of a metaphor. The metaphor meaningful to me at the current time is that of a wheel having individual spokes, like that of a bicycle wheel. This wheel has the possibilities of spinning or remaining still. Each component of the wheel symbolizes some dimension of my journey. The spokes represent stories and lessons – past, present and future. The rim represents interdependence, and the hub represents holism and integration. Typically the wheel is in motion, like the stream of human interaction constituting the world of education. However, when the wheel is still, it is possible to distinguish individual spokes -- reflect, re-construct and express stories past and present in an effort to identify the lessons that each teaches. For my contribution to this forum, I single out one spoke – the one labeled "apprenticeship and mentor relationships" (See Figure 2).

Figure 2
A Metaphor for My Journey: A Wheel with Spokes -- Spinning and Still



689

A Story of Mentor Relationships

Mentorship has been classically defined as a "close, intense, mutually beneficial relationship between someone who is older, wiser, more experienced and more powerful with someone younger or less experienced" (Jeruchim & Shapiro, 1992, p. 23). The traditional conception of mentorship has been based on a male to male relationship, where both males give and receive, and regard the relationship as a way to achieve power (Jeruchim & Shapiro, 1992). Embracing qualities such as protective, nurturing, supportive, aggressive, assertive and risk taking, a mentor might assume roles including friend, teacher, coach, guide, advisor, guru, and counselor (Jeruchim & Shapiro, 1992; Newton, Bergstrom, Brennan, Dunne, Gilbert, Ibarguen, Perez-Selles & Thomas, 1994). Does this conception of mentorship fit with a contemporary woman's situation? Jeruchim and Shapiro propose that mentorship involving women needs to be differently conceptualized. They suggest that the age differential and the idea of a single mentor, inherent in the classical definition, might not be necessarily appropriate in mentorship involving women.

Jeruchim and Shapiro's suggestion (1992) for multiple mentors has been applicable to my situation, albeit the focus of my discussion will highlight one ongoing mentor relationship. For me, mentorship relevant to becoming a science teacher educator began long before I walked into the hallowed hallways of the College of Education at the University of Georgia. I was fortunate to have colleagues (a Title I Reading Consultant and a high school English teacher) who encouraged me in beginning a move from classroom science teaching to university-based science teacher education. After my arrival at the University of Georgia I experienced several "apprenticeships" in my roles as teaching assistant or co-instructor in methods courses for elementary and middle grades teacher education students. I also actualized my commitment to establishing mentor relationships with different faculty members in the department. One person, David, has been especially prominent in this role.

The mentorship story that I share begins during my first opportunity in university-based teaching: I co-taught a middle grades life science methods course with David. As part of a graduate course assignment and also because I wanted a written record of this experience, I kept a journal. The journal excerpt which I will share was written when David and I were getting to know one another. We had just begun to engage in discussions about science teacher education issues. I considered myself, in some way, to be a colleague with faculty in the department. As a result of my eleven years of classroom teaching, I believed that I had expertise in certain areas of science education that the university professors might not have. So, I had something valuable and worthwhile to contribute. Also, I was referred to by some of the professors as a colleague. At the same time, though, I knew that I was in a student role. I was a newcomer with creative ideas, opinions and an agenda of future intentions. Embroiled in my perceptions of roles in this mentorship relationship were perceptions of power and I wrestled with a sense of internal turmoil and tension. On September 25, 1995 my journal entry included the following excerpt:

> When the class discussion turned to assessment, the students seemed even more hesitant to identify ways to assess their learning. Their participation in the decision of whom had the responsibility for grading featured a strong hesitancy to have some level of responsibility for evaluation. Given all their complaints about evaluation schemes used in the past where they had no control over the judgment passed, I expected them to want to be involved, have some level of self-assessment. Attempting to light a match to the discussion, I volunteered an idea, one I had used at the middle school level, that being the use of three sources of assessment (self, peer, and instructor) in either or both formative or summative assignments. Wow, did this light a fire! No way did they want to be involved in peer assessment. Based on their earlier comments that it would be hard to assign grades when peers might be friends, I had expected this resistance. I was not ready, however, for the intensity and scope in consensus of their response. I agreed that evaluation involved difficult decision-making, nevertheless it was required in today's educational system. Albeit that when in a teacher role, their [middle grades level] students would probably not be their friends, the issue of dealing with favoritism [could parallel] what they encountered in this situation.
>
> Evaluation and assignment of grades is not without an emotional component, whether one is aware of this influence or not. When one assesses students' prosaic or graphic responses, it can be difficult to not let bias enter into one's interpretation of a response as a "complete correct answer." It seems to me that in any rubric there is some room for subjectivity in interpretation. Anyway, I don't think they saw the analogy. I also wondered what David thought about my use of the analogy. It is becoming clearer to me that David and I differ on issues of assessment. He seems much more willing to let the students' suggestions completely form the nature of their assessment, whereas I want to interject ideas whether they buy into the idea or not. I wonder why his attitude is this way. I wonder if I will be able to engage him in discussion on this matter.

More recently, I facilitated one part of a departmental seminar for a multicultural education initiative in December of 1997. My topic choice highlighted the nature of relationships between graduate students and professors and the significance of communication style in the development of these relationships. We used the September 25, 1995 journal excerpt as a springboard for thinking about the nature of relationships within the department. As David and I discussed the evolution of our relationship, differences in perceptions of power became apparent. In addition to evoking contemplation on the nature of relationships between graduate students and professors on the part of departmental members, the discussion opened a door for looking at our individual and collective definitions of "mentorship."

In the context of my relationship with David and with respect to my perceptions of power manifest in an uncertainty about speaking up, where am I today? Assessment in preservice teacher education is only one of many issues which we have discussed and debated. I turn to and view David as a mentor and teacher. And, in his presentation of a research study investigating gender equity issues in science teacher education at our institution, I learned from David that the mentor relationship was two-way.

Challenges

A foray into the research literature to determine the scope of discussion on mentorship in teacher education (i.e., searches through the ERIC data base the UGA's library catalogue system), with a particular interest in science teacher educator education, revealed a gap in the knowledge base on mentoring and mentor relationships. The literature predominantly focused on describing mentor programs or studies of mentorships involving K-12 teachers or prospective K-12 teachers. The exception was Slevin's (1992) report of a collaborative project involving graduate students in the humanities, college and graduate university faculties. In the context of preparing future educators of the humanities,

> The place, more particularly the status, of mentoring within graduate education remains all but ignored. Even a faculty member's mentoring of research - not to mention teaching- is a neglected, usually unrewarded and marginal activity. It is pursued by the most dedicated faculty members with care and enthusiasm, but is not much appreciated at the departmental and institutional levels (p. 25).

I believe that the establishment and nurturing of mentor relationships between prospective and established science teacher educators is crucial in the development of science teacher educators. I agree with Slevin that this activity needs to be rewarded. We might ask ourselves, does reward need to be formalized within the cultures of university academia? What means can be created within an institution or a department to formally acknowledge and reward this activity, hence, perhaps ascribing greater status to engagement in mentor relationships? This leads me to propose three questions for discussion:

1. What are the natures of mentor relationships that we desire?
2. What forums and culture in a department nourish the establishment of such relationships?
3. How are issues of power manifested and dealt with?

Constructing Identity and Negotiating Roles in Educational Research (by Lynn Bryan)

The purpose of this round table discussion was to explore the various masks we wear, the researcher roles that we play, when conducting interpretive inquiry and the issues associated with the masks in our collections. Identifying the various researcher roles and the issues associated with each of these roles provides an educative opportunity for the researcher to become aware of the ways in which she/he shapes, constrains, and enhances fieldwork and the relationship between participant and researcher.

The idea and impetus for such a discussion arose from my recent experiences as a novice in conducting an interpretive research study in the field of science teacher education. What follows is a brief description of this research endeavor and the guiding questions that led the discussion.

Background

I recently conducted for my doctoral degree an interpretive research study to investigate the development of professional knowledge of preservice elementary teachers about science teaching and learning. Part of my investigation examined, through the case of one preservice teacher named Barbara, how learning from experience plays a pivotal role in developing professional knowledge. I aimed to uncover Barbara's beliefs about science teaching and learning; identify the tensions with which she grapples in learning to teach elementary science; understand the frames from which she identifies problems of practice; and discern how her experiences play a role in framing and reframing problems of practice in the process of reflecting on her own science teaching.

When I wrote the initial proposal for this study, I assumed that in my role as the researcher I would maintain a stance of empathic neutrality as described by Patton (1990): "Empathy communicates interest in and caring about people, while neutrality means being nonjudgmental about what people say and do during data collection" (p. 58). Not only did my experiences contradict such a role but my limited, naive conception of the role of the researcher failed to acknowledge: (a) the roles in which the participant cast me during the study; and (b) the very complex, multiple roles I perceived myself as eventually playing in this study.

As a result of a professional and personal relationship that evolved between myself and Barbara and my desire to frame this relationship within a research context, I felt both tensions and ambiguities with the different roles I played. On one hand, the personal engagement in interpretive inquiry permitted me to gain an in-depth understanding of what I was investigating with Barbara, facilitated a high level of trust between the two of us and provided both of us with an opportunity to further our own professional development. On the other hand, my personal engagement often felt incompatible with my perceived professional obligations in conducting the study and raised questions about bias, distortion, and credibility of the research findings. Furthermore, I found that conducting research in teacher education provoked another dilemma: When was it appropriate to take off the "data collector/interviewer" mask and don the "teacher educator" mask? I often faced a moral obligation to play the role of a teacher educator, yet questioned the influence that this role would have on my relationship with Barbara and on data collection. In short, I found that during the evolution of my collaborative relationship with Barbara, I was constantly negotiating the roles that I was playing in this research endeavor and the responsibilities associated with each of those roles.

Round Table Discussion

As a springboard for the round table discussion that transpired during this session, I briefly shared a personal account from my research with Barbara and introduced the various masks that I wore during the study. I described some of the specific tensions and ambiguities that I experienced in my collaborative relationship with her. I proposed the following questions for roundtable participants to contemplate and discuss:

1. What are the various masks that you have worn in conducting your own interpretive inquiry? Please share some of your experiences.

2. What are the moral/ethical responsibilities associated with each of the masks?

3. How do these responsibilities intersect or interfere with each other?

4. How does the researcher negotiate her/his multiple masks while maintaining a focus on the purpose(s) of the research endeavor?

5. How do the various roles influence the research findings? How does one resolve questions about bias, distortion, and credibility of the research findings?

Conclusion

Revealing the masks in our extensive collections and discussing publicly the issues associated with them serve several purposes. First, such dialogue illustrates the highly personal experience in which we engage when conducting interpretive inquiry and emphasizes the intersection between procedure, context, and human action. It also helps us make sense of our contributions to the field of educational research. Examining our researcher roles and the issues associated with them raises our consciousness about the influence we have on our work, the assumptions that we might otherwise take for granted in conducting interpretive studies, and the implications these issues have for the quality of our research. Finally, it allows us to think reflexively about our work and possibly extend the boundaries of our thinking about conducting and communicating interpretive inquiry.

Engaging Preservice Elementary Teachers in Research (by Valarie Dickinson)

It is traditionally recognized that elementary teachers are neither interested in nor comfortable teaching science. Some problems reported with elementary teachers avoiding science are lack of materials and funding, lack of knowledge about science, and a general belief that science is not important in the elementary school (Cox & Carpenter, 1989; Perkes, 1975; Tobin, Briscoe, & Holman (1990). Atwater, Gardener, and Kight (1991) reported that even though teachers agree that science should be taught in a hands-on fashion teachers are unsure of their abilities to do so. Bybee (1991) stated that even when using a curriculum designed to make teaching hands-on science more teacher friendly, elementary teacher still often feel inadequately prepared. Even preservice elementary teachers with science backgrounds do not necessarily know emphasis (Abell & Roth, 1992). What can help elementary teachers improving the science teaching abilities and become more comfortable in their own science teaching? Perhaps helping them engage in action research projects about their own science teaching will help them see more about how science actually works, and the role in plays in their own teaching. Helping preservice elementary teachers focus on science education in their own action research projects can help them improve in their science teaching.

In many Master of Arts in Teaching (MAT) or Master in Teaching (MIT) programs preservice teachers are required to engage in action research projects during their internships. Encouraging teachers to choose science education as they are designing research projects can help them improve their own understanding of how they can best approach science instruction in their classrooms. Indeed, even inservice teachers who engaged in action research projects related to their science instruction can see how science works and can improve their own science teaching and attitudes toward science (Dickinson, Burns, Hagen, & Locker, 1997). They are engaging in science as they are researching, and hopefully, improving their own teaching of science at the same time. They are learning what works for them, what does not, and how to help their students learn. They are confronting their own ideas about how science "should" be taught by collecting and analyzing evidence of how what they do in their practice does, or does not, impact the learning of their students.

As a doctoral student in science education I was encouraged and required to engage in and improve my own understanding of the educational research. As part of my own research I began encouraging preservice elementary teachers to engage in researching their own science teaching

(Dickinson & Reinkens, 1997). The preservice elementary teacher with whom I worked learned much about his own teaching of elementary chemistry. In addition, though he had a background in electrical engineering, he became aware of various areas he needed to improve his own science teaching. He understood that though he knew more science than many elementary teachers did, he needed more experienced to be able to represent his ideas to elementary aged children. As a doctoral student I was also involved in an action research project with fellow primary inservice teachers in which we developed ways to improve our own science teaching (Dickinson, Burns, Hagen, & Locker, 1997). The teachers involved in this project are continuing to teach more primary science than they had before because they found out what worked for them and for their students.

I am currently the instructor of an action research class for preservice elementary teachers obtaining an MIT degree. These teachers are allowed to choose any content area to research in their teaching. Though only three of the 28 chose science education as their area of emphasis, hopefully with my influence, more will select science as an area of study. It is my desire that preservice elementary teachers understand if they choose to study an area in which they believe they are weak, they can find out methods that will help them improve in their instruction. This is first semester that taught in action research course, and I am learning myself. I believe that by emphasizing research with preservice elementary teachers I have improved my own knowledge of educational research. I have heard that the best way to learn something is to teach it. By mentoring preservice elementary teachers in their own research, I believe I have become more knowledgeable about research myself. If preservice and inservice teachers are to be taught to engage in action research it is imperative that they be taught stringent methods so that they can use educational research on their own in their classrooms. Holding them to high standards can help them to understand and appreciate the value of educational research (Lederman & Niess, 1997).

Summary and Conclusions

The purpose of the forum began as a way to explore our own developments as science teacher educator/researchers. Developing and planning the forum became a way for us to network with each other-to compare experiences and provide and receive advice from each other. We have learned from each other in the process. Some of our experiences have been common to us all, and some are unique to each individual.

We have vicariously experienced the difficulties of enculturation and socialization to the science teacher education from multicultural perspectives through noting the meanings of multiculturalism provided by Barbara and HsingChi. Barbara reminded us of the cultural shock we all felt when moving from being the teacher to being once again, the student. We noted the difficulties HsingChi faced when in a country foreign to her, and admired her persistence in working toward obtaining her goal. Katherine and Andy spoke of the process of becoming science teacher educators. Katherine related the importance mentoring had on her selection to begin into university teacher education, from when she was teaching to her current mentoring at the university level. Andy spoke of the process of becoming an effective teacher supervisor, and the difficulties associated with that. From Lynn we learned there sometimes is a difficulty in maintaining a division between the many roles a science teacher educator must fill. She sometimes fell into the role of teacher educator during her research. She found that the roles were not mutually exclusive as part of her own development as a teacher educator/researcher. From Valarie we learned that the process of helping others with conducting their own research we can become better researchers ourselves. We will improve in our role as a researcher with each new study we conduct, and that we mentor others to conduct.

From the papers presented in this panel it is evident that the common theme that runs throughout the development of a science teacher educator is the importance of mentoring. Part of the journey of becoming an effective science educator is being mentored, and learning to be a mentor for others. From Katherine's tale of being mentored by several persons, to HsingChi's description of the difficulty of finding mentoring for an international student and the positive effect finding mentoring had on her education, to the question Andy raises regarding whether more mentoring is needed for doctoral students to become effective intern teacher supervisors, mentoring was an important factor. Indeed, even Barbara noted the importance of her team of advisors on her menu. Lynn's description of falling into the role of teacher educator while studying the teacher foreshadows the mentoring role she undertakes now as a university faculty science educator. The role Valarie played in helping preservice and inservice teachers conduct their own action research projects served not only to help Valarie define educational research more fully for herself, but also allowed her to try on and practice the role of mentor for others.

It is evident that we have felt some success during our development as university science teacher educators. The success has not been met without difficulty along the way. We have found encouragement and mentoring from many valued persons. There have been friends, colleagues, fellow teachers, and important university advisors. Through this process of exploring our own development, we have been energized to help others who follow us. We intend to use the mentoring we have received, and the skills we have developed in science teacher education to continue the cycle, and mentor others realizing their goals and help them reach their successes in becoming science teacher educators.

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GENDER, ETHNICITY, AND GRADE LEVEL AS PREDICTORS OF MIDDLE SCHOOL STUDENTS' ATTITUDES TOWARD SCIENCE

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Interest in how attitudes toward science are formed, and how they affect learning, school course selection, and personal, civic, and work choices, has been increasing for the past thirty years. There are several reasons why research on students' attitudes toward science is important. First, attitudes toward science are believed to influence behaviors, such as selecting courses, visiting museums, and supporting scientific inquiry (Kaballa & Crowley, 1985). Second, a relationship between attitudes and achievement has been shown to exist. Schibeci and Riley (1986) report that there is support for the proposition that attitudes influence achievement, rather than achievement influencing attitudes. Students with positive attitudes toward science tend to have higher scores on achievement measures (Oliver & Simpson, 1988; Weinburgh, 1994). Third, nationwide assessments of attitudes toward science indicate that, by third grade, fifty percent of students are not interested in science. How America is Shortchanging Girls (AAUW, 1992) graphically points out that many students, especially females, associate science with negative feelings and attitudes which discourage them from continuing with scientific inquiry. Having established these three reasons for the importance of student attitudes toward science, science educators can no longer assume that students will acquire positive attitudes simply because they are required to take additional science courses. Research that attempts to discover which variables most influence attitudes toward science is necessary so that appropriate intervention can be planned.

Research indicates that males have a more positive attitude toward science, are more highly motivated to achieve in science, and more likely to select science courses as electives in high school (Hykle, 1993). Schibeci (1984) reported that of all the variables that may influence attitude toward science, gender has generally been shown to have a consistent influence. Simpson and Oliver (1985), in an ongoing multidimensional study among 4,000 students in grades 6 through 10, found that males show significantly more positive attitudes towards science than females. Although females make up one half of the workforce, only about 15% of U. S. mathematicians, scientists, and engineers are females. In fact, even though scientific thinking is of value to everyone, that scientific jobs pay almost 50% more than non-scientific ones requiring the same degree of education, and that people trained in scientific thought are increasingly needed in today's society, there has been a drop in the total number of Americans preparing for scientific careers in the last few years (Chapman,1997).

There is not a lot of research on student attitudes as influenced by ethnicity AAUW, 1992). However, ethnic differences in science course selection are pronounced (NSF,1996). African American students are as likely as white students to take biology in high school but much less likely to take chemistry or physics. In addition, differences in achievement by ethnicity are more pronounced than differences by gender. Scores for whites are substantially higher than those for African Americans (NSF, 1996).

Kahle and Lakes (1983) suggest that the lack of positive attitudes toward science by females begins in the elementary grades. However, in a study of 1,200 students enrolled in grades four through six, Pogge (1986) found that students have a positive attitude toward science. The Sadkers (1986) report that gender differences are more pronounced in middle school, while Weinburgh (1994) reports that they continue into high school and that grade level is a significant predictor of student attitudes toward science.

Purpose

The purpose of this study was to examine differences by gender, ethnicity, and grade level in middle school students' attitudes toward science. The main questions being asked in this study are: 1. Do middle grades students exhibit different attitudes toward science according to gender? 2. Do middle grades students exhibit different attitudes toward science according to ethnicity? 3 .Do middle grades students exhibit different attitudes toward science according to grade level?

Method

Subject

The inventory was given to 1,381 students, 680 males and 697 females and 4 not coded. .The racial composition was 458 (33%) African American, 94 (7%) Asian, 576 (42%) White, 102 (8%) Hispanic, 33 (2%) Native American 91 (6%) Other, and 27 (2%) not marked. There were 337 sixth grade students, 563 seventh grade students, and 475 eighth grade students. Because of the low numbers of Asian, Hispanic, Native American, and Other students, the sample was reduced to include on the African American and White students. This produced a sample of 1034, with 517 males and 517 females, 468 African Americans and 576 Whites, and 237 sixth graders, 416 seventh graders, and 376 eighth graders. The students were from six schools in two suburban school districts in the Southeast. All students were proficient English speakers.

Instrument

The Attitude Toward Science Inventory: Version A (ATSI) was used to examine the students' attitudes toward science. One reason this instrument was selected is because of the high construct validity reported by Goglin and Swartz (1992) and Weinburgh (1994), and the high content validity reported for the mathematics version by Sandman (1973). Another reason for selecting this instrument was because of its multidimensional nature. The ATSI is a 48-item inventory which consists of six scales with eight statements: perception of the science teacher, anxiety toward science, value of science in society, self-concept in science, enjoyment of science, and motivation in science. A four point Likert scale was used in order to force the student to strongly agree, agree, disagree or strongly disagree with each statement. The alpha reliability coefficients for gender ranges from 0.66 to 0.82, for ethnicity from 0.56 to 0.83, and for grade level from 0.63 to 0.84. These are within the range of acceptability (Nunnelly, 1967).

Procedure

Students were administered the ATSI during the science period, or home room, at the end of the first grading period. The teachers were given verbal and written instructions on the procedures for administering the instrument in order that the conditions be as similar as possible in each testing site. Students were asked to circle the number of the response on the instrument that best described their feeling toward the statement at the moment.

The first step after data entry was to reverse the scoring of negatively worded items in all scales except anxiety. For this scale the positively worded items were reversed. The student responses to each scale were tallied to give each student six attitudinal scale scores: possible scores on each scale ranged from 8 (indicating all negative responses) to 32 (indicating all positive responses), except for the anxiety scale which is the opposite.

Descriptive statistics were calculated. A MANOVA was run in order to determine if there was a difference by gender, ethnicity, and grade level. No interactions were significant but all three main effects were significant at the $\alpha = .05$ level (gender $F(6,1012) = 4.74$; $p < .01$, ethnicity $F(6, 1012) = 2.31$; $p < .05$, grade level $F(12,2026) = 8.85$; $p < .01$). Having found a significant MANOVA, an ANOVA was run for each attitudinal scale to assess its relationship with each of the independent variables of gender, ethnicity, and grade level.

Results

Gender

Student attitudes by gender vary on the different scales. Females have more positive attitudes toward the teacher and the value to society and are less anxious. Males have more positive attitudes toward self-concept in science, enjoyment of science, and motivation in science. Although only two of the scales are statistically significant (teacher, $p<.01$, in favor of females and enjoy, $p<.05$, in favor of male), all of the scales differ significantly from neutral.

Table 1

Means for the Six Subscales of the Attitudes Toward Science Inventory

(Neutrality = 20) by Gender.

Subscale of ATSI	Male	Female	F
Perception of Science Teacher	23.8	24.6	7.04**
Anxiety toward Science	16.7	16.6	0.19
Value of Science	23.6	23.8	0.82
Self-Concept in Science	23.3	23.2	0.12
Enjoyment of Science	21.9	21.2	4.65*
Motivation in Science	20.2	20.1	0.14

Note: * $p < .05$, ** $p < .01$.

Ethnicity

An ANOVA showed that five scales were significant at the $\alpha = .05$ level. Motivation was not significant (p=.054). The white students were significantly more positive than the African-American students on the teacher, value, self-concept, and enjoy scales, and less anxious about science. The scales showing the greatest degree of difference were perception of teacher, value, and self-concept.

Table 2

Means for the Six Subscales of the Attitudes Toward Science Inventory by Ethnicity (Neutrality = 20).

Subscale of ATSI	African-American	White	F
Perception of Science Teacher	23.6	24.6	13.80 **
Anxiety toward Science	17.2	16.3	13.10 **
Value of Science	23.3	24.1	11.04 **
Self-Concept in Science	22.8	23.7	12.38 **
Enjoyment of Science	21.1	22.0	9.68 **
Motivation in Science	19.9	20.4	3.71

Note: * $p < .05$, ** $p < .01$.

Grade Level

Five of the six scales were significant at the $\alpha = .05$ level. All differed significantly from neutrality (neutral = 20). On every scale students showed less positive attitudes as they continued in school. The 6th grade students showed more positive attitudes than the 7th grade, the 7th grade showed more positive than the 8th grade. Motivation actually became less than neutral (mean of 19.8) for the 8th grade students. For three of the scales (teacher, value, and self-concept), the mean of 6th graders was above "agree" (agree = 24) as did the teacher scale for 7th graders.

Table 3

Means for the Six Subscales of the Attitudes Toward Science Inventory

by Grade Level (Neutrality = 20).

Subscale of ATSI	**6th Grade**	**7th Grade**	**8th Grade**	**F**
Perception of Science Teacher	25.5	24.6	22.9	30.94**
Anxiety toward Science	16.2	16.6	17.2	4.43*
Value of Science	24.5	23.8	23.1	8.33**
Self-Concept in Science	24.4	23.8	23.1	13.02**
Enjoyment of Science	22.1	22.0	21.0	4.48*
Motivation in Science	20.5	20.2	19.8	2.58

Note: * $p < .05$, ** $p < .01$.

Discussion

This study investigated gender, ethnicity, and grade level differences as predictors of student attitudes toward science. Six attitudinal scales were studied. Findings from this sample indicate that gender is a significant predictor on student attitudes toward the teacher and enjoyment of science. Ethnicity and grade level are significant predictors for five scales.

Gender

Because there has been a slight decline in gender differences over the past decade, some people have suggested that gender inequality is no longer an issue in education (Catsambis, 1995). This study shows that of the three variables examined, gender does appeared to be the least predictive. As indicated by other studies, males have an overall more positive attitude toward science than do females. Gender is a significant predictor of the perception of the teacher and enjoyment. This agrees with earlier studies by Weinburgh (1994). However, it should be noted that males are more positive in their enjoyment of science, motivation in science, and self-concept of science whereas the females are more positive in their perception of the science teacher and the value of science to society. These are critical differences in how students feel about the whole concept of science. From this data, one might suggest that males are going to be more likely to continue with science than are females.

It has been suggested by Kahle and Lakes (1983) that social and cultural factors may contribute to the differences found in science attitude by gender. Responses to the NAEP show that males far out number females in early experiences with scientific activities and skills. This may help to explain why the males are more positive on the enjoyment of science scale. These findings agree with the research that indicate that females want to please, and therefore are more aware of the teacher, and of pleasing the teacher.

Ethnicity

The difference seen between African American students and white students is alarming. Traditionally, this population has had lower achievement scores (Schibeci & Riley, 1986) and have not pursued science degrees (Atwater & Wiggins, 1995). The lack of a positive attitude on five of the scales indicates that these students are not likely to continue selecting to take science courses as they move into high school. It is particularly unsettling that African American students have such low opinions of their teacher, the value of science in society, and enjoyment of science. This study contradicts Hill, Pettus, and Hedin (1990) who found that the main effect for race was higher for the total score and for teacher encouragement.

Grade level

The declining positive attitudes toward science found in this study are consistent with the findings of Hofstein, Maoz, & Rishpon (1990), Catsambis (1995), and Weinburgh (1994). This study indicates that grade level is a significant predictor on five of the scales. On all six scales, the mean declined with each grade level. These declines in the science attitudes could affect their achievement and learning opportunities during high school. The reason for the continued decline should be further examined. One explanation may due to the way that science is taught in the upper grades. Indications are that science is often taught as a group of facts and vocabulary words that are to be memorized and not as a way of investigation. It may be that the natural curiosity of children has been dampened as they move through the grades.

Implication

This study shows that more research is needed about students' attitudes and about what is happening in schools that would cause students to develop less positive attitudes over time. Researchers also need to look at how ethnicity affects students' attitudes toward science.

In addition, teachers need to be aware of the trends in student attitudes toward science by gender, ethnicity, and grade level. Knowing the results of studies such as this one may help in developing programs that address the needs of females and minority students as they study science. It may also help curriculum designers in producing science materials that help to capture the interest of students and keep them more interested in science. These efforts should being in the elementary grades. Several studies (Bredderman, 1982; Shymansky, Hedges, & Woodworth, 1990) indicate that elementary programs that involve inquiry-based, hands-on strategies increase the later science success of students. Inquiry-based science in middle grades may help to achieve the same affect.

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PREPARING "PROFESSIONAL" SCIENCE TEACHERS: CRITICAL GOALS

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The Professional Science Teacher: Need of the Times

Current science education reform efforts such as the National Science Education Standards (National Research Council, 1996) and Science for All Americans (American Association for the Advancement of Science, 1994) promote teaching and learning of science that goes far beyond a simple transmittal of scientific facts, figures, and processes to be learned in a rote manner for their own sakes. They call for science instruction that, among other goals, enhances student understanding of the nature of science, enables them to critically analyze scientific information and apply it to real-life situations, and sets them on a path of life-long learning in science and science related matters. In order to implement such reform, new professional responsibilities must be undertaken by the science teacher. In order to foster the ability to undertake and fulfill these responsibilities (*i. e.*, facilitate the kind of science instruction characterized above), substantial reform of both pre-service and in-service science teacher education must occur. A variety of teacher education "standards" has been developed (Danielson, 1996; National Research Council, 1996) and continues to be developed through efforts such as the CASE (Certification and Accreditation in Science Education) Project to guide the necessary reform of science teacher education. These standards are being designed and implemented to produce "professional" science teachers capable of undertaking the new responsibilities. However, we are faced with the question: What is it that sets the professional teacher apart from a teaching craftsman (one who is capable of merely transmitting scientific knowledge)?

Professional science teachers can be characterized by several attributes related to the teaching and learning of science. The goals of any science teacher education program must include the development of these attributes if the program aims to prepare professional teachers rather than mere teaching craftsmen. Focusing on pre-service science teacher education, this paper elaborates the critical importance of the following three attributes to the development of professional science teachers.

1. Science teachers must be reflective practitioners of their profession.
2. All instructional practice and decisions of science teachers must be based on research-based rationale which they are consciously aware of and are able to defend.
3. Science teachers must be able to impact student learning in multiple domains of science.

In the ensuing pages I turn to a discussion of why the development of each of the following attributes should be a critical goal of pre-service science teacher education programs and what strategies in the program could help accomplish each of these goals.

Critical Goal 1: Reflective Practitioner

Science teachers must be reflective practitioners of their profession. Three questions immediately arise here: 1) What exactly does it mean to be a reflective practitioner? 2) Why is it important for teachers to be reflective? 3) How does one learn to be reflective?

The answer to the first question is far from simple. Reflectivity is construed in a variety of ways and this variety can "disguise a vast number of conceptual variation" (Calderhead, 1989, p. 2). LaBoskey (1993) notes that the definition of reflection is quite complex and that most definitions have built upon a conception of reflectivity originally posited by Dewey (1910). Thus, in order to understand the meaning of reflectivity, it is worth considering Dewey's conception of the term.

According to Dewey (1910), reflection is the "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" (p. 6). To the 'careful consideration of belief and form of knowledge' might also be added 'careful consideration of practice or strategies', from the perspective of the teaching profession. The implication here is that reflection involves continued evaluation of one's own practice in the light of what Dewey has called the "ground of belief".

Why is such evaluation (or being reflective) important in the teaching profession? Dewey (1904, 1910) argued that teachers should be encouraged to become thoughtful and alert students of education rather than just proficient craftspeople. This is important because "Unless a teacher is such a student, he may continue to improve in the mechanics of school management, but he cannot grow as a teacher, an inspirer and director of soul-life" (Dewey, 1904, p. 151). Growth as a teacher and inspirer is critical for those who teach science. Scientific knowledge is the product of much exploration, experimentation, and continued analysis of information thus generated. Students need to learn the importance of such analysis and learn how to do it for the purposes of both getting into the scientific enterprise themselves and being able to scrutinize scientific information that impacts their lives. Being able to continually analyze and evaluate also lies at the heart of reflectivity. It is crucial for science teachers to be able to reflect both about the scientific knowledge they expect their students to learn and the ways in which they will help them learn. Unless teachers are reflective, they will not be able to foster reflectivity in their students because students copy their teachers' behavior. In effect, non-reflective teachers will produce students who do not know how to think for themselves.

Hullfish and Smith (1961) have argued that "apart from gaining control of the method of reflection it is impossible to learn any facts at all" (p. 210). They have also argued that if one doesn't learn to think while in school, it is fair to ask how are they to keep on learning. This argument has direct implications for pre-service teacher education programs. If student-teachers do not learn to be reflective while in school, how are they to keep on learning how to teach? Therefore, development of reflectivity in student-teachers must be a prime goal of pre-service science teacher education programs.

How can reflectivity be developed? What strategies in the program would help foster reflectivity? In order to answer these questions, one must consider the characteristics of the process of reflection. Dewey (1910) suggested that reflection is characterized by a three-step process. These include problem definition, means/ends analysis, and generalization. He further suggested that true reflection is carried out with attitudes of open-mindedness, responsibility, and wholeheartedness.

If a program aims to develop reflectivity in student-teachers, it must provide opportunities for student-teachers to identify problems in teaching practices, to analyze the means and ends related to these practices, and to draw generalizations, all with the attitudes of open-mindedness, responsibility, and wholeheartedness. There are two levels at which this could be accomplished. The first level is reflectivity about the strategies and practices employed by the course instructor. The second level is reflectivity about students' own behavior in teaching and all other experiences within the program. Accomplishment at both of these levels presumes that the course instructors themselves are reflective practitioners of their own profession, and that numerous teaching experiences are provided to student-teachers so that reflection about the earlier experience can be used to improve the later experience. Thus, reflective course instructors and multiple teaching experiences built into the program constitute two primary requisites for fostering reflectivity.

For reflecting on the instructor's practices, student-teachers should be asked to identify practices that may appear problematic to them. This could be achieved by student-teachers maintaining journals about every class meeting and then going through the journal entries to identify problems, or by video-recording class meetings and identifying problems through video analysis. Class time should be allowed on a periodic basis for student-teachers to share the problems they have identified and the instructor must then guide student-teachers in a means/end analysis of the problem. At this step, a non-reflective instructor will be of precious little help, if any, since such an instructor would most likely not have a rationale for the actions identified as problematic. When generalizations are drawn, these should be reflected in future practices of the instructor to demonstrate that reflection has resulted in his/her own growth as a professional. If the evidence of growth indicated by incorporation of generalizations into practice is not visible, student-teachers would miss the entire purpose of reflection—evaluation with the intent to change when necessary.

For reflecting on their own teaching experiences, the best strategy might be to video-tape every teaching experience, analyze the video-tapes for problem identification, and then engage in a means/end analysis of the problematic action. Here, the reflective instructor may have to help student-teachers identify problems by asking them questions about why a particular action was undertaken and then guiding them in a means/end analysis of what might be done differently to better achieve the goals student-teachers had in mind. A strategy to guide the means/end analysis would involve the instructor pursuing questions about why the student-teachers did what they did until they begin to see the problematic aspect of the specific action. Then, again through questions, the instructor could lead them to preferred alternative actions in the given situation. If there are any resulting generalizations, student-teachers should be made responsible for incorporating them in their future teaching experiences. This reflective process should be repeated later to evaluate their growth since the previous teaching experience.

The type of reflective activities described above have been identified as reflection on practice or professional reflection (Baird, Fensham, Gunstone & White, 1991). Baird et al. have also identified another kind of reflection—phenomenological reflection—that is reflection on general life experiences as a teacher, learner, or researcher. In a three-year naturalistic case study of both pre-service and in-service science teachers, Baird et al. found that both types of reflection served to improve teachers' knowledge, awareness, and control of themselves and their classroom practice.

In order to develop reflectivity in pre-service teachers, time must frequently be allocated during regular class meetings to apply the process of reflectivity as described in previous paragraphs. It must be actively undertaken during class meetings. This will help student-teachers learn the process of reflection and develop a reflective attitude. Moreover, personal reflections beyond those undertaken during class must be assigned as homework tasks in order to help develop the habit of reflection and improve the quality of reflection. This can be achieved by asking them to identify and analyze problems or issues other than those considered during class, and reporting back on their analysis either in written form or verbally during a future class meeting.

The in-class exercises and homework assignments would, hopefully, foster the attitude of reflection and equip student-teachers with techniques of reflection to the extent that they can go out to be reflective practitioners of their profession. After all, if they don't learn to be reflective while in school, how will they keep on growing after they become teachers, and in turn how will they help their students to grow?

Critical Goal 2: Research-Based Rationales to Guide Practice

All instructional practice and decisions of science teachers must be based on research-based rationales which they are consciously aware of and are able to articulate precisely and defend. Why are research-based rationales important for teachers? At least two lines of argument can be presented in response to this question.

First, being aware of current research and continually aligning practice with research findings is what makes a teacher professional and distinguishes him/her from a mere craftsperson. A professional teacher possesses specialized knowledge not only of the subject s/he teaches but also of the enterprise of teaching. The professional teacher, rather than the craftsperson type teacher, is capable of growing as a teacher by virtue of keeping up with research findings and applying them reflectively to his/her practice. A professional teacher is in touch both with changes in specific subject matter and advances in pedagogical research. Such a teacher is more desirable than the craftsperson type teacher because the professional teacher will continue growing as a teacher. Such a professional teacher would have continually improved impact on student learning. Compared to the craftsperson type teachers, science teachers whose actions are guided by research-based rationales exhibit professionalism and will be more successful in having a positive impact on student learning.

Second, teachers' work in most schools is guided by prescribed curriculum guidelines and restrictions imposed by institutional structure. In such an environment, trying something different or innovative in one's classroom may be extremely difficult and may invite criticism, opposition, and conflict. Though the teacher's action may be entirely appropriate and congruent with research findings, unless the teacher has a research-based rationale by which to defend his/her actions, s/he may not be able to convince the critics of the value and appropriateness of his/her actions (Clough, 1992). Thus, without the rationale, even a fully competent teacher may never be able to act professionally in the classroom by way of applying current research findings to his/her own teaching practice and will, therefore, not be able to impact student learning to the maximum extent.

Penick (1985) has suggested that a rationale for science teaching must include "carefully formulated goals and a well-justified set of behaviors to obtain those goals. These behaviors are based on which is currently known about how children learn, the effects of teachers and students, and the nature of science." Having such a rationale constitutes, according to Penick, one of the traits which make one a "formal operational teacher"—a teacher who is at the highest level of the continuum of teaching skills, aptitudes, and knowledge.

In order to prepare science teachers who have rationales which they are able to defend, the entire science teacher education program must be designed around the rationales, including teaching and learning goals. Right at the beginning of the program students should be asked to identify goals that they would like to have for their students in science classes. A consensus list of goals to be worked on throughout the program should be generated. In generating goals and merging them to produce a consensus list, the course instructor may need to help focus the thinking of student-teachers by asking questions such as why is this goal important, how is different from some of the other goals, and how feasible would be the measurement of the achievement of the specific goal. The next step would be to locate research literature in support of the goals agreed upon by the class. Here again, the instructor and student-teachers must be equally involved. They should all do literature searches and each student should be charged to identify at least two pieces of literature in support of each goal. This literature should comprise part of the readings for the course.

During the rest of the program, the research literature identified by the entire class should be discussed and arguments analyzed in terms of research support and their appropriateness for the goal. This should happen on a regular basis. These discussions may lead to refinement of goals and/or addition or deletion of particular pieces of research literature to build stronger bases for the stated goals. After students have gained some confidence in relating arguments to the goals and identifying behaviors that match the goals, they should periodically be asked to analyze the instructor's goals on the basis of his/her behavior in class. They should also be engaged in analyzing video-tapes of their own and their colleagues' teaching experiences to examine the extent to which their behaviors matched their goals. This analysis should be used by students to modify their behavior and align it more closely to their goals during future teaching experiences. Again, to achieve this goal, the program must provide multiple teaching experiences. Analysis of teaching behaviors in the context of specific goals will also provide a meaningful setting for the development of reflectivity.

Finally, an important assignment, which will motivate students throughout the program to think in terms of goals and rationale to defend them, is development of a rationale paper. In this paper, students will identify goals (not necessarily the ones generated by the class as a whole) which they individually think are important, provide research support for why they think each goal is important, and describe sets of teacher and student behaviors that would help accomplish each goal. Writing such a rationale paper would help students think carefully about each goal, find out the extent to which the goals are supported by educational research or current reform agenda, and identify sets of behavior justified by research to achieve the stated goals. The entire exercise will also help them see the bigger picture of the teaching profession, particularly science teaching, and provide a backdrop against which to reflectively assess their practice in order to grow as a professional.

It is preferable to start working on the rationale paper early in the program and treat it as an ongoing assignment throughout the program, revising and modifying the rationale as new knowledge about teaching science is gained, rather than treating it as an end of semester or end of program assignment. Revising the rationale paper at different stages during the program would help students refine their goals, become familiar with appropriate research in support of the goals, and be prepared to apply appropriate strategies in their own teaching practice when they enter the 'real-world' of teaching as professionals.

Critical Goal 3: Impacting Student Learning in Multiple Domains of Science

Science teachers must be able to impact student learning in multiple domains of science. Two questions can be raised in connection with this goal. First, what is meant by multiple domains of science? Second, why is learning in multiple domains important?

Domains of science imply aspects or components which should be included in good science instruction (Yager & Brunkhorst, 1987). Most often science instruction serves just as a mean to transmit currently accepted scientific knowledge from teachers to students and, sometimes, also to help students develop scientific processes and skills. This kind of science instruction usually focuses only on two domains of science—the information domain and the process domain—and presents a severely restricted view of science. A careful examination of the scientific enterprise reveals that science is more than just information and processes. It involves imagining and creating, feeling and valuing, using and applying, and forming a world view. These aspects form the other domains of science namely, creativity, attitudes, applications, and the world view of science (Yager & McCormack, 1989).

Why is learning in multiple domains of science important? If science involves more than just information and processes, students need to learn about the other domains in order to develop a holistic understanding of science and to develop attributes which would enable them to do science themselves. Science education which focuses only on information and processes provides an incomplete picture of science and is deficient in developing attributes which would help students become involved in doing science. Considering the importance of multiple domains of science in science education, science educators have been advocating approaches to science instruction (including assessment) which would enhance student ability in all of these domains (Harms, 1981; Yager, 1987; Yager & Brunkhorst, 1987; Yager & McCormack, 1989). Furthermore, several current science education reform efforts such as Project 2061 (American Association for the

Advancement of Science, 1994) and the National Science Education Standards (National Research Council, 1996) strongly advocate science education which incorporates instruction in multiple domains. For instance, the National Science Education Standards identify the 'nature of science' as a separate area of science content standards. They also identify 'science in personal and social perspectives' as an area of science content standards, which directly relates to the application domain. Instruction in multiple domains of science is not only important for students to become better scientists but also for them to understand and deal with the impact of science on our everyday lives. In other words, education in multiple domains of science is far more desirable than education in scientific facts and processes alone.

How can teachers be prepared to impact student learning in multiple domains of science? A teacher education program designed to meet this goal must deal with two aspects. First, the program needs to help students see that science has multiple domains. Most of the discipline-specific science education that students receive in college focuses on information and process domains. Thus, they bring a narrow-minded perspective of science to the teacher education program and would enter the 'real-world' of teaching with the same perspective unless the teacher education program does something to change that perspective.

One of the best ways to change this narrow-minded perspective is to get student-teachers involved in science activities in which they are required to ask new questions, explore resources to find answers, generate and test hypotheses, and share and discuss their findings both in terms of their experience with the activity and how they could apply the process in science classrooms. Designing cartesian divers for different sets of conditions; clay boats that would hold increasingly more weight than their own without sinking; candle suffocation experiments; and activities with batteries, bulbs, and wires are just a few examples of a number of activities that could be used for this purpose. Such activities would help student-teachers see that science involves more than just memorizing facts or developing specific skills such as the use of a microscope. They would help student-teachers see the creative aspect of science, the importance of applying to new situations what one already knows, and develop a better understanding of the nature of science as they take each activity to greater level of complexity or use them to answer new questions related to the concepts they are designed to explore. Of course, only one or two experiences with these activities will not suffice. The program must be infused with multiple opportunities for engaging in such activities throughout the duration of the program.

Discussions following the activities are extremely important. One cannot simply hope that doing these activities would suddenly enlighten the participants regarding multiple domains of science. They need to be engaged in discussions that would require them to reflect upon the experience and how it relates to the real-world of science. These discussions should focus on identification of various domains of science through questions (raised both by the instructor and students themselves) which would serve to analyze the activities in terms of the domains. As appropriate and possible, student-teachers should be asked to relate their experiences of these activities to professional scientific research to identify the domains in professional science. The discussions should also consider strategies regarding the use of these activities (and others like them, which the student-teachers will design or locate from available resources) in ways that would help their students see the multiple domains of science which they can learn and practice in their own lives.

Apart from making them aware of the multiple domains of science, the teacher education program must also prepare student-teachers to assess student learning in multiple domains of science. This can be accomplished by asking student-teachers to develop rubrics for assessing growth in each domain within the context of the activities they participate in. Prior to the development of rubrics, the instructor would have to help student-teachers get an understanding of what rubrics are all about and what kind of items might be appropriate for inclusion in the rubrics for each domain. This understanding can be developed by the instructor providing specific research information and leading students in discussions of this information. Whenever students engage in an activity meant for broadening their perspective of science, they should be asked to design rubrics for assessing growth in multiple domains of science through that particular activity. This would help them practice how to assess student growth in multiple domains of science.

Then, during the teaching experiences, they must be required to design assessment items or activities for each domain during every unit of instruction they undertake. Required assessment in multiple domains will ensure that they get into the habit of providing science experiences to their students which enhance learning in multiple domains of science and then assessing this learning.

Compared to the craftsperson type teacher, professional science teachers who teach science to impact student learning in multiple domains, whose instructional strategies are based upon research-based rationales, and who are reflective about their practice would do a better job of implementing the quality of science education promoted by current national reform efforts. Professional teachers of this sort are a critical need of our times.

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ACIDS & BASES CURRICULUM UNIT: AN INQUIRY-BASED CONTEXT FOR TEACHING THE PARTICULATE NATURE OF MATTER AND CHANGES IN MATTER

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Project SEPIA

The design and implementation of full-inquiry units requires a blending of curriculum-instruction-assessment goals. Project SEPIA with support from NSF and OERI has examined the design of middle school science learning environments that support full-inquiry science. The inclusion of full-inquiry science units at each grade level is a recommendation of the National Science Education Standards. Curriculum units 5 to 6 weeks long are developed with problem-posing, problem-solving and peer persuasion components. In addition to the development of conceptual knowledge, SEPIA units stress: (a) development of nature of science and (b) communication in science as goals of science learning. Our session presents the key features of the SEPIA model of instruction through an examination of the *Acids & Bases Curriculum Unit.*

Curriculum Units

The *Acids & Bases Curriculum Unit* has been developed as part of Project SEPIA (Science Education through Portfolio Instruction and Assessment) supported by NSF and OERI funding. Project SEPIA investigates curriculum, instruction, and assessment models that put an emphasis on epistemological, representational, and cognitive goals of science learning (Duschl & Gitomer, 1997; Erduran & Duschl, 1995; Smith, 1995; Schauble et al., 1994). The project broadens the idea of the content of science from its conceptual basis to include (a) the processes that generate the evidence, and (b) the criteria, rules and standards used to evaluate scientific observations and knowledge claims.

The content of a SEPIA unit represents, among other things, (a) the creative and imaginative steps used during investigative methods and theory building; (b) the design and development of instruments and tools to observe and measure; (c) the analytical strategies and cognitive reasoning processes that identify patterns and link evidence to explanations; and (d) the representation and communication strategies used to persuade others of scientific findings, arguments, models, and explanations. Along with the Acids & Bases Unit, we have developed two other middle school science units: *Vessels Unit* (Buoyancy & Flotation) and *Earthquakes & Volcanoes Unit* which accommodate these features.

Design Principles

Teachers, researchers and advisors working on Project SEPIA believe the science learning environment approach proceeds from five key design features: (a) The topic of investigation is an authentic question or problem that has some consequence to the lives of the children; (b) Conceptual goals are kept to a limited number so as to facilitate an understanding and adoption of criteria that assess the accuracy and objectivity of knowledge claims; (c) Assessment of students' understandings and ideas proceeds from assignments that by design produce a diversity of outcomes; (d) Both the criteria for the assessment of students' products and performances and the products and performances themselves are publicly shared employing a teaching discourse/feedback strategy labeled an 'assessment conversation'; (e) The depth of student understanding is assessed and communicated employing a portfolio process. Together, these five principles contribute to the design of a learning environment that promotes science as inquiry and develops students' understanding about scientific inquiry, both elements of the National Science Education Standards.

Description of the *Acids & Bases Curriculum Unit*

Writing of the *Acids & Bases Curriculum Unit* by project teachers and researchers began in 1993, and has undergone numerous revisions ever since. Between 1993-1997, the unit has been implemented in a total of 15 classrooms in 14 schools from 3 states. *Acids & Bases Curriculum Unit* is a performance-based activity unit where the main problem-solving tasks are the identification of unknown substances as acids and bases, and the generation of strategies for the proper disposal of these substances. The problem-solving tasks necessitate the formulation, evaluation and revision of chemical models that can explain the physical and chemical properties of acids and bases. The sequence of activities which make up the curriculum unit are included at the end of this paper.

The unit lasts about 5-6 weeks and initially consists of activities that encourage the generation, refinement and validation of several models (e.g. symbolic, physical, pictorial models), which culminate in the Arrhenius model of acids and bases. Thereafter, a paradigmatic shift (Kuhn, 1970) is reinforced through anomalies in data that present the case of the existence of substances that register as acids or bases with analytical tools but do not fit the Arrhenius model by chemical composition. The last part of the unit then includes activities that guide the evaluation of the old model and formulation of a new model, the Lewis model of acids and bases which can account for the anomalous data.

Overall the curriculum unit promotes students argumentation about (a) properties of matter, within the context of physical and chemical properties of acids and bases, and (b) changes in matter, within the context of neutralization reaction between acids and bases which results in the formation of new substances (i.e. salt and water). The unit has social, reasoning and knowledge goals. Social goals aim to develop students' communication and representation skills in science. Reasoning goals target improvement of students' cognitive and metacognitive skills. Knowledge goals engage students in the evaluation of claims on evidence and how evidence relates to model building.

Throughout the unit students carry out experiments, construct models of acids and bases based on evidence from experiments, make their results public and engage in whole class discussions and arguments for evaluating their models. Students keep a record of their investigations in the form of storyboards and written reports. These reports are assessed, refined and revised on an ongoing basis using modeling criteria. Models can be symbolic, pictorial or physical. Symbolic models begin to introduce students to chemical symbolic conventions.

Pictorial models are based on students' depictions of their experience with acids and bases in the form of drawings. Physical models are ball-and-stick representations of atoms and molecules.

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APPENDIX

Sequence of Activities in the *Acids & Bases Curriculum Unit*

Page 1

ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
Video & Video Script	Context for problem	Significance of problem	Class	HazMat Video "Video Script" sheet Five bottles containing unknown substances (prepared with hydrion buffer capsules)	-	-	-
Nature of Task **P1** What are you being asked to do?	Recognition of task	Nature of task Things to know to be able to do task	Individual/Class	P1 sheet	-	AC on nature of task	-
Contract Letter	Description of task	Nature of task	Individual	"Contract Letter" sheet	-	-	-
Table of Contents	Indexing of items to go into portfolio	Organization of portfolio	Individual	"Table of Contents" sheets	-	-	-

729

730

ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
Everyday acids, bases and neithers	Initial ideas on acids and bases	Exploring definitions of acids and bases	Class	no student worksheet	-	AC on how acids and bases can be defined	Class list of examples of familiar acids and bases
Acids and bases through sensory experience **P2-A** Testing acids and bases with your senses! Part 1	1. Data collection based on sense experience	Sampling Sense experience to detect acids and bases Patterns in data	Group	P2-A Lemon, Orange, Milk of magnesia, Baking powder, Unsweetened chocolate, Soft drink, Tums, Vinegar, Water, Grapefruit, Alka-Seltzer, Laundry detergent/soap Toothpicks, Test tubes, Test tube rack	Sensory properties (acids are "sour," bases are "bitter," bases are "slippery") stem from the nature of constituents	AC on patterns in sense experience	Class list on patterns in acids and bases recognized by sense experience
Part 2	2. Dilution	Dilution	Group				
Part 3	3. Representation of dilution	Concentration	Individual				
First models of acids, bases and neutralization **P2-B** Everyday acids and bases!	Examples of acids and bases from everyday substances	Acids and bases as part of everyday life	Individual	P2-B	-	-	-

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ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
P2-C Model of acids and bases!	Modeling acids and bases from sense experience Modeling acids and bases put together (neutralization)	Models describe sense experience of acids and bases (pictorial) Models of acids and bases put together	Individual Individual Group/ Class	P2-C	-	AC on the characteristics of models describing sense experience	Pictures of models for acids, bases and acid-base put together
Indicators **P3-A** Testing acids and bases with indicators!	Patterns in data: color of acids, bases, neither with indicators Indicators as instruments to find out about acids and bases	Color changes in indicators when acids and bases are added- no color change with water	Group	P3-A Lemon juice, Vinegar, Ammonia, Distilled water, Alka-Seltzer, Soft drink, Milk of magnesia, Red and Blue Litmus, Universal indicator, Phenolphthalein, Bromothymol Yellow, Bromothymol Blue, pH Paper, Test Tubes, Test Tube Racks	Patterns in color of acids and bases with indicators ("bromothymol blue is yellow in all acids") stem from properties at chemical level. Color formation involves a chemical reaction.	-	-

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ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
Second Model: Acids and Bases in Indicators **P3-B** Indicators added to acids, bases and water! Part 1 Part 2	Rule for acid and base Rule for water	Model of acid and base (pictorial) Model of water	Individual Individual	P3-B	-	AC on rule for telling acid and base (Consistency with reports from PI-2A and PI-2C)	List of rules for telling an acid, base and water with indicators
Choice of indicator **P4** Which indicator should we use to identify unknowns?	Evaluation of indicators towards use for task	Uses and limitations of indicators	Individual, Pair, Group, Class	P4 P3-A, P3-B	-	AC on instrument choice	List of evidence to support choice of instrument
P5 Test of unknowns!	Application of prior learning on indicators to identification of unknowns	Identifying unknowns as acid, base or neither	Group	P5 P3-A, P3-B, P4 hydrion buffers (prepared from capsules)	-	AC on identity of unknowns and need of more clues for safe disposal	List of unknowns as acid, base or neither
Making Hydrogen Gas **P6-A** Demonstration 1!	Producing hydrogen gas	Model of acids includes hydrogen	Pair	"Figure for Demonstration 1" sheet P6-A Zinc, Hydrochloric Acid, Test Tubes, Rubber Tubing, Metal Stand, Water Bath, Rubber Stoppers, Wooden Splint, Matches, Ring Stand	Acids must contain hydrogen in some form since in their reactions with metals, hydrogen gas is released.	-	-
Reference on gases	Physical and chemical properties of gases released from acids and/or bases	Telling a gas from its chemical and physical properties	Class	"Reference on gases" sheet	-	-	-

735 736

ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
Base making **P6-B** Demonstration 2!	Base-making	Model for splitting of water Model of base-making	Pair	P6-B Sodium, Water, Phenolphthalein, Test tubes, Rubber Tubing, Rubber Stoppers, Wooden Splint, Matches, Ring Stand	Reaction of bases with water releases hydrogen. (Water is made of oxygen and hydrogen. Therefore, bases must have oxygen and possibly hydrogen in them.)	-	-
P7-A Models from demonstrations!	Pictorial representation of models from Demonstrations 1 and 2	Model (pictorial) of reactions	Individual	P7-A	-	-	-
P7-B Compare models from demonstrations!	Comparison of reactions from Demonstration 1 and 2 both involving hydrogen production	Differences in reactions although both procude hydrogen gas	Group/Class	P7-B	-	AC on comparison of models from demonstrations	Picture and list of similarities and differences between models from two demonstrations

737

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ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
P8 Strength of acids! Parts 1, 2 & 3	Rate of hydrogen gas production	Strength	Group	P8 P4-A, P5-A, P5-B Manometer Test Tube, Ring Stand, Plastic Tubing, Food Coloring, Hydrochloric Acid, Acetic Acid, Nitric Acid, Citric Acid, Magnesium	Rate of hydrogen production differs with different acids. (Hydrogen must be "kept" differently among acids.)	AC on differences among acids in releasing hydrogen gas	List and pictures of more rules for characterizing acids
P9 Ball-and-Stick Models!	Physical representations of atoms and molecules	Physical models	Individual/Class	P9 Toothpicks, Marshmellows, PI4-A, PI4-B	-	AC on the structure of acids and bases at "molecular" level	Physical model of acid and base
Chemical Symbols The Periodic Table	Elements	Symbolic representation of elements	Class	Copy of Periodic Table	-	-	-
P10-A How to represent acids!	Chemical symbols of elements	Model of reactions from Demonstration 1 (symbolic)	Pair	P10-A	-	-	-

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ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
P10-B How to represent bases!	Chemical symbols of elements	Model of reactions from Demonstration 2 (symbolic)	Pair	P10-B	-	-	-
Chemical Formulas **P11** How to recognize acids and bases!	Chemical formulas of compounds Arrhenius model	Identifying acids and bases from chemical formulas	Group	P11 HCl, HNO3, H2SO4, NaOH, NH4OH, KOH, H2CO3	Chemical formulas of acids contain H and chemical formulas of bases contain OH.	AC on chemical representations of acids and bases	List of chemical symbols to characterize acids and bases
Self Assessment	Evaluation of model revision	Model revision	Individual	"Self Assessment" sheet, P2-A, P2-C, P3-B, P5-A, P7-B	-	-	-
Concept Map **P12-A** Acid-Base concept map!	Summary of learned concepts	Concepts are related in a network of relationships	Individual	P12-A	-	-	-
P12 -B Acid-Base concept map!	Extension and revision of previous concept map	Missing concepts and connections among concepts	Pair	P12-B	-	AC on what to include in the concept map	Class concept map

741

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ACTIVITY	THEME	UNDERSTANDING	ACTIVITY STRUCTURE	MATERIALS	EVIDENCE FOR MODEL	ASSESSMENT CONVERSATION	HAZMAT REPORT
P13 Acids, bases and electricity!	Electrical conductivity of acids and bases	Ionic nature of acids and bases	Group	P13	Electrical conductivity (has to do with ions).	AC on why acids and bases conduct electricity	Pictures of ions in acids and bases
Neutralization **P14** Mixing acids and bases!	Neutralization and pH	pH range	Group	P14	Loss of acidic and basic properties at mixing	-	-
P15 Model of neutralization!	Models of ions	Model of neutralization (symbolic)	Individual	P15 Toothpicks, marshmellows	-	AC on model of neutralization and safe disposal	Model of neutralization List of procedure for safe disposal
Another model of neutralization New Hazmat Letter	New task of proposing another model	Model revision	Class	"Hazmat Letter" sheet and aluminum oxide in a vial	-	-	-
P16 Aluminum oxide	Lewis model of acids and bases	Limitations of Arrhenius model of acids	Pair	P16 Aluminum oxide phenolphthalein ammonia	No hydrogen involved	AC on reaction of aluminum oxide and ammonia	-
P17 New model	Another model of neutralization	Role of electrons in neutralization	Group	P17	-	AC on model of neutralization	Picture of model for neutralization
Final HazMat Report	Evaluation of task performance of other groups	Adherence to criteria of good performance	Group	Final Hazmat Report" Sheet, Video Presentations	-	-	Final Hazmat Reports
HazMat Certificates	Recognition of Students efforts	-	-	-	-	-	-

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