DOCUMENT RESUME

ED 398 060 SE 058 617

AUTHOR Rubba, Peter A., Ed.; And Others
TITLE Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science (Seattle, Washington, January 11-14, 1996).
INSTITUTION Association for the Education of Teachers in Science.
PUB DATE 96
NOTE 792p.
AVAILABLE FROM Association for the Education of Teachers in Science, c/o Dr. Joseph Peters, Executive Secretary, University of West Florida, College of Education, 1100 University Parkway, Pensacola, FL 32514.
PUB TYPE Collected Works - Conference Proceedings (021)

EDRS PRICE MF05/PC32 Plus Postage.
DESCRIPTORS Action Research; Constructivism (Learning); Elementary Secondary Education; English (Second Language); Higher Education; Inquiry; *Knowledge Base for Teaching; Partnerships in Education; Professional Development; Science and Society; Science Programs; *Science Teachers; Teacher Attitudes; *Teacher Education; Technology; Writing Skills

ABSTRACT

These conference proceedings include papers presented and summaries of presentations made at the 1996 Annual International Conference of the Association for the Education of Teachers in Science (AETS). Topics include: English-as-a-Second Language (ESL) Strategies in science methods courses; writing strategies; action research and equity issues; the Investigating the Universe Project; knowledge structures of teachers; embedded practicums; Science, Technology, and Society investigations; student and teacher questions; combining demonstration classrooms and inservice; preparation and evaluation of videocases; inclusion in the science classroom; using open-ended questions; using children's ideas and literature; the role of technology; using e-mail partners; Internet Exchange Project; professional development schools; self-evaluation of the implementation of the learning cycle; integration and use of technology; Project Prism; complex instruction; promoting primary science; interdisciplinary math and science; Project Simulate; Project Pride; coaching reflective practice; assessing change in teachers' knowledge; collaborative teaching; engineering physics; incorporating computer spreadsheets into the Robert Karplus Learning Cycle; meeting the needs of Hispanic learners; further validation of the Constructivist Learning Environment Survey; case studies of new teachers; science teachers' attitudes towards their presentation of inservice workshops; partnerships; science-fiction stories; teaching science methods in a language arts method course; college level science courses; model for elementary science inservice; learning inquiry-oriented science; rubric for scoring concept maps; analyzing the effect teachers have on their students' perceptions of and attitudes toward science; vee diagramming; traditional classroom assessment; and exploring traditional ecological knowledge. (JRH)

Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science

Edited by:
Peter A. Rubba, The Pennsylvania State University
Patricia F. Keig, California State University -- Fullerton
James A. Rye, West Virginia University

Preface

In January of 1993 the Association for the Education of Teachers in Science (AETS) held its first separate annual meeting in Charleston, SC. Prior to that time, AETS annual meetings had been a formal part of the program of National Science Teachers Association national meetings. The idea for AETS to publish proceedings of its annual meeting was proposed at the Fall 1994 meeting of the AETS Board of Directors by Pete Rubba, then past-president of AETS. Board support was received in time to compile proceedings for the 1996 AETS Annual Meeting in Seattle, WA. Rubba selected Pat Keig and Jim Rye as co-editors of the *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science*.

The conference proceedings were intended to serve as the records of AETS annual meetings. Papers presented at and summaries of presentations made at AETS annual meetings would be submitted for inclusion in the proceedings. The proceedings would not to be copyrighted so authors also could submit papers and presentation summaries to journals such as the *Journal of Science Teacher Education* and *Science Education*. And, the proceedings would be submitted to the ERIC Clearinghouse for Science, Mathematics and Environmental Education so microfiche and hard copies would be available through ERIC.

Papers presented at and summaries of presentations made at the 1996 AETS Annual Meeting in Charleston, WV were submitted for inclusion in the 1996 AETS Conference Proceedings at the meeting or by sending copies to the first editor within 30 days following the meeting. The papers and presentation summaries were reviewed by the editors, and a marked copy returned to the author(s) for revision and resubmission in camera ready form.

In editing the papers and presentation summaries the editors attempted to make suggestions that would enhance their clarity. The editors did not accept for inclusion items that generally would not be considered a "paper" or "presentation summary" (e.g., overheads used in a presentation; handouts such as tables, figures and reference lists without explanatory text), and papers or presentation summaries not prepared in final version using the specified format or not submitted by a specified deadline.

The *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science* includes a copy of the conference program and 47 papers or presentation summaries from the meeting, ordered by conference session. We are pleased to have had the opportunity to edit the first AETS Annual Meeting Proceedings and hope the proceedings make a contribution to science teacher education.

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

Acknowledgment

The editors gratefully acknowledge the assistance of Vicki Brungart, Cathy Hipple and Edie Sodergren in compiling these Proceedings

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1996 AETS Conference Program

ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE, 1996 ANNUAL INTERNATIONAL CONFERENCE, JANUARY 11-14, 1996: SEATTLE, WASHINGTON

CONFERENCE PROGRAM

Thursday 8:00 am - 12:00 noon

Vashon II AETS Board Meeting

First half of the AETS Board Meeting.

Thursday 9:00 - 12:00 noon

Pre Whidbey **Preconference** General

Science Teaching Self-Efficacy Beliefs: A Special Interest Group Session Larry G. Enochs, University of Wisconsin-Milwaukee; Linda Ramey-Gassert, Wright State University; Iris M. Riggs, California State University- San Bernardino.
The goal of this session is to establish a formal special interest group on this topic.

Pre Blakely **Preconference** General

Using Benchmarks for Science Literacy in the Analysis of Instruction and Resources Jo Ellen Roseman, AAAS.
This workshop will enable educators to analyze in order to choose and adapt curriculum resources and materials in the light of science literacy goals such as Project 2061's Benchmarks for Science Literacy.

Thursday 1:00 - 3:50 pm

T1.1 St. Helens **Workshop** General

Science Education and the Internet Joe Peters, University of West Florida.
This presentation will be an interactive presentation on how to access the Internet (including AETS World Wide Web) and find applicable resources. Software will be provided.
Presider: Thomas Thompson, Northern Illinois University

Thursday 1:00 - 2:20 pm

T1.2 Adams **Panel** General

Institutionalizing Gender Equity in Preservice Teacher Education Jo Sanders, Center for Advanced Study in Education; Cathy Yeotis, Wichita State University; Maxwell Hines, University of Louisville; Janice Koch, Hofstra University.
We will address the institutionalization of gender equity in preservice teacher education in science classroom, university, and field placement schools, resulting from a national NSF-funded project.
Presider: Marletta Iwasyk, Ocara Alternative at Columbia

T1.3 Baker **Demonstrations** Elem Mid/Jr

Science Images: Visions of Effective Science Instruction Randy Knuth, Steve Baxendale, NCREL.
This session will provide an overview of the Science IMAGES video & print materials through a discussion of research-based professional development model used in the project as well as video clips from the overview and classroom videotapes.

College

Simple Strategies for Modeling Computer Use in Elementary / Middle Methods Lucille A. Slinger, University of WI-La Crosse.
Strategies demonstrating the use of computers in K-9 level science instruction as modeled in a elementary/middle science methods course will be shared. Simple ways to illustrate the computer as "tutor, tool, and tutee": (Taylor) and course assignments will be presented.
Presider: Karen L. Ostlund, Southwest Texas State University

T1.4 Vashon I **Papers** Elem College

Including ESL Strategies Within the Elementary Science Methods Course Darla Stepel, Cynthia Smith, North Tamarind Elementary, Iris M. Riggs, Esteban Diaz, California State University, San Bernadino.
This session will share strategies for easily adapting science lessons to include ESL techniques.

College Super

Write-to-Learn Science Strategies for Preservice Elementary Teachers Larry D. Yore, University of Victoria.
Three write-to-learn strategies (reaction papers, reflection-on-action paper, collaborative essay) will be described. These instructional activities promote science understanding, higher-order thinking, and expository writing.
Presider: Sandra Henderson, Oregon State University

T1.5 Vashon II **Papers** Elem College

Using Mini-action Research Projects and Technology to Teach Equity Issues in Science Robert Boram, Joyce Saxon, Morehead State University.
Undergraduate students in an elementary science methods course designed mini-action research projects to increase awareness of careers in science. The results were presented using "Powerpoint" software.

General

Pre-service Teachers' Development of the Image of Science as "How We Know" During Sequential Teaching Methods Courses J. Steve Oliver, Denise Crockett, Elizabeth C. Doster, University of Georgia.
As part of an ongoing research program, the authors have attempted to examine the ways in which preservice secondary science teachers come to understand and use the idea that science is an

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activity about "how we come to know" with regard to nature.

Presider: Yvonne Meichtry, Miami University

T1.6 .Blakely Workshop
HS

Energy Environment and Policy Choices: Learning Cycles in Energy Education Brian L. Gerber, Edmund A. Marek, University of Oklahoma.
A workshop designed to actively involve the participants present at the session in a learning cycle featuring energy related, interdisciplinary curriculum materials.
Presider: Kathy Frame, National Association of Biology Teachers

T1.7 Orcas Papers
General

Preparing Science Teachers to Develop & Implement Constructivist Lab Activities Michael P. Clough, Memorial High School.
My presentation will address how science educators might prepare science teachers to construct or reconstruct lab activities so they are consistent with contemporary learning theory.
HS

Student Construction of Meaning in the Laboratory Setting: A Critical Examination of Influence of Gender and Cultural Membership Elizabeth C. Doster, Denise Crockett, University of Georgia
Working within a critical theory paradigm, we examine group social interaction as a method of revealing power structures and interpreting their influence on student learning.
Presider: Joneen Hueni, Texas A&M University

T1.8 Whidbey Panel
Elem General

Integrating Science Concepts: A Collaborative Effort to Improve Elementary Science Teaching and Learning Norman G. Lederman, Oregon State University; Juliet Baxter, Eugene School District; Judith Sweeney, Museum of Natural History; Larry Enochs, University of Wisconsin, Milwaukee; Larry Flick, Lockwood DeWitt, Oregon State University; Michael Cohen, University of Indiana; Kip Ault, Lewis & Clark College; Marilyn Husser, Twin Oaks School , Eugene Oregon.
Presider: Lawrence B. Flick, Oregon State University

Thursday 2:30 - 3:50 pm

T2.2 Adams Other Format
General

The Science Methods Course in the Context of the Total Teacher Education Experience Ronald D. Anderson, University of Colorado.
A session on practical ideas and issues related to a science methods course which serves as the linchpin for the total science teacher education experience.
Presider: Virginia Johnson Anderson, Towson State University

T2.3 Baker Papers
General

Impetus for Change Warren J. Di Biase, Pat Obenauf. West Virginia University.
A study of the changes in perceptions resulting from participation in the NRAO-WVU-NSF Investigating the Universe Project.
General

The Private Universe Project Matthew H. Schneps, Nancy Finkelstein, Harvard-Smithsonian Center for Astrophysics.
This workshop will present and discuss video clips from a future series for public broadcast illustrating some of the serious issues confronting children in learning.
Presider: Lois H. Peck, Philadelphia College of Pharmacy & Science

T2.4 Vashon I Panels
Elem

Science and Math Partners for Elementary Teachers Elizabeth Lambert, Norman G. Lederman, Oregon State University; William D. Riley, Albany Research Center; Sue Priest, Centennial Elementary School.
Links science/math practitioners with elementary teachers to enhance science and math curriculum and spark interest in technical fields at an early age.

Partnerships Supporting Systemic Reform Eileen S. Vergino, Lawrence Livermore National Laboratory; Norm Lederman, Oregon State University; Richard J. Farnsworth, Lawrence Livermore National Laboratory.
The need to increase scientific literacy for students at all levels of education is widely recognized. One way to meet the need has been to establish science education standards and benchmarks.Through collaborations and partnerships linking the education community with LLNL's key scientific research areas and technologies we are developing strategies for implementing systemic reform.
Presider: James A. Shymansky, University of Iowa

T2.5 Vashon II Papers
General

You Don't Get What You Want, You Only Get What You Effectively Bargain For Michael P. Clough, Memorial High School.
My presentation will address common institutional constraints, and my work with student teachers and methods students to prepare them for these potential constraints.
College Super

Knowledge Structures of Teachers: an Assessment of Knowledge Structures in the Areas of Content, Pedagogy, and Practical Content Knowledge During the First Two Years of Teaching Meta Van Sickle, College of Charleston; Carolyn Dickman, Radford

University Margaret Bogan, Jackson State University.
This paper presents an assessment of the development of new teachers' conceptions of relationships between content, pedagogy and other knowledge structures during the first years of teaching.
Presider: Peter Rillero, Arizona State University West

T2.6 Blakely Papers
College

Walking Through the Wilderness: A Constructivistic Approach for the Teaching of Methods Marylou Dantonio, Paul C. Beisenherz, University of New Orleans.
Issues and questions regarding the use of constructivism in preparing teachers to teach related to curriculum experiences and student reactions are explored.
College Super

Elementary School Science Methods With an Embedded Practicum Larry D. Yore, University of Victoria.
Frequently the schedule and structure of method courses disconnect theory from practice. This presentation describes an integrated theory-into-practice program.
College

Advantages and Disadvantages of a Concentrated Elementary Science Methods Course Richard L. Williams, University of Victoria.
Aspects of a concentrated methods course will be compared and contrasted with an extended methods course. Students and faculty data will be analyzed.
Presider: Mark Latz, Oregon State University

T2.7 Orcas Papers
General

Science Teachers Teaching Teachers: Empowering Teachers Through Leadership Carol Lena Lane, Joseph P. Riley, Tom Elliott, Lisa Gansar, University of Georgia.
The ST3 project has trained classroom teachers to lead workshops for teachers in their districts.Surveys and interviews have indicated that these teachers feel empowered by leading workshops.
Elem College Super General

An Assessment of Teacher Attitude Change Three Years into Implementation of an Elementary Level Science Reform Initiative Sharon H. Harwell, University of Alabama in Huntsville.
This session presents results of a three-year study to monitor concerns of K-6 teachers involved in implementation of an exemplary elementary level science reform initiative.
Elem Mid/Jr

An Elementary Science Teacher Enhancement Project: The Teacher Perspective Beth Shiner Klein, St. Norbert College.
This session will share the results of a three year qualitative case study of an elementary science teacher enhancement project from the perspective of two teacher participants.

Presider: George R. Davis, Moorhead State University

T2.8 Whidbey Papers
College

Science Teaching for the 21st Century: Dilemmas and Dialogue Judith Johnson, University of Central Florida.
A presentation of a paper describing the impact of redesigned science teacher preparation courses.
General

Using STS Themes to Engage Diverse Learners in Science Katherine Norman, University of Texas at Brownville/TSC; Dana Caseau, California State University-Fresno.
STS modules are presented as a method of engaging learners of all ability levels in science, including at-risk and students with learning/behavior problems.
Presider: Clifford A. Hofwolt, Vanderbuilt University

Thursday 4:00 - 5:00 pm

T3.1 St. Helens Demonstration
General

Interactive Multimedia for Preservice Teacher Education Thomas Thompson, Beth A. Wiegman, Steve Wallace, Northern Illinois University.
A demonstration of Level I and Level III applications of videodisc technology designed for use in an elementary science methods course.
Presider: Randy Knuth, NCREL

T3.2 Adams Workshop
General

Case Studies by a Group of Collaborating Educators: How Do Student and Teacher Questions Facilitate Learning? Marletta Iwasyk, Ocra Alternative at Columbia; Akiko Krose, Laurelhurst Elementary School; Dorothy Simpson, Mercer Island High School; Emily van Zee, University of Maryland; Judy Wild, Sacred Heart School.
We invite participants to examine data from our classrooms and to identify aspects of questioning that seem to facilitate learning in these contexts.
Presider: Jo Sanders, Center for Advanced Study in Education

T3.3 Baker Workshop
Elem Super

Stepping Into Successful Science Teaching Karen L. Ostlund, Southwest Texas State University.
Participants will do selected activities from this program designed for training elementary science teachers. The program consists of a leader's manual with handouts and videotapes.
Presider: Lucille A. Slinger, University of WI-La Crosse

T3.4 Vashon I Panel
General

Teachers and Laboratory Scientists and the State of Science Literacy: Catalysts or Allosteric Inhibition? Sandra Henderson, Oregon State University;John Petersen, Castro Valley High School; John P.

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Knezovich, Lawrence Livermore National Laboratory; Norman G. Lederman, Oregon State University; Richard J. Farnsworth, Lawrence Livermore National Laboratory.
National Laboratory Teacher Education Programs will be examined from different perspectives--teacher, laboratory scientist, science educator, evaluator, and program administrator.What works and what doesn't?
Presider: Darla Stepel, North Tamarind Elementary

T3.5 **Vashon II** **Panel** General

Ohio Landscape Study: Efforts of Teachers and Science Educators to Reform Middle-Level Science Education Yvonne Meichtry, Jane Butler-Kahle, Steve Rogg, Miami University; Anita Roychoudhury, Miami University - Hamilton Campus.
The aim of the Landscape Study, involving more than 100 schools throughout Ohio, is to "paint a picture" of the reform for middle level science and math.
Presider: Larry D. Yore, University of Victoria

T3.6 **Blakely** **Workshop** Mid/Jr HS

Investigative Laboratories for Teaching About the Nervous System Kathy Frame, National Association of Biology Teachers.
Participants will engage in hands-on, investigative relationship to diseases, including epilepsy, pain and visual impairment.This project is the result of a SEPA grant to NABT from ADAMHA.
Presider: J. Steve Oliver, University of Georgia

T3.7 **Orcas** **Workshop** General

Tieing Science Together: The Web as a Tool for Integrating Science Joneen Hueni, Caroline Beller, Texas A&M University.
Participants will develop a web of Puget Sound and engage in one or more activities related to the web.
Presider: Michael P. Clough, Memorial High School

T3.8 **Whidbey** **Workshop** College Super

Classroom-Video Analysis Protocol Lawrence B. Flick, Oregon State University.
Teachers in an advanced strategies class engage in a Classroom-Video Analysis Protocol to integrate understanding of various models with daily teaching practice and learning theory.
Presider: Brian L. Gerber, University of Oklahoma

Thursday 5:00 - 7:00 pm

Cascade Ballroom II **Reception**

Sponsored by
Delta Education

Thursday 7:00 - 9:00 pm

T4.1 **Blakely** **Interest Group**

Enhancing University-School District Communications With Regard To Field Placements? Margaret B. Bogan, Jacksonville State University; Meta Van Sickle, University of Charleston; Carolyn Dickman, Radford University; Bill Baird, Michael Kamen, Auburn University.

T4.3 **Orcas** **Meeting**

AETS Regional Directors Meeting (All AETS Regional Directors or their designates should attend this meeting) Jim Ellis, AETS President.

Friday 6:30 - 7:50 am

AETS Committee Meetings:

Ad Hoc Committee on AETS Conventions	Vashon II
Ad Hoc Committee on Dissemination and Implementation of Science Standards and Benchmarks	Vashon I
Ad Hoc Committee on Electronic Communications	St. Helens
Ad Hoc Committee on International Science Ed.	Adams
Ad Hoc Committee on Mentor Teacher Involvement	Vashon II
Ad Hoc Committee on Mentoring New Members	Baker
Ad Hoc Committee on Regional AETS Units	Baker
Ad Hoc Committee on Science Teacher Education Standards	Vashon I
Committee on Science Education for Inclusion of Challenged Populations	Adams
Elections CommitteeWhidbey	
Membership Committee	Baker
Program Committee	Orcas
Publications Committee (Part I)	Blakely
Task Force on Corporate Sponsors	Adams

Friday 7:30 - 8:00 am

Cascade Foyer **Continental Breakfast**

Friday 8:00 - 9:20 am

F1.1 **St. Helens** **Demonstrations** College

Constructing Physics Understanding in a Computer Supported Environment Gayle Kirwan, Louisiana State University; Fred Goldberg, Jim Minstrell, San Diego State University.
Overview of an NSF-Supported project to develop and disseminate a powerful set of computer tools to promote deeper understanding of physics. HS

Introduction to Access Excellence-Make the Connection Geoff Teeter, Vivion Lee Ward, Genentech.
National science education program from Genentech. On-line resources include lessons, science news, biotechnology resource center, monthly science seminars hosted by scientists, and more.
Presider: Ron Browne, Georgia Southern University

F1.2 Adams Panel

College

The Florida Higher Education Consortium-A State-Wide Collaborative Effort to Improve the Preparation of Science and Mathematics Teachers Marianne B. Barnes, Lehman W. Barnes, University of North Florida; Barbara Spector, University of South Florida; Ed McClintock, Florida International University.
Presenters will describe the evaluation of a state-wide consortium of higher education faculty who are involved in making improvements in postsecondary instruction in science and mathematics teacher preparation and enhancement.
Presider: Lynn A. Bryan, Purdue University

F1.3 Baker Papers

Videocases for Science Teacher Education Douglas Martin, Sonoma State University.
This paper will discuss the production and evaluation of the videocases useful in science teacher education.

College Super

Combining Demonstration Classrooms and Inservice for Science Teachers Julie Wilson, University of Arizona.
An inservice program incorporated visits to a demonstration teachers' classroom. Structure of the inservice program, qualitative and quantitative findings, and suggestions for future developers will be discussed.
Presider: Elizabeth Lambert, Oregon State University

F1.4 Vashon I Papers

HS

High School Forum on Critical Issues William H. Robertson, Los Alamos National Laboratory.
A research based educational program utilizing electronic telecommunications as a forum for collaborative research among high school students, educators and scientists.

HS

JETS: Integrated Programs That Meet Tomorrow's Standards Today Daniel W. Kunz, Junior Engineering Technical Society (JETS).
JETS provides high school students and their teachers with multi-disciplinary science/math/technology events (academic and hands-on) that focus on the new and emerging education standards.
Presider: Alan Colburn, Cal. State University-Long Beach

F1.5 Vashon II Papers

General

Applications of a Teacher Developed STS Unit on Global Atmospheric Change for Middle and High School Science in Teacher Education Peter. A. Rubba, James A. Rye, West Virginia University.
Uses of a STS Issue Investigation and Action Unit on Global Atmospheric Change, which was developed by teachers under NSF funding and is available on WWW, in preservice and continuing science teacher education.

General

*Science, Technology, & Society: Issues of Curriculum & Instruction*Michael Bentley, National-Louis University; Stephen Fleury, SUNY Oswego.
Reform in science education requires significant change in content in science, technology and society. From the perspectives of democratic values and constructivist learning theory, appropriate STS pedagogy will be examined.
Presider: Fred Finley, University of Minnesota

F1.6 Blakely Panel

College Super General

Science Educator Perceptions: Inclusion in Science Classrooms Katherine Norman, University of Texas at Brownsville/TSC; Greg Stefanich, University of Northern Iowa; Dana Caseau, California State University - Fresno.
Members of the AETS Committee for Inclusion of Challenged Populations will present results of the 1994 National Survey regarding teaching science to students with disabilities.
Presider: Patti Nason, UNC Charlotte

F1.7 Orcas Papers

Using Children's Literature to Help Teachers Learn Science James A. Shymansky, University of Iowa.
Paper explains how science ideas embedded in selected children's literature pieces have been used to develop teacher understanding of basic science concepts and constructivist teaching strategies.

Mid/Jr

Thinking, Writing, and Sharing: Teacher and Student Views of Starting Science and Mathematics Class with Open-ended Questions Peter Rillero, Jo Ann Cleland, Arizona State University West.
Presents analysis of writing-to-learn technique for conceptual development in science and mathematics. Study conducted with four eight grade science and mathematics teaches.

HS College

Managing Subject Matter: Does It Really Matter? Mark Latz, Norman Lederman, Oregon State University.
The purpose of this study is to explore how subject matter may influence the classroom management behaviors of teachers in Biology and Language Arts courses.
Presider: Stephen S. Winter, Tufts University

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F1.8 Whidbey Papers
General

PRIME-Annenberg Collaboration 2004: Engineering and Biotechnology Curriculum for 5th and 6th Graders Lois H. Peck, Philadelphia College of Pharmacy & Science; Ms. Cecilia Ciociola, PRIME, Inc.; Mrs. Betty Conrad, St. Francis DeSalles.
The PRIME-Annenberg Project is a unique pilot program that reflects the reality that all students can succeed when presented with motivational and challenging curriculum.
General

An Integrated Approach to Teaching Science in Rural and Small Schools J. Preston Prather, University of Virginia.
Principals of integrated science teaching will be reviewed with emphasis on their applications to development of curricular and instructional models for small and rural schools.

Presider: M. Jenice French, Kansas State University

Friday 9:20 - 9:40 am
Cascade Foyer Coffee Break

Friday 9:40 - 11:00 am

F2.1 St. Helens Papers

Using E-Mail Partners In The Elementary Science Methods Course Janice Koch, Hofstra University.
This presentation explores the use of e-mail partners between the students of two elementary science education professors in two vastly different parts of the country.
Elem General

The Role of Technology in an Alternative Teacher Education Program William R. Veal, Deborah J. Tippins,Katherine Wieseman, University of Georgia.
The purpose of this study was to investigate how preservice elementary teachers construct understandings of technology and the role of technology in an alternative teacher education program.
College

Infusing Technology: A Study Examining the Use of Multimedia in an Elementary Science Methods Course Alan Voelker, Thomas E. Thompson, Beth A. Wiegmann, Steve Wallace, Northern Illinois University.
This study looked at the role multimedia plays in effecting preservice teacher's perceptions and attitudes toward technology and science instruction.
College

An Inter-university Internet Exchange Project to Network Pre-Service Teachers Gerald Foster, DePaul University; Dr. Derrick R. Lavoie, University of Northern Iowa.
This study analyzes Internet discourse between preservice students from two different universities to determine effective ways to enhance their understanding of teaching science.

Presider: Craig A. Berg, The University of Wisconsin-Milwaukee

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F2.2 Adams Demonstration
Elem Mid/Jr HS

Incorporating Indigenous Knowledge in the Science Classroom Roger Norris-Tull, Delena Norris-Tull, University of Alaska-Fairbanks.
Models and examples of using local knowledge and traditions to provide Native Alaskan students with relevant science instruction.

Presider: MacGregor Kniseley, Rhode Island College

F2.3 Baker Papers
College

Restructuring Science Teacher Education Through Professional Development Schools Kenneth J. Schoon, Indiana University Northwest.
A discussion of professional development schools in the preparation of science teachers and how PDS collaboration can be utilized to restructure science teacher education.
Elem Mid/Jr College Super General

Findings on Factors Influencing Successful Implementation of an Effective Science Program in Professional Development Schools Linda Ramey-Gassert, Wright State University; Christine Ebert, University of South Carolina; Gail Shroyer, Kansas State University; Melisa Hancock, Woodrow Wilson School; JoLane Hall, Pontiac Elementary School.
Science educators from two large state universities and teachers from PDS partner schools will share their insights and lessons learned about enhancing science education.

Presider: E. Barbara Klemm, University of Hawaii

F2.4 Vashon I Papers
College Super

Initial Development and Validation of a Self-Efficacy Scale to Self-Evaluate the Implementation of the Learning Cycle Charles R. Barman, William Boone, Indiana University.
An overview of a Learning Cycle Self-Efficacy Scale will be presented as well as the psychometric lessons learned from the development of this scale.
General

Redefining the Effective Elementary Science Teacher-A Collaboration Clifford A. Hofwolt, Vanderbilt University.
A series of competencies developed from research on effective teaching was submitted to experienced elementary teachers in an effort to restructure an elementary science methods course.

Presider: Lloyd H. Barrow, University of Missouri

F2.5 Vashon II Paper

Teachers' Views On The Nature of Science & Science-Technology-Society Thomas Ditty, West Virginia University.
Item statements from the VOSTS instrument were used to assess West Virginia (K-12) teachers views about the nature of science and STS Interactions.

Presider: Leon Ukens, Towson State University

F2.6 Blakely Papers
Mid/Jr HS College Super General

The Utilization of Technology in the Enhancement of the Teaching of Science Paul B. Otto, University of South Dakota.
A presentation of a variety of teaching activities in the classroom utilizing technology.The use of technology must be planned in the curriculum and the teaching of science by the utilization of the best learning theories.

HS Super

Integration and Utilization of Secondary Pre-Service Science Teachers Carolyn Dickman, Radford University; Meta Van Sickle, University of Charleston; Margaret Bogan, Jacksonville State University.
A multisite, multicase study of the changes in the perceptions and usage oftechnology by secondary pre-service science teachers at three southeastern universities.

Presider: Philip D. Wade, Presider: Oregon State University

F2.7 Orcas Papers
College

PRISM: Developing Conceptual Common Ground in 1-9 Science Education Robert E. Hollon, Robert L. Hopper, University of Wisconsin-Eau Claire; Phyllis Klawiter, Sherman Elementary School; Sam Pastorello, Delong Middle School.
PRISM is a preservice 1-9 science education sequence based on the shared expertise of 34 teachers, science educators, and scientists.

College

Sci-Math MN: A Preservice Collaborative Patricia Simpson, St. Cloud State University.
This session will describe the efforts of one state to develop a common vision for preservice math and science education and inform teacher preparation programs in participating institutions.

Presider: Lesley Blair, Oregon State University

F2.8 Whidbey Other Format
General

From Program to Practice: Preliminary Results of the Salish Study of New Science Teachers Robert James, Kristin Hamm, Kay Lubuda, Texas A&M University; Herbert Brunkhorst, California State University; James Gallagher, Joyce Parker & Don Duggan-Hass, Michigan State Un. Sheryl McGlamery, Jeff Garmer & Doug Maclssac, Un. of Northern Colorado; Barbara Spector, University of South Florida; Robert E. Yager, John Tillotson, & John Penick, University of Iowa.
Ten collaborating universities will present results of the Salish study of science teacher preparation programs, new teacher characteristics, and will examine the relationships between programs and teacher characteristics.

Presider: John R. Cannon, University of Nevada, Reno

Friday 11:10 - 12:10 am

F3.1 St. Helens Demonstration
General

Technological Support for Teacher Planning: The Project Integration Visualization Tool Joseph S. Krajcik, Barbara Crawford, Barbara Ladewski, Kathleen Brade, University of Michigan.
We will demonstrate and discuss the theory behind an innovative software tool, the Project Integration Visualization Tool, that supports science teachers as they plan, modify and share projects.

Presider: Geoff Teeter, Genentech

F3.2 Adams Workshop
General

The National Science Education Standards: A Foundation for Teacher Preparation Raymond W. Francis, Appalachia Educational Laboratoratory
During this hands-on session, participants take part in a set of activities intended to demonstrate the intent of the National Science Education Standards.

Presider: Daniel W. Kunz, Junior Engineering Technical Society (JETS)

F3.3 Baker Workshop
Mid/Jr HS

Preparing Secondary-School Science Teachers to Use Complex Instruction David Stronck, California State University, Hayward.
At Stanford University, the Human Biology Middle Grades Life Science Project uses the cooperative learning strategies for small groups by the Center for Complex Instruction.

Presider: Gayle Kirwan, Louisiana State University.

F3.4 Vashon I Panel
College

Advanced Science Teaching Methods: A Round Table Discussion William F. McComas, University of Southern California; Michael R. Cohen, Indiana University; Catherine Yeotis, Wichita State University; Philip R. Pankiewcz, SUNY Cortland.
The session features discussion of the nature of the advanced science methods course.With audience participation, panelists will refine the goals, rationale, topics and experiences to be included in such a methods program.

Presider: Marianne B. Barnes, University of North Florida

F3.5 Vashon II Posters
Elem

Development of an Integrated Math-Science Methods Course with a focus on Problem-Solving Carol Briscoe, David Stout, University of West Florida.
Interpretations of how problem solving in science/math contexts as part of an integrated

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methods course influenced preservice elementary teachers' development of problem solving skills and ability to plan and teach problem-solving to children.
Elem College

Sharing Science Success in Urban Elementary Schools Virginia Johnson Anderson, Barbara Steinberg, Towson State University.
An innovative science teaching practicum for prospective elementary teachers will be described featuring research data, city teacher feedback, video clips, and successful urban strategies.
Elem Super

Promoting Primary Science Valarie Dickinson, Oregon State University; Judy Burns, Elaine Hagen, Kathryn Locker, Finley Elementary School.
This session will discuss strategies developed and used by four first-grade teachers to increase their knowledge and comfort-level in teaching science.
Elem

Three's Company: An Innovative Environmental Education Partnership Michael Kamen, Randy Cromwell, Auburn University.
Qualitative data from an innovative environmental education partnership between an elementary school, a camp, and a university will be presented.
Mid/Jr College General

Turning Things Around and Making it Relevant: Development of a Biology Course for Middle Level Teachers Linda Ramey-Gassert, James Tomlin, Wright State University.
This session will focus on the thinking underlying and development of a specially designed biology course for preservice teachers. Preliminary results will be presented and discussed.
General

Capturing Excellence-Interactive Multimedia For Teacher Education Thomas Thompson, Beth A. Wiegmann, Steve Wallace, Northern Illinois University.
Ten videodiscs, supporting documentation and software modules for preservice and inservice teachers.

Presider: William H. Robertson, Los Alamos National Laboratory

F3.6 Blakely **Demonstration**
General

Focusing the Mind's Eye Cheryl L. Mason, Alan J. McCormack, San Diego State University.
Exciting, stimulating visual/spatial activities that were developed for K-8 students over the past two years of the project will be shared, along with the research instruments and resulting data.

Presider: Paul B. Otto, University of South Dakota.

F3.7 Orcas **Workshop**
Elem Mid/Jr

Interdisciplinary Math and Science: A Hands-on Consideration of Integrated Reform Julie Thomas, Texas Tech University; Lynne Houtz, Nebraska Weslyan University.
Participants will explore 3-4 integrated activities, review the rationale for integrated teaching and learning, consider the appropriateness of integrated math/science methods instruction, and generate further research questions.

Presider: Michael Bentley, National-Louis University

F3.8 Whidbey **Panel**
College

The Use of Portfolios in Secondary and Elementary Science Methods Courses Jodi Haney, Julia McArthur, Bowling Green State University, Caroline Kyhl, University of St. Thomas.
In this interactive panel session, we will discuss the uses and assessment of portfolios in both secondary and elementary science methods courses.

Presider: J. Preston Prather, University of Virginia

Friday 12:30 - 2:20 pm

Cascade Ballroom II **Luncheon**

Invited Speaker:
Robert Tinker, TERC & Concord Consortium
speaking on
"Information Technologies and Education Reform"

Friday 2:30 - 3:50 pm

F4.1 St. Helens **Papers**
Elem

Internet Resources for Preservice Science Teaching Ron Browne, Georgia Southern University.
This presentation will explore the use of Internet resources in undergraduate teacher preparation in elementary grades science. Student preparations and downloaded information will be presented.

Project SIMULATE: Technology Staff Development for Inservice and Preservice Teachers JoAnn V. Cleland, Peter Rillero, Arizona State University West.
Project SIMULATE is an elementary school-university partnership to improve science and mathematics instruction through the use of multimedia technology and language arts.

Presider: Janice Koch, Hofstra University

F4.2 Adams **Papers**
Elem Super

Restructuring Science Instruction for Females, Minorities, and Rural Students Carolyn Dickman, Barbara Foulks, Radford University.
This paper reports on how eight elementary teachers changed their science teaching to enhance the participation of underrepresented students and the efficacy of their teaching.
Elem Mid/Jr

Project PRIDE: Promoting Reform Through Innovation, Development, and Experimentation M. Jenice French, Gail Shroyer, Kansas State University.
The study describes the design, development and process of a bi-level action research project with in-service elementary teachers to enhance equality and achievement in science and mathematics.

Presider: Alan Voelker, Northern Illinois University

F4.3 Baker **Papers**

Elem

Coaching Reflective Practice Among Preservice Elementary Science Teachers Lynn A. Bryan, Sandara K. Abell, Purdue University.
We describe in our paper a novel reflection program that we have developed for use in an elementary methods course.

College

Using Case Studies in Methods Courses Alan Colburn, Cal. State University-Long Beach.
Case studies can increase students abilities to think critically about teaching.This presentation includes a sample case, and video excerpts of the case being taught.

HS

Science Teachers as Culturally Dependent Rational Decision Making: What are the Science Teachers' Reasons? Fred Finley, University of Minnesota; Anita Roychoudhury, Miami University - Hamilton Campus.
This study of preservice teachers' reasons for their planning decisions indicates that discipline-based reasoning becomes more diverse after a methods course and clinical experiences.

Presider: William R. Veal, University of Georgia

F4.4 Vashon I **Papers**

College

Starting a Career in Higher Education Stephen S. Winter, Tufts University.
Professors Winter and Havey will converse informally about aspects of their mentorship that were helpful to both when Dr. Harvey joined Tufts University.

College

Preparing to be a Professor Lloyd H. Barrow, University of Missouri.
This session will summarize a course to assist graduate students in securing science teacher education positions and progress through the higher education system.

Identifying Characteristics of Exemplary Science Teacher Educators Philip R. Pankiewicz, SUNY Cortland.
This session presents results from undergraduate and graduate student surveys at three different college/universities.

Presider: Geraid Foster, DePaul University

F4.5 Vashon II **Papers**

Elem College Super

Assessing Changes in Teachers' Content and Content Pedagogical Knowledge James A. Shymansky, University of Iowa.
Paper will focus on a portfolio system to assess the effectiveness of an inservice program designed to enhance K-6 teachers' understanding and teaching of hands-on science topics.

General

The Science Methods Portfolio as Part of Continuous and Program Evaluation in an Elementary Education Program Tony Lorsbach, University of Alabama in Huntsville.
A science methods portfolio assignment is described that is part of a continuous evaluation of student progress and program evaluation in an elementary education program.

Presider: Kenneth J. Schoon, Indiana University Northwest

F4.6 Blakely **Papers**

General

National Dissemination of the Project MOST (Minority Opportunities in Science Training) Model David Andrews, California State University at Fresno.

General

A Year of Collaborative Teaching in an Urban School: Barriers and Insights Lee Meadows, Cecilia Pierce, University of Alabama at Birmingham.
Two teacher educators report on barriers encountered and insights gained while teaching in an inner-city school one day weekly for a full year.

General

Reforming an Urban Science Teacher Education Program: Guiding Principles and Recommendations from Practicing Teachers Craig A. Berg, University of Wisconsin-Milwaukee.
This is a presentation of the Milwaukee Science Teacher Education Program that is undergoing massive reform based on a set of guiding principles and an advisory group consisting of science teacher educators, science profs and science teachers.

Presider: Linda Ramey-Gassert, Wright State University

F4.7 Orcas **Papers**

College

Engineering Physics for Teachers: A Project Based Integrated Science Course Bill Baird, Ralph Zee, Auburn University.
A new course at Auburn University is designed to introduce teachers to selected principles of physics, numerical computation, group-based project work, and energy technology for the 21st century.

Mid/Jr HS College Super General

Incorporating Computer Spreadsheets into the Robert Karplus Learning Cycle Paul B. Otto, University of South Dakota.
A presentation of the use of computer spreadsheets in teaching physics based on the Learning Cycle. Students need to have opportunity to Explore phenomena, followed by experiences.Modules developed and tested in a NSF Spreadsheet Physics project will be discussed.

Presider: Charles R. Barman, Indiana University

F4.8 Whidbey **Panels**

Elem Super General

WISE-STEP Carole Kubota, Sally Luttrell-Montes, Barbara Reine, University of Washington, Bob Wright, Western Washington University; Jane

Morton, Bellevue School District; Andrea Freed, University of Washington.
NSF-funded, 2.5 year teacher enhancement project working with 5 institutions statewide to improve the teaching of science by preparing elementary teachers as teachers leaders and science advocates.The model includes teams of scientists, teachers, and science educators who work with regional teachers towards systematic reform.

Elem Super General

VINE-Follow Through Carole Kubota, University of Washington; Bob Wright, Western Washington University; Kristi Stoa, Susan Hunter, Mark Emmet, Seattle Public Schools; Anita Lagerberg, Seattle Audubon Society; Amy Martin,University of Washington.
NSF-funded, 3 year teacher enhancement project to develop a professional development model for elementary teachers.The project involves a team composed of teachers whose 4th graders investigate the out-of-doors as real scientists do, science educators, the Seattle Audubon, and the North American Association for Environmental Education.
Presider: Roger Norris-Tull, University of Alaska-Fairbanks

Friday 4:00 - 5:00 pm

F5.1 St. Helens Demonstration
Elem

Decisions in Teaching Elementary School Science James D. Ellis, Kathrine A. Backe, BCSC; Paul J. Kuerbis, The Colorado College.
BSCS will demonstrate the final version of classroom video and print materials for enhancing teaching in elementary school science.
Presider: Robert James, Texas A&M University

F5.2 Adams Papers
HS

Advantages and Disadvantages of Core Teaming in a School-Within-A School Restr :cture: Opinions Expressed by Core and Nonco. e Teachers E. Barbara Klemm, University of Hawaii.
Teachers' opinions on the advantages and disadvantages of school restructuring and team planning. Grade nine and ten students are randomly placed into school-within-a school cohorts taught by teams of science, mathematics, English, and social studies teachers.

General

KITES (Kits in Teaching Elementary Science) Project: A Cooperative Approach to Educational Reform MacGregor Kniseley, Associate Professor, Rhode Island College.
This is a presentation of the vision and results of the early stages of an NSF "Local Systematic Initiative" among eight school districts and 53 elementary/middle schools in Rhode Island.
Presider: Cheryl L. Mason, San Diego State University

F5.3 Baker Workshop
General

Using Computer Simulations To Facilitate Science Teachers Use of the Jigsaw Model of Cooperative Learning Craig A. Berg, The University of Wisconsin-Milwaukee.
A presentation of computer simulations designed to facilitate the jigsaw model of cooperative learning. Used with pre or inservice teachers this software assists teachers in developing powerful learning environments.
Presider: David Stronck, California State University, Hayward

F5.4 Vashon I Panel
College

What Should a Secondary Science Methods Course Contribute to the Knowledge, Skill and Attitude Base of Preservice Teachers? Patricia R. Simpson, St. Cloud State University; John Penick, Alan Colburn, University of Iowa; Michael Clough, Memorial High School; Craig Berg, University of Wisconsin-Milwaukee; J. Russett, Purdue University Calumet.
This session will focus on what should be taught in methods classes, that needs to be left out, and the atmosphere to be established so that students will not only learn what is needed but so that the instructor can also model appropriate instruction.
Presider: William F. McComas, University of Southern California

F5.5 Vashon II Panel
General

Meeting the Needs of Hispanic Learners in Science Through a Model Inservice Program Kathy Norman, University of Texas at Brownsville/TSC; James Barufaldi, University of Texas at Austin; Rey Ramirez, Brownsville Independent School District; Eli Eric Pena, Elva Laurel, University of Texas at Brownsville/TSC.
Components of a model program designed to meet Hispanic learners' needs will be described.Included are curriculum reform, teacher enhancement, and coordinated-thematic science activities.
Presider: Carol Briscoe, University of West Florida

F5.6 Blakely Papers
Elem

Do Baccalaureate Core General Science Courses Relate to a Non-Science Major's Life? Philip D. Wade, Norman G. Lederman, Oregon State University.
Non-science students were surveyed to find out their beliefs on the relevance of required general science classes for an undergraduate non-science degree.

College

Further Validation of the -Constructivist Learning Environment Survey (CLES)-: Its Use in Introductory College Biology, Chemistry, and Physics Courses John R. Cannon, University of Nevada, Reno.
This paper describes research investigating learning environments in introductory college science courses.

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The CLES appraises the level of constructivist learning environments in the course.

College Super

Peer Supervision as a University Teaching Assistant Training Too Lesley Blair, Oregon State University.
Teaching assistants were trained to collect pedagogical data from each other's classrooms. Results and implications of this technique as a training tool will be presented.
Presider: Valarie Dickinson, Oregon State University

F5.7 Orcas Workshop

Operation Primary Physical Science Leon Ukens, Towson State University; Gayle Kirwan, Louisiana State University.
Presenters will provide an overview and engage participants in sample hands-on activities, from this NSF-supported national primary grade teacher enhancement project.
Presider: Linda Ramey Gassert, Wright State University

F5.8 Whidbey Panel

General

Developing a Community of Practice: Supporting Teacher Learning Barbara G. Ladewski, Barbara A. Crawford, Joseph S. Krajcik, University of Michigan; Carolyn Scott, Scarlett Middel School; Scott Heister, Willow High School; Vivian Lyte, Willow Run Community Schools.
Presider: Farella L. Shaka, Southwest Missouri State University

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Friday 7:00 - 10:00 pm

Reception

Reception at the Pacific Science Center
sponsored by
Apple Computer, Inc.

Saturday 6:30 - 7:50 am

AETS Committee Meetings:

Ad Hoc Committee on Faculty Development	Vashon I
Ad Hoc Committee on Funded Projects	Vashon II
Ad Hoc Committee on Liaison with INTASC	Baker
Ad Hoc Committee on Liaison with Science Societies	Baker
Ad Hoc Committee on Professional Development of Science Teacher Educators	Vashon I
Awards Committee	Whidbey
Committee on Liaisons with Professional Organizations of Science Educators	Baker
Editorial Review Board - Science Teacher Education Section of *Science Education*	Orcas
Financial Advisory Committee	Whidbey
JSTE Editorial Board	Orcas
Long Range Planning Committee	Adams
NCATE Subcommittee of NSTA Science Teacher Education Committee	Vashon II
Publications Committee (Part II)	Blakely
Task Force on Professional Development of Classroom Teachers	Adams

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Saturday 7:30 - 8:00 am

Cascade Foyer — Continental Breakfast

Saturday 8:00 - 12:10 am

S1.1 St. Helens Workshop

General

The "Net" for Beginners: What can I do? Note: This session extends through S3.1 James A. Russett, Purdue University Calumet; Betsy Price, University of Utah.
This session will be a one-on-one hands-on session designed to help participants understand what they can do on their own systems.
Presider: Vincent Lunetta, Penn State University

Saturday 8:00 - 9:20 am

S1.2 Adams Papers

Multicultural Science Teacher Bharati Devisk, Mary Atwater, University of Georgia.
A developmental study in the ego, moral, and reflective thinking development of a preservice science teacher.

General

Preparing Prospective Teachers to Teach Culturally Diverse Learners Sherry Nichols, Linda Bullock, University of Texas at Austin.
In this session we will present a study which examine how elementary and secondary science student-teachers generated their visions of teaching culturally diverse learners.

General

Gender Issues in Science Education: Focused Observations and Interpretive Assignments for Preservice and Inservice Teachers Patricia F. Keig, California State University, Fullerton.
No teacher intends to perpetuate gender discrimination in their classroom. Concrete experiences to engage teachers and consider typical practices from a new perspective are presented.
Presider: Andrew T. Lumpe, University of Toledo

S1.3 Baker Papers

General

Development and Utilization of an Instrument to Evaluate Science Teachers' Attitudes Towards Their Own Presentation of Inservice Workshops William J. Boone, Indiana University; Valerie Chase, National Aquarium in Baltimore.
This paper will present an instrument which measures teachers' attitudes towards the presentation of science inservices. Changes in

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summer teacher enhancement programs. that could be made in light of these data will be outlined.

General

The Evolution of Biology Teachers: What Six Case Studies Imply for Teacher Education Deborah J. Trumbull, Cornell University.
The findings from a longitudinal study of teacher development offer insights of ways to support new teachers trying to teach in ways consistent with constructivist/conceptual change viewpoint.
Presider: Judy Beck, University of Toledo

S1.4 **Vashon I** Papers
HS College Super

The Development and Incorporation of Technology Skills, Educational Philosophy, Philosophy of Learning and Pedagogy in Preservice Science Teachers Margaret B. Bogan, Jacksonville State University; Meta Van Sickle, University of Clarleston, Carolyn Dickman, Radford University.
Reflective journal data, questionnaires and computer communications were used to map the thought processes of students as they incorporated the use of technology with pedagogy concomitantly developing their philosophies of science, teaching and learning sequence.

College

The Development of a New Science, Mathematics & Technology Education Facility & Predicted Effect on a Secondary Science One Year Sequence. Hedy Moscovici, Irwin Slesnick, Western Washington University.
This study analyses the dynamic development of a new Science, Mathematics and Technology Education facility at Western Washington University and its effect on the secondary science teaching and learning sequence.
Presider: Pamela Fraser-Abder, The New York University

S1.5 **Vashon II** Panel
Mid/Jr HS College

Geology Education and the Problem of Interdisciplinary Science Teacher Preparation J. Preston Prather, University of Virginia; Elizabeth S. Klein, St. Norbert College; Michael L. Terry, Charlottesville School System.
The panelists will present and justify interdisciplinary science curriculum models for high school and undergraduate college, with emphasis on the need to reform teacher education accordingly.
Presider: Margaret Niess, Oregon State University

S1.6 **Blakely** Paper
Mid/Jr College Super

Evaluation of an Integrated Thematic Science Teacher Training Program Sandara S. West, Melanie C. Lewis, Southwest Texas State University.
Multiple lines of evidence are presented from a three vear project at Southwest Texas State University, funded by the TX Higher Education Coordinating Board.
Presider: Julie A. Weisbert, Agnes Scott College

S1.7 **Orcas** Papers
General

Systematic Reform As A Function Of Intensive Professional Development Of Science Teacher Aaron Burke, Project Discovery-Ohio SSI.
An examination of the variables in an intensive, constructivist professional development program that can lead to building and system reforms and improved student performance.

Elem College

Elementary Science Education Partners: Pathway for Professional Growth for Elementary Science Teachers Molly Weinburgh, Georgia State University; Bob DeHaan, Camille Goebel, Emory University.
The design development and implementation of the elementary science education partners will be shared.Preliminary data on one aspect, profession development, will be shared.
Presider: Scott B. Watson, East Carolina University

S1.8 **Whidbey** Papers
College

Teaching and Learning Science Methods in a Language Arts Methods Course Valarie Dickinson, Oregon State University; Julie Flanigan, Washington State University.
Can science teaching be influenced by integration with language arts instruction?This paper describes methods by the instructor to integrate science teaching methods into a language arts method course, and discusses how the preservice teachers integrated those methods into their science teaching.

College Super

Utilizing Science Fiction Stories to Reinforce Student Learning in Earth/Space Science Courses Kathie Black, University of Victoria.
This presentation describes an assignment of writing stories given as an exam in an Earth/Space content course for preservice elementary education students.
Presider: Gloria Snively, University of Victoria

Saturday Cascade Foyer **9:20 - 9:40 am**
Coffee Break

Saturday **9:40 - 11:00 am**

S2.2 **Adams** Papers
General

Teach As I Do Cynthia E. Ledbetter, University of Texas, Dallas.
Elementary teachers are taught science through use of hands-on lab activities rather than through lecture.

College

A Procedure for Introducing Curriculum Integration to Elementary Methods Gilbert Naizer, Susan Kent, Ohio State University at Newark.

The presentation will share a procedure which has been successfully used in assisting preservice elementary students in developing high-quality integrated science/social studies units.
Presider: Paul C. Beisenherz, University of New Orleans

S2.3 Baker Papers
College

Modeling Science and Science Learning in Introductory College Science Katherine Denniston, Joseph Topping, Rachel Burks, Towson State University.
Design and implementation of three introductory level integrated science courses for preservice teachers as part of the Maryland Collaborative for Teacher Preparation, an NSF supported program.

General

Incorporating Science as How We Know into the Middle School Curriculum Renna B. Calvert, J. Steve Oliver, Wyatt W. Anderson, David P. Butts, University of Georgia.
A study of the degree to which middle school teacher/participants have knowledge of science as how we know and the uses to which this knowledge is put.
Presider: Kathryn Powell, Texas A&M University

S2.4 Vashon I Paper
Elem

Intensive Teacher Enhancement is a Start James D. Ellis, Donald E. Maxwell, BSCS; Paul J. Kuerbis, The Colorado College.
The panel will describe variations on an approach to enhancing programs elementary school science.
Presider: Jack Wheatley, N.C. State University

S2.5 Vashon II Papers
College

The Efficacy of a Gender and Ethnic Equity in Science Education (GEESE) Curriculum for Preservice Teachers Linda D. Bullock, Univ. of Texas at Austin & Science Academy of Austin.
The Gender and Ethnic Equity in Science Education (GEESE) program teaches preservice teachers to use clinical techniques as discovery vehicles of diverse students' disparate science experiences.

General

Creating a Cycle of Equitable Teaching Kathryn Scantlebury, Dr. Bambi Bailey, Mr. Will Letts, University of Delaware;Ms. Susan Gleason, Middletown High School; Mr. Rennie Clements, Glasgow High School; Mr. Bob Lewis, Bob Lewis, Hanby Middle School; Ellen Johnson, Concord High School.
This paper discusses a project that incorporated gender equity into the secondary science education program at the preservice and inservice levels.
Presider: Katherine Norman, University of Texas at Brownsville/TSC

S2.6 Blakely Demonstration
Elem College

Integrating Children's Literature into the Elementary Science Curriculum: the Search for Quality Beth A. Wiegmann, Northern Illinois University.
This interactive presentation will examine criteria for evaluating effective children's literature for use in science instruction. Selection criteria will be shared.
Presider: Betsy Price, University of Utah

S2.7 Orcas Other Format
General

Interactive Session on NSTA/NCATE Accreditation and Certification Initiatives Steven Gilbert, Ivy Tech State College.
Brief overview and invitation to discuss an initiative to integrate and extend national standards for science teacher preparation through state partnerships medicated by NCATE.
Presider: Ken Appleton, Central Queensland University

S2.8 Whidbey Papers
General

Student Perspectives on Learning Integrated Science Concepts Lawrence B. Flick, Oregon State University; Charles Ault, Lewis & Clark College.
Student science knowledge and observations about instruction are used as components of an evaluation of inquiry-oriented, constructivist-based teaching practices.

Elem College

Model For Successful Elementary Science Inservice With Broad Implications for Replication (NSF) Edward E. Jones, Miami University.
The design and results of a five-year NSF sponsored inservice project conducted with the cooperation of a university and an urban school district.
Presider: David Crowther, University of Nebraska

Saturday 11:10 - 12:10 am

S3.2 Adams Papers
HS College

Development of Preservice Teachers' Ability to Assess Students' Understanding Judith Morrison, Oregon State University.
Preservice teachers were interviewed to assess their views of students' preconceptions and how they would identify and attempt to change these in the classroom.

HS College

Design Your Own Computerized Testing Program Ronald F. Pauline, Gannon University.
A demonstration of how to design an individualized, self-paced testing program which targets your students and your classroom teaching strategy. Hypercard for Macintosh will be used.
Presider: William J. Boone, Indiana University

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S3.3 **Baker** **Panel** General

Video Case Studies in Science Education Matthew H. Schneps; Nancy Finkelstein, Harvard-Smithsonian Center for Astrophysics.
Participants will view and discuss video clips of teachers in their classrooms addressing an issue or concern about science education.
Presider: James A. Russett, Purdue University Calumet

S3.4 **Vashon I** **Demonstrations** Elem Mid/Jr

Modeling Alternative Assessment in Preservice Math, Science and Technology Methods Courses. Beth Shiner Klein, St. Norbert College.
The session will demonstrate the various methods of alternative assessment that are being implemented in elementary math/science technology methods courses.

Mid/Jr

Facilitating Change Through Self-Assessment: An Instrument for Middle School Science Patti Nason, UNC Charlotte; Bob James, Texas A&M University.
The development and implementation of an instrument designed to help middle school science teachers assess the extent of their implementation of effective science programs in a middle school context. Demonstration and results will be presented.
Presider: Deborah J. Trumbull, Cornell University

S3.5 **Vashon II** **Workshop** Mid/Jr

The Merging of Science and Special Education: Teachers as Partners in Retooling Science Activities Kevin D. Finson, Donald T. Powers, Christine K. Ormsbee, Mary Jensen-Welber, Western Illinois University.
We will retool a science activity following project guidelines so that it is appropriate for special education and general education students.
Presider: Bharati Devisk, University of Georgia

S3.6 **Blakely** **Demonstration** Elem

"Investigating Our Blue Planet:" A thematic and community-learning approach to enhancing elementary science teaching Rick Tinnin, University of Texas Marine Science Institute;Dr. James Barufaldi, University of Texas at Austin.
The demonstration session will feature a sample activity and research data from a project that used interdisciplinary science themes to link science and math instruction across the elementary curriculum.
Presider: Sherry Nichols, University of Texas at Austin

S3.7 **Orcas** **Workshop** Elem

Connecting the Curriculum through the National Mathematics and Science Standards Raymond W. Francis, Appalachia Educational Laboratory.
Participants make use of a unique teacher-developed matrix approach to develop connections between science and mathematics.
Presider: Margaret B. Bogan, Jacksonville State University

S3.8 **Whidbey** **Papers** Elem College Super

Assessment Practices in the Elementary Science Classroom: Implications for Teacher Preparation Joseph Jesunathadas, Janet Woerner, California State University, San Bernardino.
FOSS and Macmillan/McGraw-Hill Science are adopted science materials assessment practices of teachers who use these materials. The paper will report findings of assessment practices and make suggestions for teacher preparation.

Elem College

Constructing Constructivism: Elementary Science Teachers in Progress Andrea B. Freed, University of Washington.
Two self-identified constructivist elementary shared their beliefs and attitudes about science instruction and discussed how their educational and experiential background influenced how they interpreted and responded to student reasoning during science lessons.

College

Preservice Teachers Changing Attributions for Elementary Students Success or Failure in Science. Stephen R. Wallace, Northern Illinois University.
This study examined preservice teachers attributions for elementary students success or failure at a guided discovery, hands-on activity.
Presider: Hedy Moscovici, Western Washington University

Saturday 12:30 - 2:20 pm

Cascade Ballroom 2Luncheon

Awards Ceremony/Business Meeting

Saturday 2:30 - 3:50 pm

S4.1 **St. Helens** **Demonstration** Mid/Jr HS Super

Software as Change Agent in Science Curriculum & Implementation David Longdon, Michael Jay, Chancery Software, Inc.
Talk will include a demo of CSL Curriculum Orchestrator, a review of early use and a discussion of how it supports change in math & science education.
Presider: Katherine Denniston, Towson State University

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S4.2 **Adams** **Papers**

General

Construction and Validation of a Rubric for Scoring Concept Maps Farella L. Shaka, Betty L. Bitner, Southwest Missouri State University.
The rationale for designing a rubric for scoring concept maps and the validation of the rubric will be presented.

General

Customizing the Draw-A-Scientist Test Juanita Jo Matkins, Cathy Orange, Lanaux Hailey, University of Virginia; Jeanette Curtis, Walker Upper Elementary School; Kay Weaver, Cale Elementary School; Dr. J. Preston Prather, University of Virginia.
A group of elementary/middle school classroom teachers have adapted and tested the Chambers' Draw-A-Scientist Test for program evaluation.

Presider: Cynthia E. Ledbetter, University of Texas, Dallas

S4.3 **Baker** **Papers**

College

Assessment of the Implementation of the Constructivist Learning Model as Methodology in and Elementary Science Methods Course Patricia L. Nason, University of North Car-Charlotte.
Description of how preservice teachers construct understanding of science methodology in their elementary science methods course is described and analyzed.

College

An Analysis of Elementary Majors' Progress With Vee Diagramming Mike Nelson, M. Virginia Epps, University of Wisconsin-Whitewater.
Data suggests that preservice elementary students investigative skills improve while using vee diagrams. Strategies and associated variables will be discussed.

Presider: Renna B. Calvert, University of Georgia

S4.4 **Vashon I** **Panel**

General

Publishing Papers in Science Teacher Education Vincent Lunetta, Thomas M. Dana, Penn State University.
Policies, procedures, statistics, etc., will be presented and discussed for preparing and submitting manuscripts on science teacher education for publication in journals in the field.

Presider: Gilbert Naizer, Ohio State University at Newark

S4.5 **Vashon II** **Papers**

General

Teachers' Beliefs and Their Implementation of Personal Relevance in the Classroom Judy Beck, Andrew Lumpe, University of Toledo.
Linda D. Bullock, Univ. of Texas at Austin & Science Academy of Austin

General

Science Teacher Staff Development Strategies for Reform: Using Active Learning Models to Address Teachers' Beliefs Andrew T. Lumpe, University of Toledo; Jodi J. Haney, Bowling Green State University; Kathy Backe, BSCS.
We will share science teacher staff development strategies based on active learning models and designed to address teacher beliefs.

Presider: Linda D. Bullock, Univ. of Texas at Austin & Science Academy of Austin

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S4.6 **Blakely** **Papers**

General

Overcoming Gender and Cultural Barriers in the Science Classroom Pamela Fraser-Abder, The New York University; Brian Murfin, New York University.
Session examines global issues of access and gender, cultural and psychosocial barriers to Science and Technology Intervention Strategies for overcoming these barriers are presented.

Mid/Jr College General

Two Year Study of an Inservice Program Designed to Promote Integration of Science Throughout the Curriculum Charlene M. Czerniak, The University of Toledo.
Results of a 2-year study of an inservice program will be shared. The program was designed for middle grades teachers to encourage integration of science.

Presider: Kathryn Scantlebury, University of Delaware

S4.7 **Orcas** **Panel**

General

Project 2061's Blueprint on Teacher Education Jo Ellen Roseman, AAAS; James Gallagher, Michigan State University.
Panelists and participants will discuss the recommendations for action proposed in a draft Blueprinting Report on Teacher Education prepared for Project 2061. The recommendations address undergraduate education, teacher recruitment, and more.

Presider: Edward E. Jones, Miami University

S4.8 **Whidbey** **Panel**

College

The Fifth-Year Graduate Preservice Teacher: Juggler in the Circus of Teacher Preparation Margaret Niess, Norman Lederman, Janet Scholz, Oregon State University; Scott Mortlock, Philomath Middle School; Michael Roberson, Oregon State University.
Diverse perspectives of effective teaching/professional development of the individuals actively involved preservice preparation of science and mathematics teachers in a graduate program.

Presider: Beth A. Weigmann, Northern Illinois University

Saturday 4:00 - 5:00

S5.1 **St. Helens** **Demonstration**

General

Resources for Science Literacy: Professional Development Jo Ellen Roseman, AAAS.

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This demonstration will introduce Resources for Science Literacy: Professional Development, Project 2061's latest print/electronic tool designed to help educators enhance their own understanding of science literacy.
Presider: Matthew H. Schneps

S5.2 **Adams** **Papers**
General

The Effect of Traditional Classroom Assessment on Science Learning Scott B. Watson, Amy R. Taylor, East Carolina University.
Findings of this study indicate that there was no difference in science achievement of students in testing situation and those not in testing situations.

College
Preservice Teachers' Perspective on the Nature of Science Kathryn Powell, Diane Adoue, Texas A&M University.
Teachers from both elementary and secondary science methods' courses share their perspectives on nature of science.

College
Perceptions of Prospective Elementary School Teachers Toward Three Required Courses: Physics, Physics Lab and Science Methods Paul C. Beisenherz, Marylou Dantonio, University of New Orleans.
Significant differences in prospective teacher perceptions were found in a study comparing the content and methodology within three required courses--physics, physics laboratory, and science methods.
Presider: Ronald F. Pauline, Gannon University

S5.3 **Baker** **Papers**
College Super

Constructing Constructivist Teaching: A Teacher Leadership Institute for the Global Thinking Project Julie A. Weisberg, Agnes Scott College; Susan Dunkerly-Kolb; Jack Hassard.
We will discuss our own evolving understanding of what it means to create constructivist learning environments for teachers, as well as some effects of such experiences on teachers' classroom practices and understandings.

General
Linking Global Education to Multicultural Science Education Gloria Snively, University of Victoria; John Corsiglia, University of Northern British Columbia.
This presentation argues for broadening the science curriculum to include the natural science of long-term populations of traditional peoples to sustain both community and environment.
Presider: Judith Morrison, Oregon State University

S5.4 **Vashon I** **Workshop**
Elem Super

Using a Constructivist Learning Cycle at the Elementary Level BSCS's Science for Life and Living Jack Wheatley, N. C. State University.
This activity-based K-6 program uses a unique 5 stage Learning Cycle that spans each unit (4 to 8 weeks) with multiple activities at each stage.
Presider: Charlene M. Czerniak, The University of Toledo

S5.5 **Vashon II** **Paper**
College

Environmental Education for Pre-Service Elementary and Secondary Science Teachers George R. Davis, Moorhead State University; Patricia R. Simpson, St. Cloud State University.
Report on one Minnesota and one national program which center on modifying pre-service teacher education programs to prepare teachers to deliver K-12 environmental education curricula.
Presider: Andrea B. Freed, University of Washington

S5.6 **Blakely** **Workshop**
General

Educational Research-A Working Tool for Curriculum Development Betsy Price, University of Utah.
Educational research is a powerful tool to build hands-on teaching kits for though subjects like genetics.We'll show you the kits and how they were made.

S5.7 **Orcas** **Paper**
Elem

Preservice Science Teacher Education and Learning Theory: A Report on Practice Ken Appleton, Central Queensland University.
Constructivist views of learning have been applied to an elementary preservice science teacher education unit. Applications of the theory are explained, and evaluations summarized.
Presider: Joseph Jesunathadas, California State University

S5.8 **Whidbey** **Workshop**
Mid/Jr HS College Super General

H20=Hands & Heads-on Undergraduate Science David Crowther, Ronald J. Bonnsetter, University of Nebraska.
This session describes four new science courses, designed jointly by Arts & Science faculty and Teachers College as alternatives to the large introductory "one size fits all" lecture/lab courses.
Presider: Rick Tinnin, University of Texas Marine Science Institute

Saturday **7:00 - 10:00 pm**

Reception

Reception at the Museum of Flight
Sponsored by
The Boeing Company & Delta Education

1996 AETS Conference Papers and Summaries of Presentations

INCLUDING ESL STRATEGIES WITHIN THE ELEMENTARY SCIENCE METHODS COURSE

Darla Stapel, North Tamarind Elementary School, Fontana, CA
Cynthia Smith, North Tamarind Elementary School, Fontana, CA
Iris Riggs, California State University, San Bernardino
Esteban Diaz, California State University, San Bernardino

The Commission on Teacher Credentialing in the state of California now offers elementary teachers the opportunity to pursue a multiple subject credential program with emphasis on Crosscultural, Language, and Academic Development (CLAD). Teacher preparation programs which prepare teachers with this emphasis must include content and methodology which develop their preservice teachers' ability to teach all students, including those who are developing skills in English as a second language. Many California institutions of higher education now offer only this credential option to their students. Even within states which do not yet offer a credential with this special emphasis, most teacher preparation programs are attempting to prepare teachers who can facilitate the learning of students with limited English proficiency.

Because of this increasing need to develop teachers who can facilitate second language development within the regular elementary classroom, many methods courses are attempting to integrate strategies which promote this facilitation within the content areas. Based upon their experiences in a teacher enhancement project[1], the authors will discuss how to include and model ESL strategies within the elementary science methods course in addition to strategies which promote second language students' science content learning.

Background

The Science Education and Equity Project (Project SEE), an NSF-funded program has recently been completed in southern California. The purpose of Project SEE was to improve the

[1]Based upon a grant (ESI 9155270) funded by the National Science Foundation.

pedagogical and content background of elementary teachers, especially in reference to their ability to teach science effectively to English Language Learners (ELL).

Project SEE engaged teachers in a curriculum based upon the district-adopted Full Option Science System (Lawrence Hall of Science, 1990), in addition to teaching methods designed to facilitate the learning of ELL students. Project instructors modeled FOSS science lessons while project teachers participated in the hands on lessons. Sheltered English strategies were incorporated into the lessons and defined after teachers had experienced them as students. Teachers practiced teaching their own sheltered FOSS lessons to their peers and instructors.

Although Project SEE worked with inservice teachers, many of the same teaching strategies can be incorporated into the science methods preservice course so that teachers are better prepared to meet the needs of their diverse student populations. As methods instructors attempt to do this, they might consider the following sections which describe sheltered strategies and activities which are designed for the science methods course.

Sheltered Strategies for Science Instruction of ELL Students

Science instruction can be meaningful for ELL students if appropriate strategies are used to make instruction comprehensible. The science content should not be simplified in any way, but the method of delivery should be adjusted to provide students with ample opportunity for participation, thereby making the concepts comprehensible. The following strategies might be utilized:

Simplify The Input

To do this, teachers need to deal with the same content and vocabulary, but should slow down their speech and enunciate their words clearly. Teachers should use proper science terminology, restate, redefine, give examples and attempt to utilize students' prior knowledge.

Provide Context Clues

Gestures and/or actions can be used to communicate meanings. Realia also helps ELL students; in addition to graphs, visuals and other props.

Draw on Prior Background

Students can be expected to share their prior knowledge through short verbal responses. The teacher might also provide realia to communicate the concept and allow students to communicate prior understanding by making a nonverbal choice.

Provide Opportunities for Group Work

ELL students can learn much science and English from their peers. The teacher might consider heterogeneously grouping by language for some activities. The teacher should accept and encourage students' dialoguing in their preferred language within groups. Group reports of learning can be helpful as this provides frequent restating and expansion of important concepts.

Use Materials

Whenever possible, science lessons for ELL students should be activity-based with all students having hands on access to materials.

Assess All Students

During instruction, teachers might be especially observant of ELL students' behavior. Student use of materials can be one indicator of involvement and understanding. When questioning, teachers need to be sure to provide adequate wait time and give students the option of responding through nonverbal signals. Teachers should give serious consideration to performance-based assessments for formal evaluation. They might also consider accepting drawings and primary language as indicators of learning within a science journal.

Shelter-Based Methods Activities

In order for preservice teachers to become proficient in teaching their ELL students, sheltered strategies must be modeled, practiced and discussed within the science methods course. The instructor might consider the following as potential activities.

The Sheltered Experience

A good initial activity engages preservice teachers within a sheltered science lesson in which they play the part of students and the "teacher" does all instruction in a language other than English. If the instructor is not bilingual, a bilingual student or guest can play the part of "teacher".

The lesson should be one that utilizes as many supportive strategies as possible. After completion, preservice teachers might write in a journal followed by group sharing of emotions and frustrations during the lesson. As a whole group, students should share what the "teacher" did that was a help or a hindrance to their learning. These observations should be recorded by the instructor and related to the modeled sheltered strategies.

Cooperative Learning

Because cooperative learning has been found to be an effective instructional strategy to use with ELL students (Krashen, 1981; Chamot, 1983), the methods instructor should include it as a modeled strategy. A part of cooperative learning that is especially helpful when dealing with ELL students is that of assigning roles to individual group members. This assures all of an active part and helps to ensure that all eventually have the opportunity to fulfill each important role and its responsibilities. Without teacher and student attention to roles, the ELL student (and others) may find themselves always playing a more limited role within the learning team.

In the methods course, instruction in cooperative learning strategies and role assignment is important. It might be most beneficial to sequence this instruction after preservice teachers have participated within cooperative learning lessons. Just like an elementary teacher, the methods instructor should implement cooperative strategies, teach roles and their functions, and utilize role name tags to help the "students" and their instructor remain aware of role responsibilities throughout the modeled lesson. Jones (1985) has described a number of roles which can easily be used within the elementary science classroom. Kessler, Quinn, & Fathman (1992) have specifically described cooperative science lessons for ELL students.

Lesson Design

The needs of ELL students should to be taken into consideration when planning lessons. To promote preservice teachers' specific consideration of these students, the methods instructor might require a specific section be included in all assigned lesson plans to delineate the preservice teachers' thoughts in this area. When giving feedback and evaluating the plans, the instructor needs to also give ample attention to this section.

Peer Teaching

Lesson plans lead to implementation. Oftentimes, preservice teachers are expected to teach planned lessons to their peers or to share video taped lessons of their field teaching. These experiences provide opportunities for reflection and growth in all teaching abilities. Again, strategies for meeting ELL students' needs must become part of the focus.

Project SEE teachers and instructors followed up each peer teaching segment with independently recorded written feedback to the "teachers". Each person took note of at least two positives and one "wish" about any aspect of the lesson. A handout of sheltered strategies was used to encourage reflection on this specific component of each lesson. Whole group discussion followed with all dialoguing about strengths and weaknesses of the lesson. Specific attention was given to the topic of sheltered strategies.

Student Assessment

Observation and interview of an ELL student can be a valuable assignment for preservice teachers. If they are in the field throughout the course, they can study their focus student's learning continuously. This attention promotes the teacher's understanding of the ELL student's level of learning and ways to assess that learning.

Conclusions

Elementary teachers need to be able to effectively teach all their students science. Those students who are English Language Learners deserve teachers who have developed some understanding and skill in sheltered strategies within their preservice program. To do this, the science methods instructors need to develop their understanding and skills within this area. As they do this, they will be more able to more fully integrate sheltered strategies throughout their science methods course.

Acknowledgment

The authors wish to express gratitude to all staff members of Project SEE for their support of this work: Klaus Brasch, Joseph Jesunathadas, Javier Torner, Kathy Mouzakis, Allen Pelletier, Lisa Shamansky, Sam Crowell, Teri Majalia, Albert Lozano, Curt Jacquot, and Julie Murphy.

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WRITE-TO-LEARN SCIENCE STRATEGIES FOR PRESERVICE ELEMENTARY TEACHERS

Larry D. Yore, University of Victoria

Interactive-constructive perspectives of science teaching and science learning suggest that teaching is a public event within a sociocultural context while learning is a private act (Hennessey, 1994). The knowledge-construction, knowledge-storage, and knowledge-retrieval aspects of these perspectives continue to be unclear. It is reasonably well-accepted that the internal construction act is enhanced with social interactions and supportive scaffoldings provided by peers, experts, and teachers. Talking science and listening to peers, adults and teachers have positive influence on science learning and have demonstrated the value of verbal language as learners share, debate, and negotiate meaning (Lempe, 1990; Pea, 1993; Shymansky, 1994).

The logical extension of these results would suggest that print-based language arts would also influence science learning, especially knowledge storage and retrieval. The value of writing a list to improve memory and webbing and concept mapping to illustrate hidden connections and internal organization are popularly accepted. The relationships among reading to learn, writing to learn, and science achievement are not well established but the available "research does not support the concocted claims that reading and writing in science naturally inhibit students' creativity, curiosity, and interest" (Holliday, 1992, p. 60). Connolly (1989) stated:

> Writing-to-learn involves and emphasizes the powerful role language plays in the production, as well as the presentation of knowledge. Writing to learn is less about formal uses of writing...than it is about informal writing...that is forming meaning; about writing that is done regularly in and out of class to help students acquire a personal ownership of ideas. (pp. 2-3)

He suggested that this new rhetoric was compatible with constructivist perspectives of learning and illustrated that the symbol systems used to communicate play a critical role in constructing meaning. He emphasized:

> Writing-to-learn is not, most importantly, about 'grammar across the curriculum' nor about 'making spelling count' in the biology paper. It is not a program to reinforce standard English usage in all classes. Nor is it about 'formatting across the curriculum': mastering the formal convention of scientific, social scientific, or business writing. It is about the value of writing 'to enable the discovery of knowledge' (p. 5).

However, writing-to-learn science tasks do provide authentic opportunities to develop scientific vocabulary, patterns of argumentation, and technical genre. Sutton (1992) described clearly the fabric of words, science and learning, and the interpretive nature of language frequently mistaken as simply a label system by scientists. Halliday (1993) cautioned science educators about over-emphasizing the interpretative nature of scientific language, disregarding the unique structure-function relationship of specific science genre, and assuming that narrative genre will improve science understanding. Elementary school teachers appear to emphasize expressive writing and de-emphasize expository and personal writing (Rivard, 1995).

Although limited research has substantiated the value of print-based language in science learning (Holliday, Yore & Alvermann, 1994; Rivard, 1994), the common-sense and grass-roots supporters of reading and writing across the curriculum have purported generic relationships among reading, writing, and learning. This paper assumes that discipline-specific expository and personal writing tasks that match the epistemology and the evaluative nature of science will enhance science learning. Unfortunately, "we must persuade a group of teachers who themselves did not learn science...this way, that writing-to-learn is not only useful but essential for a certain type of student" (Tobias, 1989, p. 48). Two purpose-specific writing tasks (summary-reflection reaction paper and collaborative explanatory essay) used with preservice elementary school teachers will be described to provide a framework for future write-to-learn science inquiries.

Background

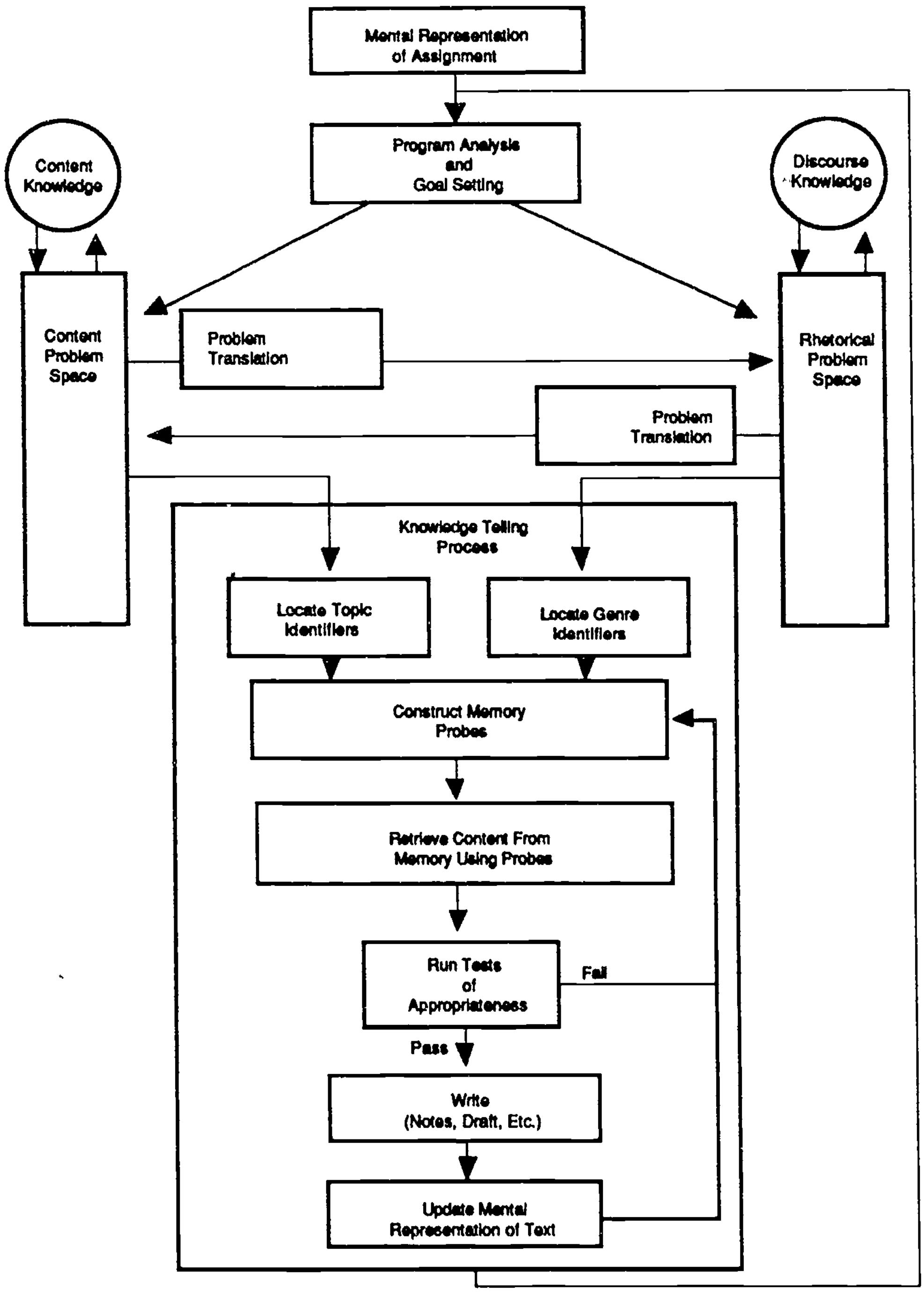
This study was based on two distinct bodies of research: writing-to-learn and content-pedagogical knowledge needs of teachers. Collectively, these literatures suggest that elementary school preservice teachers need to encounter well-focussed experiences and explicit instruction with write-to-learn strategies that help them understand specific science or science education concepts and associated pedagogy that could be utilized in their future classrooms. The choice of topic must be appropriate to adult learners and be practical, relevant, and valued by preservice elementary school teachers. Therefore, this paper provides a background of the write-to-learn literature in postsecondary institutions to address the target learners' needs as well as the write-to-learn literature in elementary, middle, and junior high schools where these preservice teachers will be ultimately teaching.

Newell and Winograd (1989) stated that "there is at present only slender empirical base from which to conceptualize how writing may aid learning about the topic, that is, how the writing process and what writers take from writing are interrelated" (p. 196). However, writing science appears to clarify fuzzy thinking and enhance understanding. Woodford (1967) suggested that young scientists needed to perfect their writing skills in order to expose woolly thoughts, shoddy thinking, and inaccurate insights. Writing allows ideas to be made permanent and to be publicly analyzed, dispassionately criticized, checked for precision, verified for logic, and tested for content. It is easy to assume that writing is a natural extension of speaking, but Vygotsky (1978) pointed out that communicating with an unseen audience represents a significant jump in cognitive demand from face-to-face speaking and listening with someone.

Rivard (1994) found that write-to-learn was reasonably well researched at the secondary and postsecondary levels but was very limited in the elementary, middle, and junior high school levels. Much of the research reported appears to be based as a mechanistic interpretation of the writing process and a knowledge-telling model of writing. Students systematically select a topic, recall understanding, draft a product, and produce a final copy. Holliday, Yore, and Alvermann (1994) suggested that the knowledge-transforming model of writing provides a promising breakthrough for writing to learn science. Scardamalia and Bereiter (1986) encouraged teachers to help their students move from the predominant knowledge-telling writing , which involves converting knowledge from long-term memory into written words essentially unaltered, to a knowledge-transforming approach in which knowledge is actively reworked to improve understanding—"reflected upon, revised, organized, and more richly interconnected" (1986, p. 16).

The knowledge-transforming model (Scardamalia & Bereiter, 1986) clarifies the role of conceptual knowledge about the target topic and the metacognitive knowledge about discourse, patterns of argumentation, and genre (Figure 1). Utilizing the knowledge-transforming model as an operational framework would encourage teachers to get students spending more time setting purpose, specifying audience, thinking, negotiating, strategic planning, reacting, reflecting, and revising. Teachers would also provide explicit instruction embedded in the authentic context of scientific inquiry designed to clarify what writing is; the purpose-specific nature of scientific genre; the interactive, constructive, generative nature of science language; the relationship between evidence, warrants, and claims; and what, how, when, and why to use specific writing strategies.

Figure 1
The Knowledge-Transforming Model (Bereiter and Scardamalia, 1987)



Howard and Barton (1986) stated the "idea is to learn to think in writing primarily for your own edification and then the eyes of others. This approach will enable you to use writing to become more intelligent to yourself—to find your meaning—as well as to communicate effectively with others" (p. 14). Holliday (1992) suggested that effective science writers consider their audience and purpose; strategically plan, draft, revise, and edit; structure writing for maximum effect; typically read, listen, and speak well; and understand language is interpretative, interactive, and constructive.

The following principles should guide the development of writing-to-learn tasks in science (Tchudi & Huerta, 1983):

- Keep science content central in the writing process
- Help students structure and synthesize their knowledge
- Provide a real audience for student writers that will value, question, and provide supportive criticism
- Spend time prewriting, collecting information from various sources (concrete experiences, print materials, experts, electronic data banks, visuals, etc.), sharpening focus, and strategic planning
- Provide on-going teacher support, guidance, and explicit instruction
- Encourage revisions and redrafts based on supportive criticism to address conceptual questions and clarify understandings
- Clarify the differences between revising and editing (format, spelling, mechanics, grammar)

Postsecondary Colleges and Universities

Sullenger (1990) found that science teachers had limited understanding of writing to learn and the related instructional strategies. Rosen (1989) provided several questions to guide exploration and implementation of writing-to-learn strategies with preservice and inservice teachers.

1. What is their current metacognitive awareness of writing to learn?

2. What is their current level of knowledge application in developing effective write-to-learn strategies?
3. To what extent are teachers in metacognitive control of the complexities associated with the implementation of writing-to-learn strategies?
4. What are their attitudes and dispositions toward writing to learn?
5. Which aspect of writing to learn is the most interesting and challenging to them?

These questions suggest that education should focus on teachers' metacognitive awareness of issues related to writing to learn; executive control of strategies, language and knowledge; and habits of mind associated with writing. Rosen suggested using teachers' own writings as a starting point for enhancement of writing-to-learn strategies. This requires the selection of relevant topics, authentic situations, explicit evidence of learning related to the writing task and direct instruction to improve writing and learning.

Writing in science to promote epistemic insights, thinking, and conceptual understanding requires utilization of science-appropriate genre: field logs, triple-entry journals (observations, inference, further questions), summaries, explanatory essays, persuasive editorials, position papers, resumés, research proposals, case histories, technical reports, and popular science newspaper articles (Martin, 1993; Mullins, 1989). Moore (1993) found college students' science achievement improved if writing was embedded with explicit writing instruction. Liss and Hanson (1993) found that students who had an internal locus of control appeared to value writing tasks and worked harder than students with an external locus of control. Generally, application of write-to-learn approaches are being more widely used in university/college level science courses than ever before (Ambron, 1987; Madigan, 1987a, 1987b; Squitieri, 1988).

Iding (1994) and Iding and Greene (1995) addressed the type of feedback that influenced adult writers. Iding (1994) found that college composition students benefitted most from comments that described the desired changes, such as additional information, local structure, and global structure. Students believed comments that provided a different perspective to be useful.

Iding and Greene (1994) found the peer comments were useful to preservice teachers. The quantity and quality of peer comments could be improved with explicit instruction.

Elementary, Middle, and Junior High Schools

Feely (1993) used written prose, pictorial diagrams, and concept webs to capture the richness of science talk. This explicit talk-text approach helps students to focus their thinking, visualize ideas, organize their thoughts, and connect concepts. Feely (1993) encouraged students to write before, during, and after investigations. These texts also provide a permanent record of their thinking and progress.

Jan (1993) used implicit and explicit modelling to help students learn about the various ways language is used in science and to have students use print-based language to learn science. She stressed that writing in science "must not be relegated to mere completion of worksheets or to the recipe-type" writing tasks (p. 41). Rather, students need to be engaged in authentic science situations that involve different writing forms for specific purposes and audiences. Teachers must emphasize the structure-function relation of written text to match purpose, form, and audience.

Unsworth and Lockhart (1994) explored how junior primary (Grade 2) teachers attempted to integrate print-based language arts into their science classes in two inner-city schools. They found writing (12%, 17%) and reading (15%, 11%) accounted for a minority of the instructional time for science in the two classes (27%, 28%). The writing involved a variety of tasks: factual, extending text, lists, and diagrams. Unfortunately, little preparatory or explicit instruction was provided for science writing and science reading. There was variation in how writing was dealt with, and the limited explicit instruction provided generally involved modelling or a structured worksheet. Little effort was directed at self-regulation.

Grade 2 and Grade 5 students utilizing a scaffolding to write science reports demonstrated different growth patterns (Morris, Frances & Hill, 1993). The younger students increased the number of words produced, while the Grade 5 students' word production decreased. The number of sentences produced decreased for Grade 5 students, while the Grade 2 students increased and then decreased the number of sentences produced. The students regardless of grade level were able to structure the reports eventually without the aid of the scaffolding.

Burkhalter (1995) investigated the effects of an instructional scaffolding dealing with persuasive writing on the data, warrants, and claims used by male and female Grade 4 and 6 students. She found significant pretest/posttest growth, a significant explicit instruction effect, a significant gender effect favoring females, non-significant grade-level effect, and some two-way and three-way interaction effects. She concluded that students as young as nine years can benefit from explicit persuasive writing instruction.

Bergin (1995) explored a combined approach to teaching summarizing. She stated:

> The cognitive operations involved in summarizing include knowing how to select, condense and transform information. Selecting information involves identifying information which is relevant and important. Condensing involves synthesizing information so that the structurally important information is gleaned; and in order to transform information, students must relate main ideas to each other and reconstruct a meaning which is concise but representative of the original text's structure and content. (p. 30)

These cognitive operations have been demonstrated to be part of an expert scientist's and science learner's repertoire. Bergin found that students improved their ability to select and combine main ideas when the instruction provided an effective framework, active role, and encouraged self-regulation, and improved skills.

Santa and Havens (1991) provide practical insights for using learning logs, scientific reports, and scientific explanations in the secondary schools. They believe explicit instruction, structured tasks, and peer discussions, reflections, and reactions are critical to the effectiveness of these writing-to-learn science approaches. Students use journal entries, reports, and explanations to demonstrate their thinking, to grasp the complexities of scientific inquiry, and to internalize scientific patterns of reasoning.

Keys (1994) found that writing tasks helped develop scientific reasoning in Grade 9 students. She used a collaborative laboratory report writing task that encouraged students to select and process text, draw conclusions, formulate models, compare and contrast alternative understandings, and construct personal meaning.

Rivard (1995) explored the influence of talking and writing science in Grade 8 science. He found that talk-only produced the greatest posttest gains about ecology but talk-write produced the greatest retention. He utilized concept mapping and constructing written scientific explanations of real-world ecological issues to consolidate and elaborate science knowledge.

Writing-to-Learn Science Education

Over the last 25 years I have used several writing tasks as assignments for preservice elementary teachers in a science methods courses and in science education major courses. Recently, two of these writing assignments have been modified to emphasize a writing-to-learn perspective rather than simply a written evaluation perspective. Reaction papers have been used for three years and collaborative explanatory essays have been used for one year.

Reaction Papers

The reaction paper has been used with a variety of students to teach the strategies of summarizing and reflecting and to improve understanding of science education. The example reported here was used with undergraduate students taking the required elementary school science methods course (ED-E 745) and involved the students reading a science education article and writing a one-page summary of and reaction to the article.

Summarizing is a strategy related to both science reading and science writing, and it incorporates a cluster of subordinate skills. Summarizing requires the writer to recall or comprehend information, to select important main ideas and supportive details, and to craft a concise understandable synthesis of this information. Hare (1992) described the writer, task, and context variables that influence summarizing (view of task, skill level, prior knowledge, length of information source, genre, complexity, access to information, purpose, length restrictions). She provided specific instructional hints and rules for summarizing, but suggested the research support for lower-level and higher-level rules was mixed. Hare (1992) stated:

> It is true that both direct instruction and more intuitive approaches have been shown to improve students' summaries, although only reciprocal teaching seems to offer some promise of assisting students with the resistant construction rule. (p. 115)

Reflection requires the writer to assess the internal consistency and applicational value of the ideas summarized. The writer is expected to deliberate, draw conclusions, and articulate a rationale. Reflection involves many of the critical response skills identified in *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993). These include:

- Asking "How do you know?" in appropriate situations and attempting reasonable answers when others ask them the same question. (Kindergarten-Grade 2)
- Offering reasons for their findings and considering reasons suggested by others. (Grades 3-5)
- Seeking better reasons for believing something than "Everybody knows that..." or "I just know" and discounting such reasons when given by others. (Grades 3-5)
- Questioning claims based on vague attributions (such as "leading doctors" celebrities, non-experts). (Grades 6-8)
- Noticing and criticizing the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, (2) an analogy is not apt, (3) no mention is made of whether the control groups are very much like the experimental group, or (4) all members of a group (such as teenagers or chemists) are implied to have nearly identical characteristics that differ from those of other groups. (Grades 6-8)

- Noticing and criticizing arguments based on the faulty, incomplete, or misleading use of numbers, such as in instances when (1) average results are reported but not the amount of variation around the average, (2) a percentage or fraction is given but not the total sample size (as in "9 out of 10 dentists recommend...", (3) absolute and proportional quantities are mixed (as in "3,400 more robberies in our city last year, whereas other cities had an increase of less than 1%", or (4) results are reported with overstated precision (as in representing 13 out of 19 students as 68.42%). (Grades 9-12)
- Insisting that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position being taken—whether one's own or that of others—can be judged. (Grades 9-12)
- Being aware, when considering claims, that when people try to prove a point, they may select only the data that support it and ignore any that would contradict it. (Grades 9-12)
- Suggesting alternative ways of explaining data and criticizing arguments in which data, explanations, or conclusions are represented as the only ones worth consideration, with no mention of other possibilities. Similarly, suggesting alternative trade-offs in decisions and designs and criticizing those in which major trade-offs are not acknowledged. (Grades 9-12)

Furthermore, reflection is designed to encourage writers to make connections among ideas found in the summary with ideas in other articles and courses by using cross references. Quality reflections not only provide a judgment but specify the criteria and thinking used to reach the judgment thereby reinforcing critical thinking.

<u>Objectives and Assignment</u>

The reaction paper task was designed to:

1. develop reading strategies associated with detecting main ideas based on conceptual importance by using headings, pictures, diagrams, context, margin notes, bold print, signal words, etc.
2. develop writing strategies associated with utilizing main ideas to craft concise, cogent summaries.
3. develop critical reflection strategies related to content-pedagogical knowledge and ideas in elementary school science.
4. develop content-pedagogical knowledge about elementary school science curriculum and instruction.
5. develop self-directed professional development strategies utilizing the science education and general education journals.

The following description was given the ED-E 745 students to initiate the reaction paper tasks (Figure 2). The full purpose of the assignment was not revealed and strategy instruction was delayed and provided progressively after reaction papers one and two were completed. The assignment required a restricted response length to force writers to make critical selections of important ideas and supportive details and to redraft their responses.

Although the audience was the professor, students were provided complete freedom in the article selected to impress on them the idea that the professor would not necessarily have read the article and therefore had to be considered an interested, but uninformed reader. Common language was used to describe the assignment to minimize the necessity for explicit instruction and to maximize the free response for the first reaction paper. Explicit instruction following each reaction paper focussed on exemplary reaction papers and common concerns. The length restriction was a common early concern, while the attributes of an effective summary and insightful reflection were normally revealed after the first reaction paper. Following the third reaction paper, a more comprehensive discussion of reading to learn and writing to learn was the topic of the course. Specific articles about content reading instruction and writing across the curriculum were used to elaborate on the in-class activities of detecting main ideas, rounding up main ideas, using compare-contrast genre.

Figure 2
The Reaction Paper Assignment Provided ED-E 745 Students

Reaction Papers
Continued development of professional attributes is a personal responsibility. Your teachers association, school district and teaching specialty groups design conferences, provide workshops and publish journals to facilitate your continued professional education. These activities demonstrate and discuss the craft knowledge, research and instructional innovations related to effective teaching/learning and contemporary issues.

The three (3) reaction papers are designed to develop the habits and strategies related to self-directed professional development utilizing science education journals and science related articles in generalist journals: **BC Catalyst, Science Activities, Prime Areas, Science and Children, Instructor, Science Scope**, etc. The 1 page (typed, double spaced, 12 point type) assignment consists of 2 parts. First, a concise summary of the article with complete reference information provided in the title. Second, a concise informed analysis and evaluation of the proposed ideas in the article. A photocopy of the article should be attached to the reaction paper. The reaction papers will be evaluated for writing style and content and will be graded as 1.0 for satisfactory, 1.5 for good and 2.0 for insightful. The three (3) reaction papers are due September 28, January 25, and February 15.

Scoring Rubrics

Each reaction paper was assigned a value of 0-2 points in small increments. The following rubrics describe the expectation for 2.00, 1.50, 1.00, 0.50, and 0.00. The other scores can be inferred by splitting the difference between the adjacent levels of performance.

2.00 Summary provided a concise, cogent passage of important ideas that accurately reflects the author's position; the reaction is a reflective analysis of the article containing documented connections to other appropriate literature or content-pedagogical knowledge; and the paper had a logical organization, clear message and a sense of audience.

1.50 Summary provided a rather lengthy but insightful collection of main ideas, and the reaction revealed critical thinking but rather isolated professional insights and no explicit connections to other ideas about elementary school science education.

1.00 Summary indicates that writer comprehended the main idea of the article, but the summary contains some irrelevant ideas; and the reaction was rather shallow and the judgment, criteria and thinking were not explicit.

0.50 Summary indicates that the writer had read the article but could not identify the main ideas and important information, and the reaction did not reveal critical thinking.

0.00 Not submitted.

Results

In an attempt to analyze the effectiveness of this writing-to-learn task, the reaction papers for 1994 (N=48) and 1995 (N=85) were scored; and qualitative comments were compiled. Furthermore, the 1994 students were asked specifically to evaluate the importance, satisfaction, and value ascribed the reaction papers and the reading to topics, activities, writing-to-learn presentations as well as others and assignments in the ED-E 745 course.

Qualitative Results

The common trend was that the first reaction paper was longer than one page; the majority of the writing related to the summary; the summary revealed a "tell as much as you can" perspective; and the reflections were brief, shallow, and unrelated to other ideas in their prior teacher education and this course. The second reaction paper generally achieved the length restriction but devoted approximately 66 to 75% of the text to the summary; the summary identified the main ideas, some supportive details, but lacked a cohesive synthesis; and the reflection provided some evidence of connections, criticality, and practicality. The third reaction paper generally contained a concise synthesis of main ideas and supportive details and a reflection that contained mention of other ideas, values, and experiences; but less than 50% had explicit reference to other articles.

Voluntary comments were encouraged about the reaction paper assignments on the teaching effectiveness evaluation asked of students at the end of the year. All sections of this course normally rated ED-E 745 and the professor highly (4.4 - 4.6 out of 5.0). The following comments were specifically made about the reaction papers. These comments clearly indicate the difficulties in balancing the number of reaction papers required, time required, and evaluation priority assigned.

1994 Student Comments

- *At times the [reaction papers] seemed tedious since we have done so many over the past years. I still learned from them.*
- *I think the number of science reaction papers should be reduced to perhaps 2 or 3. This will show what [was desired—self-directed professional development], while not creating too much work for 2 marks.*

1995 Student Comments

- *[The] idea to do reaction papers...is a good one.*
- *[Reaction] papers were a great harmless way of learning new information—keep using [them].*
- *Reaction papers were worthwhile.*
- *I think that having three [reaction papers] was efficient for polishing my critical assessment of articles. If we did five [reaction papers], I would have felt bogged down.*
- *Reaction papers are a good idea—maybe a class could be used to read through some of the papers/articles which were rated as being good. They should be worth five marks each.*
- *Reaction to articles should be worth more maybe just do two for five [points] each.*
- *Reaction papers—there should have only been two to do.*
- *The reaction papers got to be too much. I don't know if three papers were necessary, two would have sufficed.*
- *The reaction papers were worth too little for the amount of time they took.*
- *The marks for the reaction [papers] should have more weight.*
- *Article reviews should be worth more than two [points], maybe five [points].*
- *I found the reviews to be worth too little.*

Quantitative Results

The scores assigned for each of five (1994) and three (1995) reaction papers assigned were inspected to detect any differences over time. Table 1 summarizes the mean scores for the combined ED-E 745 classes and individual sections for 1994 and 1995. The scores indicate that on average these students were reasonably good at summarizing and reflecting and that their writing ability improved with feedback and explicit instruction. At this time the differences and variations across the reaction papers have not been statistically tested, but the difference between the first and last reaction paper has improved. No comparison should be attempted between the two years since the scoring rubrics changed with experience.

Reaction papers normally started out being longer than one page, which indicated that students attempted to avoid making selection decisions or were unable to determine importance because of their limited background in science education. The reflections were frequently limited to comments based on vague personal beliefs. The final reaction papers clearly indicated that students had developed the background and ability to identify important ideas and supportive details. The reflections started to demonstrate the critical response skills of an informed science educator avoiding many of the pitfalls of popular bandwagons and unsubstantiated approaches.

Students in the 1994 classes were asked to express their disposition toward 16 aspects of the ED-E 745 course using a triad Likert scale: importance, satisfaction, and value. Students were asked to indicate the perceived importance (critical to teaching science), satisfaction (level of comfort with idea, activity, and class presentation), and value (worth the effort and time spent) of/with specific topic, activities, and assignments on a five point scale (5: very, 4: somewhat, 3: neutral, 2: somewhat un-, 1: very un-). The results for a primary grade section (Table 2) and an intermediate grade section (Table 3) were analyzed to determine the relative importance, satisfaction, and value ascribed the reaction paper task and the general print-based language strategies. The internal agreement for importance, satisfaction, and value were tested using pair-wise t-Tests.

Table 1
Means Scores for Reaction Papers

ED-E 745 Classes	Reaction Papers				
	1	2	3	4	5
1994 Combined	1.73	1.68	1.80	1.78	1.86
Section Y02	1.67	1.70	1.78	1.79	1.82
Section Y03	1.81	1.65	1.83	1.77	1.90
1995 Combined	1.59	1.76	1.75		
Section Y01	1.58	1.71	1.77		
Section Y02	1.62	1.78	1.73		
Section Y03	1.56	1.80	1.76		

Both 1994 sections of ED-E 745 rated the importance, satisfaction, and value of the reaction papers drastically lower than most other topics, activities, and assignments. The K-3 preservice teachers ascribed a lower rating in all three categories to the summarizing-reflecting tasks than the Grades 4-7 preservice teachers. This was likely influenced by their anticipated application of specific writing-to-learn strategies in the primary grades. Both groups rated the general topics of writing to learn and reading to learn above the average of all other topics (Y02: 4.59, 4.20, 4.39; Y03: 4.68, 4.42, 4.48), which appears to indicate that they had a more positive disposition toward other print-based language arts strategies. Furthermore, these preservice teachers expressed a significantly lower disposition of value (worth effort) than importance of the written summaries and reflections.

Collectively, these results appear to indicate that reaction papers can be used effectively with middle year preservice teachers as a context to teach summarizing and critical analysis strategies. The combination of ratings and written comments suggests that requiring five reaction papers was expecting too much for the perceived gains. Three reaction papers with more targetted explicit instruction appear to be more reasonable than five reaction papers and less structured instruction. Furthermore, the margin comments provided on the students' papers appear to have more potential in shaping their writing strategies than was realized.

Collaborative Explanatory Essay

Writing has been classified as expressive (poems, fictions, creative stories, etc.), expository (analytic tasks, cause-effect, problem-solution, descriptions, lists, etc.), and personal (diaries, private notes, etc.). This explanatory essay did not specify a single genre, but the assignment was expected to promote expository-type writing that involved analytic strategies of acquiring information and reformulation of personal understandings to inform or persuade an uninformed audience about a specific issue. It was further expected that the task would require an analysis of the audience, an evaluation of the necessity and sufficiency of information, an assessment of the epistemic character and logic of the argument, a clarification of ideas and issues, an explanation of the central position, and an integration of new understandings. Explanatory essays clearly require the writer to explain relationships and apply knowledge (Newell, 1986).

Numerous researchers have encouraged the use of explanatory writing in the content areas to enhance learning (Ammon & Ammon, 1990; Rivard, 1995, Schumacker & Nash, 1991). Explanatory essays encourage conceptual change, depth of processing, connecting isolated ideas, and clarification of patterns of evidence, claims, and warrants (Beyer, 1982; Scardamalia & Bereiter, 1986; Strenski, 1984). Kempa (1986) suggested that the following explanatory tasks be used to enhance science learning:

- Developing causal relationships among facts, observations, theories, and models.

Table 2

Descriptive Statistics and Pair-Wise t-Test Results for the 1994 Primary (K-3) Section of ED-E 745

Activity/Assignment (t-test Results)	Importance (X, SD, N)	Satisfaction (X, SD, N)	Value (X, SD,N)
Curriculum Overview (*,**,***)	4.75, .52, 28	4.18, .72, 28	4.50, .69, 28
Interactive-Constructive Model of Learning (*,***)	4.71, .46, 24	4.38, .65, 24	4.63, .50, 24
Guided Inquiry (*)	4.85, .37, 26	4.65, .56, 26	4.77, .59, 26
Pre-experience Activities (*,***)	4.79, .42, 28	4.50, .58, 28	4.75, .44, 28
Experience Activities (*,***)	4.93, .27, 27	4.70, .47, 27	4.89, .32, 27
Post-experience Strategies (*,***)	4.82, .48, 28	4.29, .76, 28	4.68, .67, 28
Unit Planning (*,**)	4.81, .40, 26	3.88, 1.14, 26	4.19, 1.02, 26
Basic Science Processes (*,***)	4.73, .45, 26	4.19, .63, 26	4.58, .58, 26
Integrated Science Processes (*,***)	4.68, .48, 25	4.00, .71, 25	4.52, .65, 25
Guided Imagery	4.19, .75, 26	4.08, .85, 26	4.00, .98, 26
Concept Mapping (*)	4.69, .55, 26	4.42, .70, 26	4.50, .71, 26
Project Wild	4.56, .71, 25	4.44, .96, 25	4.32, 1.07, 25
Health Activities (*)	4.20, .71, 25	3.72, .89, 25	3.84, 1.03, 25
Learning Centre (*)	4.65, .56, 26	4.35, .75, 26	4.31, .97, 26
Reaction Papers	3.54, .95, 26	3.50, 1.03, 26	3.35, 1.20, 26
Writing-to-learn and Reading-to-learn Strategies (*,***)	4.48, .77, 25	3.92, .76, 25	4.28, .79, 25

* denotes $p \leq 0.05$ between importance and satisfaction, ** between importance and value, and *** between satisfaction and value

Table 3
Descriptive Statistics and Pair-Wise t-Test Results for the 1994 Intermediate (4-7) Section of ED-E 745

Activity/Assignment (t-test Results)	Importance (X, SD, N)	Satisfaction (X, SD, N)	Value (X, SD,N)
Curriculum Overview (*,**)	4.68, .56, 25	4.24, .72, 25	4.28, .98, 25
Interactive-Constructive Model of Learning (*,**)	4.54, .59, 24	4.21, .78, 24	4.25, .74, 24
Guided Inquiry (**)	4.71, .55, 24	4.63, .58, 24	4.54, .66, 24
Pre-experience Activities (*)	5.00, .00, 24	4.67, .57, 24	4.79, .59, 24
Experience Activities (*)	4.96 , .20, 24	4.79, .42, 28	4.88, .34, 24
Post-experience Strategies (*)	4.96, .20, 24	4.67, .64, 24	4.79, .51, 24
Unit Planning	4.75, .44, 24	4.33, 1.05, 24	4.67, .87, 24
Basic Science Processes (*,***)	4.79, .42, 19	4.47, .61, 19	4.68, .48, 19
Integrated Science Processes (*,***)	4.84, .38, 19	4.53, .51, 19	4.74, .45, 19
Guided Imagery	4.15, .93, 20	4.35, .75, 20	4.10, .97, 20
Concept Mapping	4.58, .51, 19	4.32, .58, 19	4.32, .58, 19
Project Wild	4.65, .59, 20	4.70, .57, 20	4.70, .57, 20
Health Activities (*)	4.29, .56, 21	3.86, .66, 21	4.00, .63, 21
Learning Centre	4.55, .61, 20	4.45, .61, 20	4.25, .85, 20
Reaction Papers (**)	4.32, .58, 19	4.05, .97, 19	4.00, .88, 19
Writing-to-learn and Reading-to-learn Strategies (*,**)	4.85, .37, 20	4.40, .75, 20	4.55, .61, 20

* denotes $p \leq 0.05$ between importance and satisfaction, ** between importance and value, and *** between satisfaction and value

- Proposing hypothetical relationships between unfamiliar and familiar ideas.
- Applying scientific ideas to real-world issues.

Objectives and Assignments

This assignment was used with undergraduate students majoring in elementary school science education (ED-E 445A). The collaborative explanatory essay was designed to:

1. Develop insights into knowledge-transformation model of writing.
2. Develop insights about the persuasive term paper genre.
3. Develop content-pedagogical knowledge about collaborative write, edit, revise process.
4. Develop content-pedagogical knowledge about the nature of science, discourse in science learning, and multiculturalism including gender equity in science education.

The explanatory essay assignment provided a concrete experience with a collaborative, interactive, write-to-learn strategy (Figure 3). The assignment utilized a "jig-saw" cooperative learning approach in which three topic-specific groups were established. These "expert" groups were randomly assigned one of three topics. Each group collaboratively planned, located information, shared resources, and supported one another; but individual papers were submitted.

Figure 3
ED-E 445A Explanatory Essay Assignment

Term Paper
A ten-page position paper on an assigned topic. The paper will include 10-15 references. Your expert-group will share ideas and resources, while the other expert-groups will provide reactions and editorial feedback on drafts #1 and #2. The instructor will provide feedback on any of the preliminary drafts. Draft #3 will be graded.

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. Multiculturalism. How should it influence what we teach and how we teach Elementary School science.
C. Written and verbal discourse in science. What kinds of discourse promote science learning and conceptual change.

(35 points)

Each expert group served as an authentic audience for the other expert groups and provided conceptual and editorial feedback on the topical papers for which they were not experts. Since students were to be tested on all three topics, they were responsible for developing conceptual understanding by carefully reading these papers and seeking consultation with the expert group. The assignment required a progressive development in which early drafts were submitted for peer review. These drafts were revised and resubmitted. The final draft was submitted to the professor for evaluation.

Scoring Rubrics

Each essay was scored on a nine-point scale associated with the university's letter grade system. The following descriptors guided the scoring procedure:

7-9 Excellent: A compelling, clear explanation with relevant examples and connections to the audience's reality. Highly valued references from respected sources. The pattern of argumentation develops logically with clear relationships between evidence, warrants, and claims. Critical thinking is explicit with judgments clearly linked to criteria and clearly justified.

4-6 Good: A well-referenced explanation that has a clear central position, but the audience's reality is not fully considered. The argument and explanation appear to be valid, but the deliberations and thinking are not fully explicit.

1-3 Satisfactory: The essay technically addresses the assignment's requirements, but the writer has not provided the insights and examples that demonstrate depth of understanding.

0 Did not attempt or complete the assignment.

Results

Three versions of the assignment with margin notes provided by two peers and the professor were analyzed to determine a collective description and to detect any trends among the three versions. The ED-E 445A students were also requested to provide specific comments about the collaborative explanatory essay assignment on their course/teaching effectiveness evaluations.

Analysis of five sets of three draft papers for content, peer feedback, professor comments, and grades reveals a distinct improvement in the message, logical development, and writing style. Content analysis across the topics (multiculturalism, discourse, nature of science) indicated that students had reasonable conceptions of the topic, but some ideas were loosely connected and underdeveloped. Content was improved until all students had a good-excellent understanding of the topic in their final essay (8 A's, 7 B's).

Peer feedback varied drastically from limited editorial comments about grammar, punctuation, and style to conceptual clarity, confirmational agreement, and alternative perspectives. There appeared to be a relationship between the writing and science education understanding of the reviewer and the quality of the comments. Margin notes indicated that further discussions occurred between the writers and reviewers. The professor's comments indicated that referencing was a common problem and elaboration of well-selected central assumptions would improve the clarity of the essays. Generally, explicit instruction about the genre, structure-function, referencing, and other writing strategies would be useful. Furthermore, explicit editorial/review instruction would be useful in the quantity, quality, and focus of comments (Iding & Greene, 1994).

Nine of the 15 students provided specific comments on the writing-to-learn tasks. The comments indicated that students believed the collaborative explanatory essay task was an important strategy and made suggestions on how to improve the original assignment.

- *I found the writing to learn activity very effective. Not only did I learn about my subject, but also the subjects written in the papers I edited. I thought it was such an effective idea, I recommended my fiance use it with his students (he teaches high school psych) and he did.*
- *I enjoyed the process. It was difficult, however, to actually "learn" or "understand" the papers we were reading because we had no other experience with the materials.*

- *Writing to learn activity was good. It should be started sooner in order to get better understanding through course.*
- *In regards to the writing to learn activity, I thought itwas an interesting approach to an activity that is usually done without any consultation from other people. It gave me not only the opportunity to have my work read and evaluated by others but also to read other peoples and learn from them. I liked it and plan to use it in my class.*
- *I thought that the writing to learn activity for our research papers was an excellent idea and fits in well with (mine as well) your philosophy on learning/teaching science. It also gave me a chance to read some other students papers as well.*
- *Writing to learn - a good activity. I liked getting feedback from peers. More instruction on comments and marking would be good. Could see how this would be useful in a school classroom.*
- *Writing to learn activity: I think this is an excellent strategy and one that I will use because I've "done it". As well as learning about other people's topics, I got good advice as to how to improve my paper. Things that I might do differently - allow sharing with people writing about the same topic..I would have like to read my own group's work, too. Be more specific with editing. My second editor was fantastic - not afraid to give advice etc....however, my first editor only wrote 1 or 2 things which wasn't as helpful as it could've been.*
- *While I was doing the writing to learn activity I found it to be a lot of work. When I finish a paper I usually get my room mate to proofread it and then I am done. With this process I felt it went on and on. A never ending stress! I also found it difficult to give feedback on topics that I hadn't researched. On the final draft I [also] exchanged papers with someone with the same topic as I had. I felt that I could provide more indepth and accurate feedback with this method. After it was finally handed in and I reflected on the whole process I found it to be a good experience. One that I would use in my own class.*

- *Writing to learn activity: I think you need to emphasize more the conceptual feedback mostly I received grammatical comments or none at all. In this case the activity did not have much meaning for me. We need to be encouraged to make conceptual comments. It was good for us to be able to read other papers on different topics and to think critically about what these papers were saying.*

Taken collectively, these data indicate that the collaborative essay writing approach has the potential to enhance learning and provide an authentic situation that encourages redrafting and maximizes feedback from various sources. The suggestions have encouraged the use of a third draft shared and edited within the expert group. Furthermore, the introduction to the assignment should consider developing collaboratively a set of scoring rubrics that would help clarify the characteristics of an explanatory essay. This activity would likely be useful to both the writing and editing tasks.

Summary

The writing-to-learn science approaches are not designed to replace concrete experiences, visual information, or expository text. Rather writing-to-learn strategies are designed to complement information sources and enhance the minds-on aspects of science learning by encouraging learners to aggressively manipulate ideas, restructure arguments, clarify thinking, select more appropriate vocabulary and linguistic devices, present ideas and opinions publicly, and to negotiate meaning with their audience.

Students need to:

- practice knowledge-transforming writing strategies and genre
- utilize a variety of information sources as a basis for constructing meaning
- write short and lengthy papers more often
- focus on prewriting and rewriting rather than production of text
- realize effective writers redraft several times
- focus on clarity and persuasiveness, not grammar and spelling

- share their writing
- receive supportive, corrective criticism and feedback about editorial and conceptual issues (Holliday, 1992, pp. 59-60)

Moore (1993) found that merely writing about biology did not improve science achievement, but when explicit writing-to-learn instruction was provided science achievement improved and attitudes toward writing to learn improved. This occurred without negative impact on the students' perception of the teachers' instructional effectiveness.

The two write-to-learn science education strategies described here were selected for their strategic impact on science reading and science learning and for their applicability in upper elementary and middle school (4-9) classrooms. Furthermore, these two strategies can be accomplished in a busy science education course by concerned science educators with limited writing-to-learn backgrounds.

Another real benefit to the short, frequent writing tasks (learning logs, reflective journal, and reaction papers) is the individualized discourse that occurs between professor and student. Bahns (1989) stated these "provide a vehicle for dialogue between student and me on the teaching and learning of science and or science content that requires further clarification" (p. 181). I have found the same benefits but learning logs and reflective journals are difficult to use for grading purposes although they provide data that can inform instruction. I have recently modified my reflective journal requirement into a simpler, more concise, structured reflection on the student classroom science teaching and science unit during the six-week November-December practicum.

Murray (1987) summarized the importance of writing when he stated:

> There were always surprises on the page. Sometime the surprises were large, sometimes small, but there was always something unexpected. ...Writing is the most disciplined form of thinking. It allows us to be precise to stand back and examine what we have thought. (pp. 2-3)

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USING MINI-ACTION RESEARCH PROJECTS AND TECHNOLOGY TO TEACH EQUITY ISSUES IN SCIENCE

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Goals of the project:

1. Introduce pre-service elementary teachers to the concept of action research.
2. Develop an understanding of gender equity issues as they relate to the elementary school classroom.
3. Develop an awareness among elementary students that career options are not limited by gender.

Project Guidelines:

The pre-service elementary teaching students do at least one activity each week which increases their awareness of gender equity issues, particularly as they relate to science. The activities include responding to newspaper and journal articles, researching women Nobel prize winners, analyzing the marketing of children's toys to look for bias and stereotyping, and draw-a-scientist activities. These awareness building activities continue until the students begin preparing for their mini-action research project.

The pre-service teachers were divided into groups of three or four to plan and implement a mini-action research project. They were to design a pre-test, post-test, and an activity which would increase awareness of career options for both men and women.

The mini-action research was to be carried out in a primary elementary classroom during a one hour period. After completing the field portion of the project the pre-service teachers used PowerPoint to organize the data into a computer generated presentation. Each group presented their data to the class. To encourage all the students to learn to use PowerPoint, each presentation was to have at least 12 slides with each person in the group preparing at least four slides.

Project Results:

There seemed to be some evidence of increased awareness of gender equity issues and stereotypes among the pre-service teachers. Several of them mentioned that the children seemed to have well established gender stereotypes.

The pre-service teachers responded very positively to producing the PowerPoint presentation. They indicated that it was a very useful skill for teachers to possess.

Student Comments Regarding the Gender Equity Mini-Action Research Project:

"The gender equity project helped me to realize how we stereotype children without really being aware that we are doing it. The students that we worked with didn't really think of astronauts as being either male or female. When asked if they could name an astronaut they could name a male but I think that is because they had just studied space and knew about Neil Armstrong being the first man on the moon. At the end of the activity they could name the women that had been in space and were real excited about being able to name them."

"As a future teacher I need to teach to the individual student and help them understand that they can do and become anything that they want. Teachers need to help them realize that fathers can cook and that mothers can use a hammer."

"I think the gender equity experience was well worth it. I felt I woke up to reality by realizing that the majority of teachers out there are only familiar with successful man scientist, and this hurts their ability to teach the students a wider range of successful individuals. So many time we read only about men who have succeeded, therefore we share our knowledge. What we really need to do is dig a little deeper to find out the individuals who were involved, but weren't given credit. To our surprise we will probably find many women, and individuals of other races besides White."

"Our gender equity lesson also had an impact on myself. The lesson impacted me because it made me realize that most of us, whether intentionally or not, make remarks about male and female jobs. Although most of us stereotype unconsciously, we still do it and it still has a huge impact on the students. I think that this teaching experience has made me much more aware of stereotyping."

"The gender equity project made me aware of some very important things. I personally didn't have a problem with women and men being able to do the same types of jobs. I was very shocked to learn that such young children are already setting certain jobs into stereotypes. This project has make me aware that I need to do things in my classroom to reduce this type of thinking. Perhaps if we can educate children about this issue now, it won't be as necessary in the future. This project really showed me something I was ignorant of. Thank you."

"I feel that this gender equity lesson had a great impact on all parties involved. It allowed me as a teacher to see and recognize the discriminations and stereotypes of everyday life. Overall, I feel that this experience had a great impact and was a good experience for everyone."

"Before doing the research, I never gave THAT much thought to how CHILDREN viewed gender equity. I see the importance now, both for myself and my students, to stress gender equity in practice."

"As for myself, it changed my mind about some of the occupations such as, construction worker, fireman, and farmer. I kind of stereotyped these occupations as male ones, but as I conducted the activities I changed my mind. So, in a sense it helped me more than most of the boys. It helped me realize that all boys and girls are equal and can do anything they want in life, if they only set their minds to it."

"The effect it had on me was also a positive one. I was able to experience first hand how students are made believe that certain things were for boys, and certain things were for girls. I also learned that students need to be taught at an early age that they are capable of doing anything they want whether it be cooking or working on cars."

"One thing that I was aware of was that I tried to have a gender equitable group. After all we talked about it in our class, I was very careful to be fair, especially since I had one boy in particular that wanted to answer everything, and one girl in particular that probably wouldn't have said a word the entire time if I hadn't specifically asked her questions. I am really glad that we spent time talking about gender equity. It really made me watch my techniques for calling on students."

"My experience with the gender equity project was quite an experience. The group I had was very diversified. I was amazed at the attitudes that have already been formed in those young minds. ...With the exception of a few of the boys, the group did seem to change their opinions. Some even made some comments such as 'I think anybody can do anything they try hard to do' and 'There was a woman that run for president one time, and maybe next time a woman runs she might win and be the president.' Unfortunately, other comments were made such as 'Women can't do that 'cause they ain't as smart as men are' and 'Women don't need to work 'cause they just take all their husband's money and spend it' and 'A man ain't supposed to be a nurse; he's supposed to be the doctor.' Despite the frustration I felt with a handful of boys in the group I do feel we left them with something to think about. It's hard to change attitudes in one hour that have been instilled in them all of their lives."

"I think that our gender equity lesson had an impact on the students and myself. I think the students were impacted because when we gave the pretest most of the students gave a male name when they were asked to list an astronaut. When we taught the lesson we tried to include both male and female astronauts. When we gave the post-test, the amount of female astronauts and male astronaut names given were evenly disbursed. Our gender equity lesson also had an impact on myself. The lesson impacted me because it made me realize that most of us, whether intentionally or not, make remarks about male and female jobs. Although most of us stereotype unconsciously, we still do it and it still has a huge impact on the students. I think that this teaching experience has made me much more aware of stereotyping."

Student Comments Regarding the use of PowerPoint to make Presentations:

"This is a response to the Gender Equity Research Presentations that were given in class. I really found this very interesting to watch. I had no idea how neat these could be until I saw them first hand. I think that I really made a big deal out of nothing when first putting this together it was so easy to do once you got started. This also allows me to be familiar with it for future teaching. This is a good idea to keep in mind if your school had such a system what all the things you could do for your class. I feel that everyone in today's world should familiarize themselves with the power point. This would allow you to look more professional."

"The gender equity project happened to be one of my most favorite assignments in this class. After working with the students on this issue, I realized this is a bigger problem than I thought in our society. Putting the project together was very fun and informative. The Power Point system is something everyone should learn to do. It was fairly easy after being instructed on how to use it. This Power Point system can help you now and in the future. It can make one's work more professional. So I encourage everyone to familiarize themselves with this great computerware system."

"Another great thing I learned was all about PowerPoint. I loved it! (once I figured it all out). This is a great teaching and professional tool that I would really love, and intend to utilize. This would be great for various things, in the classroom, for the students' portfolios, and for my own portfolios. I think that employers would really be impressed with this kind of professional work and experience."

"I enjoyed doing the PowerPoint presentation last week. I learned a whole lot about that program and it fascinated me. I enjoyed doing the gender equity project too. I learned that it is easy to discriminate boys and girls in the classroom and that I should make a conscious effort not to when I am teaching."

"Thank you for having us use the PowerPoint software. An excellent way to have future educators get familiar with a very useful tool. Thanks to you we will have many advantages going into the teaching field!!!"

"I absolutely loved the power point program. I am planning on getting the disk in the near future. I think it would be good to keep my own personal portfolio on as well as my students. I had fun making my presentation and learning how to use it."

"I think everyone done a outstanding job on the presentations. Everyone seemed to be pleased with this completion of the presentation. You should keep this in mind for future classes because it was wonderful."

IMPETUS FOR CHANGE: THE EFFECT OF THE NRAO-WVU-NSF INVESTIGATING THE UNIVERSE PROJECT ON THE PRACTICES, ATTITUDES, BELIEFS, AND PERCEPTIONS OF THOSE WHO PARTICIPATED

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Introduction

The Investigating the Universe Project, a collaborative project between West Virginia University (WVU) and the National Radio Astronomy Observatory (NRAO), was a National Science Foundation (NSF) funded teacher enhancement program designed for secondary teachers from 1991-1994. The developers and facilitators of the project wanted the participants to experience the life and work of a scientist and to make possible such an experience for the students they teach. Participants were welcomed to NRAO in Green Bank, West Virginia, presented with keys, and invited to make the research facility their home for two weeks and in the years to come for themselves and their students.

At the heart of the project were opportunities to make the unknown known, to be challenged and have doubts, to find within themselves the ability and resources to do research, and to experience the joy of coming to new knowledge. In groups of five, the participants worked to find solutions to research problems related to radio astronomy, an area which was quite unfamiliar to them. The scientists, engineers, electronics personnel, technicians, science educators and group mentors, as well as a 40-ft radio telescope and a library were available to the participants as they designed their approach to the problem, developed background information, collected and analyzed data, and prepared and presented their results and further research questions that they would like to pursue.

The developers and facilitators realized, that to have the participants experience the life and work of a scientist, the participants and their growth had to be the focus of attention. They kept an atmosphere of expectation, questioning, trust, and patience while working with the participant research groups. Through discussions and lectures scientists shared their own experiences and emotions as they discovered new knowledge, and they encouraged the participants as they searched for solutions to their problems.

Throughout the two weeks at NRAO, the question "How will you (the participants) create and implement research projects in your classrooms?", was asked of the participants and was a frequent topic of discussion as they developed problem statements. Thus, the academic year implementation of the research questions in their classrooms became an extension of the participants' summer experiences.

During the implementation year, the participants had an opportunity to apply to become mentors for the next group of participants and to become co-researchers in this study. We are interested in exploring how participants, who had also been mentors, perceived changes in themselves as a result of their two years of involvement in the Investigating the Universe Project (IUP).

Conceptual Framework

For the purpose of discussion, change in this study is operationally defined as any alteration, modification or transformation in the practices, attitudes, beliefs, and perceptions of participants. As such, change is something participants decide to make based on their own world view. Change is a process made by individuals and not an event (Eastcott & Hall, 1980; Fullan, 1982; Blair, 1982). For each individual participant, change is a highly personal experience which entails developmental growth (Eastcott & Hall, 1980). Baird (1989) argues the improvement of teaching is a learning process. For participants, change is a learning process (Guskey, 1986; Richardson, 1990). Mezirow (1991) asserts that change is a function of learning. Therefore, one must consider participant learning when studying participant change.

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 the theoretical basis for both teacher learning and teacher change. As such, transformation theory provides the theoretical framework describing how a teacher changes their perceptions. The individual's acquired frame of reference is central to this learning theory. It is through this frame of reference that all meaning is constructed and all learning takes place. During the learning process, the adult's habits of expectation can be transformed.

Adults construe meaning from both symbolic models or exemplar and habits of expectations. These habits of expectations are meaning perspectives and meaning schemes through which adults 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. This results in a 'loaded' perception. The meaning schemes and meaning perspectives constitute the boundary structures through which adults both perceive and comprehend new data. Adult learning, development, and change come about when meaning schemes and perspectives are transformed by reflection and critical discourse.

Methodology

This study is descriptive and exploratory in nature and utilizes a research design derived from the qualitative/naturalistic paradigm. Because of our personal involvement with the project, a methodology which will not divorce the influence of our experience from that of the participants was used. Heuristic inquiry (Moustakas, 1990) and interpretive interactionism (Denzin, 1989), forms of phenomenological inquiry, provided the method chosen for this study because they legitimize and place at the fore the personal experiences, insights, and reflections of the researcher. In this way, the researchers were able to understand the essence of the phenomenon through shared reflection and inquiry with the participants, referred to as co-researchers, as they reflected on the changes they noted in themselves as a result of project participation. The sharing, collaboration, and kinship between participants continued as a connectedness between the researchers and co-researcher as they shared the experience of reflecting on how this phenomenon, the IUP, has changed their lives and perceptions.

Two IUP institutes were conducted each summer for years 1991through 1993. Sixty educators, two groups of 25 participants and 5 mentors per group, took part each year. Mentors are former participants who returned at subsequent institutes to work with project staff and act as facilitators to a research team or group of five first-year participants. The mentors, co-researchers for this study, were selected from past project participants. Of the 29 mentors (30 counting the researcher) who served during this time period, 16 co-researchers, 5 females and 11 males, were selected. Criteria used in the selection of the co-researchers were gender and a willingness to participate and make a commitment to working with the researchers (Moustakas, 1990, p. 46).

Nature of Data

Qualitative interviewing was the primary procedure for data collection employed in the study. In qualitative interviewing, it is assumed that the perspective of others is meaningful, knowable, and able to be made explicit (Patton, 1990). Each co-researcher participated in one semi-structured interview, in which the following open-ended questions were used:

1. What was it about the institute that attracted you to it?
2. How would you describe the two weeks you spent at Green Bank?
3. What academic year activities did you implement the year following participation?
4. What was the mentoring experience like for you?
5. Do you believe you know enough about the Project to assess its effectiveness?
6. How has participation in the Project effected you professionally?
7. In thinking about how you have changed since participation in the institute, implementing the academic year activities, and mentoring, how much have these experiences caused those changes compared with other influences in your life at this time?
8. How do you think these experiences will affect you in the future?
9. Are there any thoughts or feelings you would like to share with me right now concerning how these experiences have affected you?

In this format, a conversational give-and-take between the researcher and co-researcher was emphasized. In addition, data were gathered from application materials, a biographical data sheet, a pre-institute questionnaire, and two post-institute evaluations.

Determining Changes in Perceptions

Determining the co-researchers' perceptions of change occurred in the following way:

1. Writing a biographical sketch for each of the co-researchers from data provided in the application materials and biographical sheet. The biographical sketches provided frames of reference for both analyzing the interview ranscripts and constructing the co-researchers' profiles. In addition to their use in data analysis, the biographical sketches were used in the presentation of data. The sketches preceded the respective profiles of each co-researcher and provided a frame for the reader.
2. Interpreting the interview transcripts. In this phase, the analysis focused on the themes and/or patterns of change that emerged from the words and experiences of the co-researchers. The end point of this phase was the construction of a classification system for the emerging themes.
3. Classifying data. The reflections, insights, and perceptions of the co-researchers were categorized and classified.

4. Writing the narratives. The classified data was used to construct a written narrative or profile explicating each co-researcher's experience. These profiles describe in a comprehensive thick-way, the changes in perceptions experienced by the co-researchers resulting from participation in the phenomenon under study. [A sample narrative is found in the Appendix]
5. Crafting a creative synthesis. Creative synthesis is the process of bringing together the pieces that have emerged into a total experience, showing patterns and relationships. The creative synthesis of the co-researchers' narratives explicates in a comprehensive thick-way the themes, patterns, and essential meanings of the Green Bank experience.

Findings

The sixteen co-researchers learned of the project from one of four different sources: a National Science Teachers Association (NSTA) publication, a mailing received at home or school, word of mouth from a previous participant, or attending a presentation on the Project at a science teachers conference. All co-researchers were attracted by the astronomy, a topic about which all had more than a passing curiosity. For those who had expectations, they were as varied as the localities in the United States from which they came. Many of the co-researchers experienced the same feelings and emotions their first day at Green Bank. They lacked confidence and felt inadequate in their knowledge and ability to learn and keep up with the other participants.

For the co-researchers, the observatory at Green Bank became much more than a place, or the location of the two week institute. For them, Green Bank is a place connected with much feeling and emotion about the universe and themselves. Green Bank is a harmonious blend of a facility, a location, the people that live and work there, and the science that is done there.

The co-researchers identified a number of factors which they described as either high points, strengths of the institute, or reasons for the institute's effectiveness. These include the location, collaboration, working on a research project, time for reflection and critical thought, and implementing the academic year activities. When the co-researchers returned to their classrooms in the fall, each was armed with expectations for both themselves and their students. They implemented research projects and other new activities and changed their pedagogy with one thing in mind, to effect a change in the classroom and increase student learning.

The Green Bank Experience

The co-researchers, when describing the institute spoke of and alluded to the Green Bank experience. The Green Bank experience was a total package, an integral fit of the institute's pieces. It includes the milieu, the staff, the astronomers, the participants, the diversity, the interaction, the frustration, the excitement, the sharing, the caring, the laughing, the crying, the learning, the growing, the fear, the doubt, the confidence, the friendship, and the unknown. The experience however, is connected by a common thread, the research project, identified by the co-researchers as the most crucial aspect. Analysis of the co-researchers' words, thoughts, views, and ideas suggests that the Green Bank experience is comprised of nine distinct but interrelated stages.

1. Formation of the research group
2. Receiving the research project
3. Trying to find one's place in the group
4. An early sense of direction
5. Weekend relaxation and reflection
6. New sense of direction or purpose
7. All the pieces fit together
8. Putting it all together
9. Presentation of the Project

The Green Bank experience provided the impetus for the co-researchers to change many of their perceptions. These include their perception of science, research, and scientists. In addition, the co-researchers realized many professional changes. These include: using a constructivist approach to teaching and learning, using research problems in the classroom, becoming more bold, assertive, and apt to take risks, developing new interests, becoming more accepting and tolerant of their students, and believing they had become better teachers, who were more in tune with their student's needs. However, the most profound effect the Green Bank experience had on the co-researchers was in the way it impacted the perception they had of themselves. The co-researchers left Green Bank with increased self-respect, self-esteem, and self-reliance. Participation in the project gave them increased confidence and a positive self-efficacy. Eleven of the co-researchers made specific references to epiphanies or changing life experiences when discussing their experience.

Conclusions

We expected the project's greatest impact to be professional, bringing about change in the classrooms of the co-researchers. We expected the co-researchers to implement research problems, group work, and employ a constructivist approach to both teaching and learning. We expected the co-researchers to have a different perception of science, scientists, and research. These things did occur. What we never expected was the impact the Green Bank experience had on the personal lives of the co-researchers. The Green Bank experience left each co-researcher with increased confidence, self-esteem, self-reliance, and self efficacy. These changes in perception enabled each co-researcher to not only implement but to affect change in their classroom.

The Green Bank experience brought about changes in perceptions because it enabled the co-researchers to become critically aware of how and why their current habits of expectations confined, constricted, and delimited the way they interpreted both prior and new experiences. This awareness nurtured both transformation of meaning schemes and perspective transformation.

The findings of this study demonstrate that teacher-learning is a precursor for teacher-change. Therefore, those elements which foster teacher-learning support teacher-change. The results of this study identify fourteen elements which support teacher-learning and thus teacher change. These include the following:

1. Actively experiencing an unknown,
2. Collaboration,
3. Feelings of frustration followed by a sense of accomplishment,
4. A non-threatening and supportive climate,
5. A system or network of support,
6. Reflection,
7. Freedom from distraction,
8. Critical discourse,
9. Perspective taking,
10. Epiphanies or turning points,
11. Interacting with individuals from may localities with diverse backgrounds,
12. Increased self-efficacy,

13. A conscious or subconscious volition to learn or effect change,

14. Believing that the change(s) improved student.learning.

Implications for Science Educators

The results of this study have implications for science educators. When designing learning experiences, science educators must make certain they incorporate those elements which facilitate learning and support change. As such, the learning experience must possess the following attributes:

1. Hold some sort of attraction for the teacher.
2. Center on the use of an unknown.
3. Challenge the teacher both professionally and personally.
4. Provide the teacher with the opportunity to become an active learner and look through learner's eyes.
5. Provide opportunity for both reflection and critical discourse.
6. Provide opportunity for interaction, collaboration, and camaraderie.
7. Take place in a location where the teacher is removed from distraction and everyday routine.
8. Take place in a non-threatening and supportive climate.
9. Facilitate the perspective taking of others..
10. Must foster transformation of meaning schemes and perspectives.
11. Enable the teacher to leave with improved self-esteem, self-confidence, and self-reliance.
12. Include a system of support, such as feedback meetings, to aid the teacher as s/he undergoes the change process and implements change in the classroom.
13. Provide the teacher with an opportunity to assess the impact the implemented change is having on teaching and learning in the classroom.
14. All aspects of the learning experience must support and reinforce each other as an integrated whole.

A great potential for improving science education lies with the classroom teacher. As such, teachers can be the change agents of reform. However, in order for teachers to facilitate reform they too must change. Therefore, programs directed at changing teacher practices, attitudes, beliefs, and perceptions are essential components in the process of improving science instruction (Abell & Pizzini, 1992). The IUP has been successful in changing the practices, attitudes, beliefs, and perceptions of those who participated which in turn fostered change in the classroom. As such, it could and should serve as a model for future teacher enhancement programs.

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Appendix

Anna is a 55 year-old single parent with two grown children. For the past 22 years, Anna has taught high school science in a mid-Atlantic state. Anna teaches in a school with an enrollment of about 830 students. During her tenure as a teacher, Anna has taught Earth Science, Physical Science, Environmental Science, Computer Science, Chemistry, and Biology. Currently, Anna is teaching both Conceptual Chemistry and Space Science.

As an undergraduate, Anna majored in Chemistry/General Science with a minor in Biology. Her masters degree is in the field of Communication Studies. Anna opted for a major in this area because she believes that effective communication is at the base of all personal encounters, especially teaching.

The Investigating the Universe project was the first two-week institute Anna had attended. After returning home from Green Bank, Anna participated in two additional institutes. Anna learned of the Project from a flyer she received at work. Anna has always been interested in Astronomy. This interest, together with her love of learning and desire to have new experiences and meet different people, attracted her to the institute.

Anna believes that we always have expectations. However, she admits that she traveled to Green Bank

> ...not know[ing] what to expect, and anything that I might expected would not have been what I found. I had been to workshops where you listened to lectures and you got materials. You went back home, and didn't really share in the experience. You were passive.

However, despite the fact that Anna had no preconceived notions of what she would be doing at the institute, she admits that, when she got there on the first day, she found out quickly what was expected of her,. "...and it did exceed my expectations in that respect"... She continued.

> I went there with the idea that it would be like other things I had attended. That you would just sit there and be talked to and come home with a lot more information and maybe some materials to use in classes. But I didn't think I would get so actively involved in it.

In reflecting back on her first day at Green Bank, Anna remembers that

> my first experience was meeting all the people, and finding out that I was probably the only one there who wasn't teaching astronomy or space science. And I felt a little bit out because these people were talking about things they were doing in classes. I didn't have all those experiences, although that's what I want to do. So, I felt a little intimidated by some of them, who say [they] had worked in planetariums for a number of years and [had] a really good background in astronomy. ... I was intimidated at first by a lot of people.

The feelings of intimidation experienced by Anna the first day plagued her as she began to work with other members of her group. Anna was embarrassed because she did not know something that everyone else seemed to know and felt she didn't have much to offer. As a result, she kept her mouth shut and contributed very little the first few days. However, this would change. Anna was undergoing a metamorphosis.

Anna soon realized that by working in collaborative groups "everybody got a chance to offer what was best for them, and that we all work together, and we developed a strong line ... within our groups". Anna now believes that she can "get up in front of a group of people and talk to them". Anna no longer believes that she has nothing more to offer, for she now knows "that what I say might have a bit of importance". By the end of the two weeks Anna realized that she is "not such a dummy after all".

> I had a lot more self-confidence when I came out [of] there than I did when I went there. I felt that I came through the two weeks and did what I was supposed to do and was successful. I felt that I had learned a lot. I met a lot of people who meant a lot to me. I think the biggest thing was [that] I had a different perception of myself, that I could go into a group of people even though at the beginning I felt intimidated. At the end of the two weeks, I felt that I was on level.

Anna believes that the boost in self-confidence she realized was brought about by both the success she felt as a group member and the encouragement she received from the other members of her group. For Anna, these are two of the institute's high points.

> ...Successful at what we were doing, our project. The things we worked [on] so hard ... started to work. Then all of a sudden things started to fit, and you just wanted to yell "Hurrah". ... Yeah, we do have a product, you know, we do have an answer to what our problem was! I think it was the night we were all working together, ... and we said, "hey, we got it!"
>
> It was that [working in groups] and the encouragement that I got from some of the people down there. ... There was a lot of encouragement, and it's sad that, you know at that age, I still needed encouragement.

Anna left Green Bank really happy, for she knew the institute had done a lot for her. As a person, she had a lot more self-confidence, a higher self-image, and became very calm.

> And people were asking me what was wrong because I did a lot of thinking. ... Friends that I was with said I became very quiet. But, I was really thinking about everything- you know, when you are down there, you're so busy you don't have time to think and analyze. It's when you are home, you think about all the interaction you had, and everything you accomplished, everything you learned, everyone you met, the opportunities you had but you might never have again.

Anna spoke more about her relationship with people at home before and after Green Bank.

> At that time I was associated with a lot of people who did not look at learning as important. I was maybe a little bit odd, or spent too much time reading things. [I] wasn't as out-going and social as they were. I came back [from Green Bank] and it didn't bother me anymore. I just felt, okay, I can just sit here listening to you all. But I can escape. I guess I kind of withdrew from that group of people. I am very comfortable with [this].

The boost in self-confidence and the calmness were not the only changes realized by Anna following her two weeks at Green Bank. On a professional level, Anna says that

> I got more interested in how to teach and how people learn instead of just giving information to go along with my other answer. I got a little bit more interested in that. I also got a little bit interested in how people work in groups. And, right now, I'm involved in cooperative learning in the conceptual chemistry [class].

In addition to the use of collaborative groups in her classes, another change Anna implemented in her classroom was 'wait time'. Although Anna considers wait time to be important, she says that the biggest change she realized was that she turned into a "person who wasn't giving them information". In other words, Anna was no longer interested in just 'getting the content across, ... you make them think about it, or look it up somewhere else".

Anna could not believe that she was asked to return to Green Bank as a mentor. "I never thought that they would ask me back as a mentor, I thought, well, I'll never be picked because I'm not outgoing". Realizing she was chosen however, Anna was "afraid again". Arriving at Green Bank that second summer "I felt pretty comfortable except I was intimidated by all these people, you know, I still felt that some of those math people were wizards, and physicists, and all that, I felt inadequate".

From the perspective of a mentor, Anna found it interesting to see the participants

> go through the same process that I went through the year before. It was interesting because they went through the same shock at first and then confusion. I always believe that confusion is the first stage in learning. And, then they went through the stress time. Then they went through the relaxation period, and they all hated to leave, but that was exactly what we went through, most of us.

Anna believes change was brought about for the following reason.

> ...At home you have your preconceived niche in school and in society. It wasn't until I went down there and everything was fresh and the people there knew that I could do something without, you know, at home you are labeled, aren't you? ... You're a weirdo science teacher or a parent or your thing or that. And you don't get out of that. But down there, you had the freedom to get out of it. Nobody knew you were very quiet or wouldn't talk in front of a group. You started out fresh, and that was definitely a changing point in my life.

While at Green Bank, Anna interacted with scientists and NRAO staff. Anna realized that scientists are all very different, and that none of the scientists she interacted with were like the stereotype portrayed in the media. Anna now realizes that scientists are human beings who might collect sports cards or old cars. Why the change in perception? Anna is quick to point out that "I never really had a chance to talk to anybody like that. You didn't have a chance to sit down at the dinner table and talk to [scientists]. When did you ever have the opportunity ... to talk with a Nobel prize winner?"

In talking about science, Anna points out that texts often define it as a way of solving problems. After spending time at Green Bank, Anna now sees observation as the most important aspect of science.

Anna traveled to the institute believing the purpose of the institute was to learn about radio astronomy. She no longer believes this to be so.

> The more I think about it, the less I think the goal was to learn things about [radio astronomy]. I think it was a way of getting people to analyze their teaching methods. And to look at them a little bit, maybe think about what they were asking. Because we were students. I think maybe it was to make us think about how we learned and our teaching methods.

In reflecting back on her involvement with the institute, Anna says that

> I don't know how to explain it. It changed me greatly. That's all I can say. If you knew me before I went down there and if you knew me now, you would not have known that I was the same person. The changes that I felt, content with myself, secure with myself, I think maybe that was it, secure that I could go places, could talk to people , and I had things to tell them. ... There you were in a group who accepted you as the way you are, if you were a little bit strange, that was okay. ... It was wonderful, all the outward stuff disappeared and you were judged on what you were doing and what you were accomplishing.

Anna believes she will always have the calmness. She says that "I can look aback and think about being down there and it takes away a lot of stress". For Anna, participation in the IUP was a "religious experience", a "turning point" in her life.

KNOWLEDGE STRUCTURES OF TEACHERS: AN ASSESSMENT OF KNOWLEDGE STRUCTURES IN THE AREAS OF CONTENT, PEDAGOGY, AND PRACTICAL CONTENT KNOWLEDGE DURING THE FIRST TWO YEARS OF TEACHING

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Typically beginning teachers' thoughts about teaching concern two distinct lines, content and pedagogy (Lederman, Gess-Newsome & Latz, 1992; Shulman, 1987). Some current educational research indicates a new domain called pedagogical content knowledge (PCK) (Shulman, 1986 & 1987). Shulman (1987) describes PCK as the intersection of several knowledge domains. The interaction of the content and pedagogy remains an enigma among first year teachers, and PCK examples as described by Shulman typically do not occur. Current studies suggest some first year secondary science teachers understand and can describe some relationships involved between content and pedagogy and use the overlap in teaching their courses, while others maintain separate categories (Van Sickle, 1992; Lederman & Latz, 1993; Bogan, Van Sickle & Dickman, 1994). To date tyro teachers do not label the connections that they are making in the same way as researchers do according to the findings of this study (Van Sickle, Dickman & Bogan, 1994). In fact the evidence to date suggests that novice teachers (as defined by Spector, 1989) with up to five years of teaching practice do have the experience to make the connections necessary to meet the criteria of PCK that Shulman describes (Lederman, 1995).

To address the issue, what connections are first year teachers making and what do they label the knowledge domains, a qualitative longitudinal study was designed. The purpose of this longitudinal study was to assess the development of new teachers conceptions of the relationships (if any) between or among the knowledge structures defined by tyro teachers during their first years of teaching. These tyro professionals graduated from education programs in three southeastern universities: College and University of Charleston, SC, Radford University, VA, and Jacksonville State University, AL. (see Bogan, Van Sickle & Dickman, 1994 for program descriptions). Questions were used to guide the identification of pedagogy and content structures that the teachers built between content and pedagogy. The same questions were used and data were gathered as these teachers were finishing their professional development through the education programs at the above universities. Additional open ended questions and diagrams were used to discover and identify other knowledge domains and connections voiced by the novice teachers.

The data for this study were generated by preservice secondary science teachers over one to two and a half years. They were asked the same set of questions several times during this time span. The questions were asked several times during the students' methods course, the student teaching experience, and through the first year and a half of public school teaching. In other words, the participants were questioned both as pre and inservice teachers. The original four questions adopted from Lederman, Gess-Newsome & Latz (1992) were:

1) What topics make up your primary teaching content? What would it look like to use these topics to diagram your content area?

2) Have you ever thought about your content area in the way you have been asked to do in question one?

3) What topics make up important elements/concerns of teaching? What would it look like to use these to diagram the important elements/concerns of teaching?

4) Does your content area and teaching practice overlap? If so, how; if not, why not?

After the third collection of answers to these questions, the three investigators noted a pattern among the preservice teachers' responses. The students repeatedly used words like "linked", "bridged", "connected", and "related" in their descriptions of content and pedagogy. At this point the investigators developed a fifth questions that was used during subsequent interviews. This question was:

5) What relationship(s), if any, do you see among content, pedagogy, and teaching objectives?

Research Techniques and Data Sources:

Teachers develop pedagogical content knowledge in the same way that they truly come to comprehend anything: through experience. However, just surviving the teaching experience is insufficient. Teachers must reflect on and analyze the parts of PCK and make connections among these parts (Draft of the National Science Education Standards, 1994). In order to facilitate the formation of these connections, we as teacher educators need to understand the processes by which new teachers begin to make these connections, when they start this process, and what vocabulary they use to describe this process.

A basic assumption of this research was that the underlying content and pedagogy structures and knowledge domains were changing constantly and thus a descriptive longitudinal study would best inform the researchers. A multiple case study method (Bogden & Bicklen, 1982) was considered the most appropriate design for this longitudinal study both because of the multiple sites and in-depth data that were collected. Data were collected and analyzed in several phases beginning with entrance knowledge structures on content and pedagogy, followed by conceptions on these same structures several times during student teaching and the first year(s) of public school teaching. Teachers were also interviewed after each formal data collection was completed and after each phase of writing the final documents. To ensure that the teachers' perspective was heard, each interview and written document was reviewed by the teachers (Douglas, 1976).

When this group of teachers began working in the public school system, they were asked the same set of questions once a year. To assist their memory, the last paper written about their experiences was mailed to them along with the questions. Included with these original questions was a new set of questions. Additionally, field notes and artifacts such as lesson plans, were collected from each teacher. Interviews were conducted at each data collection point. These questions were developed by the researchers as a secondary interview protocol. These questions were:

1) Do you still think you are making the connections named in the paper? If so which ones?

2) Do think you are now making other connections not named in the paper? If so name them and give an example?

3) What factors help you /allow you to the connections you named in 1 and 2 more often?

4) What factors hinder/stop you from making the connections you named in 1 and 2?

Results

The preservice categories for study emerged and were reported (Bogan, Van Sickle & Dickman; 1994 and Dickman, Van Sickle & Bogan, 1994) during a previous study. It is worthy of note that the preservice teachers did not perform nor express vocabulary consistent with the PCK literature. The categories, knowledge domains, that they defined by the conclusion of student teaching were nature of science, ethics, psychology, and sociology. This is in direct contrast to Shulman's (1986) categories of content knowledge, curriculum, knowledge of educational context, learners and their characteristics, and pedagogical knowledge. While some parallels, after two years of teaching, may be drawn between the two sources, such as psychology and learners and their characteristics, the researcher and early practitioner vocabulary is not congruous. The apparent incongruity between researchers' vocabulary and teachers' words may be part of the education facultys' dismay at pre and inservice teachers' failure to understand the research literature.

Subsequently, several of the original cohort of preservice teachers have become inservice teachers, and have agreed to answer the questionnaires and interview questions to continue a longitudinal study of their development of knowledge domains. It appears that the linkages, using the categories defined by Dickman, Van Sickle & Bogan (1994), follows an undulating path. Data generated from the initial survey (data were gathered upon entrance to the practical course work) suggested that no linkages were apparent and thus no linkages were possible. After course work and practicum work, data indicated that categories had begun to form in the preservice teachers' minds. During student teaching the categories seemed to submerge at first. Later, after school rules, discipline, and lesson planning became more routine, the initial category linkages began to emerge again in a clearer form. This same, on again--off again, pattern seemed to present itself during the first year of teaching. Some typical statements from some first year teachers were: "I'm still making those connections a little." "I was in shock after my first year of teaching." All indicated that during their first year of teaching they had fallen back, to some degree, into the lecture mode as a survival mechanism. For example, one first year teacher said,

> I have many of the same feelings outlined in the paper such as the need to correlate subject and pedagogy. I'm having a difficult time linking the two. As I feel I'm in survival mode. I fall back on lecture much too often to get content out to students.

One first year teacher appears to have regressed to a pre-practical experience position. His comment is that he feels dumb with regard to his content. He is coaching and teaching four different courses, for which he feels he had received limited or no content preparation. During his student teaching, he was observed implementing creative and effective inquiry lessons. At this point in the school year, he is relying exclusively on lecture from the text and worksheets. At the opposite extreme, another first year teacher commented that "...I went through a major paradigm shift about science and science education during my science methods class." Since that time, this teacher has moved from science as facts to understanding and delivering science using interactive pedagogy. His experiences during his first year of teaching have not dampened his interactive approach. He said, "I now realize that I will have to be asking myself questions about the connections between content and pedagogy as long as I teach." The on again--off again pattern of making linkages among the categories seemed to be reduced in most cases as teachers moved from mentor supported practica to first year teaching.

Current interviews suggest that this pattern was maintained through a second year of teaching. However, the amplitude and the frequency of category linkages increased. The following are some comments made by second year teachers,

> Inquiry is part of the nature of science, but you can only go so deep because first you have to learn what they actually believe. I still won't let them get away with all lecture, you can't learn it all by lecture. This way they have to apply and use it and think.

Another second year teacher perceives herself as making more connections in the areas of nature of science, psychology, and ethics "Discussing evolution, environmental issues and genetic engineering many of these (ethical) concerns arose." A third teacher talked about psychology as, "...some kids have good hearts. They act bad sometimes, but it's just because they don't know any better. I can't work with kids who have bad hears. They just want to hurt and cause pain."

All of the participating teachers except one, perceived themselves as making new connections. One first year teacher is struggling to connect social issues into her existing framework. "I can't teach enough about responsibility. I know the science I need to know and I learned a lot about science teaching, but not about teaching kids social skills, resourcefulness, and responsibility." A second year teacher has begun to make administrative and parental types of connections. "In order to make students independent thinkers there is a perception by parents and administrators that you are being too hard on them and they pressure you to ease up." Another second year teacher has begun to connect into the impact of culture on learning. "I have to deal with what Grandma believes--because they believe that most." A first year seventh grade life science teacher walked into the classroom and noted that there were no computers available for his students. He spoke with several "old timers" and another first year teacher, asking about grants and fund raisers to get computers in the classroom. The old timers were not interested in pursuing any such avenues. The two first year teachers teams up on a fund raising venture and raised $6,200. The new teacher found the scenario incredulous.

Initially first year teachers didn't see anything as helping them to make connections. "I have many of the same feelings outlined in the paper such as the need to correlate subject and pedagogy. I'm having a difficult time linking the two as I feel I'm in survival mode." About half way through their first year, teachers began to see some things as helping them make connections. "When I am completely prepared and have preguessed how my students may approach the subject matter I have much better results." A second year teacher saw herself as regrouping/resetting her teaching methods on where her students actually were. "My connections are more reality based now and I'm making more connections because I'm in the classroom." A second teacher describes her development;

> I feel strong feelings that these things are what's best for the students and I get positive feedback from the students. That's what keeps me going. The students eventually get better grades because of studying this way--them having to think--they get better test scores.

One teacher listed a plethora of problems hindering her development of connections. Among these were a lack of laboratory equipment, student behavior problems, drugs, student apathy and poor preparation in how to deal with students with learning disabilities. She felt that the students "...especially don't like me because I'm white and they tell me so. The school is 95% black and 95% of the teachers are black." Other external factors described by teachers were parental, administrative and student expectations, lack of safety features that prevented hands-on interactive activities, and inadequate content preparations in some programs. Two of the teachers experienced natural disasters during their first year of teaching. One teacher's classroom was intentionally burned down. A tornado destroyed much of a service community of another teacher. One teacher very clearly expressed awareness of internal factors hindering her formation of connections.

> ...I want to go back to the old model of teaching which hurts them (students) because they do not have to think. That just makes them dependent on me which doesn't help them in the long run.

Cases, where school/parent politics and discipline problems were most severe, indicated a lower frequency of linkages and frequency of ability to develop PCK.

<u>Comparison to Previous Preservice Study</u>

These teachers continued to describe the same categories (e.g. nature of science, psychology, ethics, and social concerns) and to utilize the same descriptors they used during the preservice studies. The social concerns category seems to be taking on more definition than the earlier study. For example, the new teachers have discovered that family and religion play an important part in what students will learn. The myths and legends that the family tells are more believable and seem more rational to the secondary science student than the scientific evidence that the teacher presents. Secondly, the new teachers found that teaching students "responsibility" was important. The students did not seem to want to behave in the school setting in ways that the teachers considered a socially responsible way. The students were stealing and fighting.

The tyro teachers also seemed to be forming a new category related to school administration. The administration of the schools seemed to either support the new teachers decisions or apply pressure so that the new teacher would change teaching strategies. The new teachers in the study, predominantly, retained their beliefs about student learning and science and thus, continued using pedagogy that focused on critical thinking, hands-on/minds-on laboratory activities, and higher order thinking skills, the teachers who maintained such teaching strategies found that their students eventually scored better on classroom and standardized tests. The teachers who reverted to a higher percentage of lecture in their instruction found that their students did not score higher on either classroom or standardized tests. This is a phenomenon that needs further study for clarification.

It seems likely that first year teachers can maintain some of the bridges between content and pedagogy when required to be self-reflective. These teachers continued to believe that pedagogy and the nature of science were intimately linked. The evidence gathered in this study seems to be supporting the stance that connections among knowledge domains may have environmental controls. These new teachers needed to be reminded about what they had learned in their course work and practica.

These data agree with the draft of the National Research Council's (NRC, 1994) position that experiences is essential to PCK's development if, in fact, PCK is a separate knowledge domain. While some researchers seem to be claiming that PCK is indeed a separate knowledge domain, the evidence may be pointing in the direction of experiences that do not overwhelm the teacher. For example, misbehavior on the part of students may cause the teacher to be constantly disciplining students rather than teaching. Teachers may have to respond to demands made by school administration such as paperwork requirements that also divert attention from teaching content, and parents may insist that "schools is school" and perceive that what the teacher is doing is not "school".

Student Influence on Novice Teachers

The new teachers were interviewed about the impact the students were having on the professional development of the teacher after this trend was discovered from the written results and classroom observations. All the teachers felt the students were preventing them or forcing them into a mold that was not congruent with their beliefs about teaching. The teachers seemed to feel that three main categories of student behavior were the most forceful in preventing them from teaching the "way" they believed was best. The categories the teachers described are, good heart/bad heart, but grandma/mamma said, and nobody else ever does it that way. These issues play into classroom discipline, local culture, and community beliefs's about how schools work.

Good hear/bad heart is directly related to classroom behavior. Teachers are typically willing to work with students they believe have good heats. "Oh, he didn't mean to do it. He just didn't know any better." These teachers generally believed that students did not have role models or were not taught behaviors that would be socially acceptable in the classroom. This is in contrast to bad hearts. "She meant to steal that money. She doesn't care how or if it hurts anybody else. She's just mean that way." The teachers often believed that students did know better, but were simply mean and hurtful. Teachers found such student actions overwhelming and did not want to deal with these students. Teachers with several students whom they felt had "bad hearts" reverted from proactive discipline plans to reactive and punishing discipline plans in their classrooms. The teachers did not feel good about this reversion, but felt helpless in the presence of these students to do anything else. The worst result from this reversion to punishment was expressed as,

> I hate doing this, I hate how bad it makes me feel. I think it affects me more than them, but it seems to be the only thing that gets them to do what I want. Worse I see the anger, hate, or whatever in their eyes, and I know I'm only making things worse for the long run, but I don't know what else to do.

Teachers were observed in these classrooms using tactics that they felt were punishing. One or two bad heart students in a classroom reverted the teachers from activities and discussions to worksheets completed in silence. None of the teachers felt these tactics resulted in better learning, but they felt in control of the students.

But grandma/mamma said could also be, my dad said. It happens that most of the students in our schools seem to refer to grandma or mamma most. Charleston public schools are about 60\5 African American students. Their culture is matriarchical and therefore what grandma or mamma says carries a great influence. Often cultural aspects of life conflict with the science curriculum. For instance, Sea Island students are taught that snakes are evil. When a novice teacher brought a snake in to the classroom the students expressed extreme displeasure and called the teacher as well as the snake evil. No amount of cajoling convinced the students that the hog nose snake was not poisonous. After all grandma had taught them all of their lives to kill any snake they saw and they were taught a "dance" to effect their desires. Grandma taught this due to the poisonous snakes in the area and the kinds of crops grown in this area. Dead snakes did not cause dead children from snake bites. Teachers were learning to ask what grandma/mamma said about an issue before addressing the science lesson. Teachers felt somewhat amazed by the understandings taught by the students elders as "truth". The novice teacher began to understand the research studies about alternative and misconceptions in science. Teachers began to believe they needed to learn about their students beliefs before they could become effective with delivering the science content.

But nobody else does it that way, was probably the influential key to what the new teacher eventually did in the classroom during the first year of teaching. Students have learned to be masters of deception and sometimes use "truth" to cause teachers to change their teaching strategies. For example, some students really have not previously completed laboratory experiences. Students will say they have never used, for example, a Bunsen burner, and teachers will make one of two decisions. One is to take the time to teach the students to use the Bunsen burner, or the other is to decide that if they haven't learned it by now, it's not my job to teach them. Usually the second decision occurred after speaking with the other science teachers at the school.

A second way students use, but I never..., is against other teachers. This is undoubtedly the most insidious problem students create by their words. Students claim that other teachers do not, "make me work in group", "make me figure out answers", or "make me think so hard." While there may be some truth in some instances to their statement, it is not a generalization that we found to be true in the schools where we observed. In fact, most of their previous science teachers and their future science teachers were using a variety of teaching strategies including critical thinking. Students eventually admitted that they had completed difficult thinking questions previously, when confronted by previous teachers. The problem was that the teachers believed the students before believing teachers, and usually without benefit of data about the previous teachers abilities and classroom and teaching practices. This directly relates to notions of professionalism in teaching. Teachers need to support teachers, and if a problem is perceived, they need to study the situation before making a decision to believe the student over the teacher.

Conclusions

While past studies have suggested that expert teachers develop pedagogical content knowledge, the structure changes that would occur over time were not known. Some things teachers believed would facilitate their formation of m ore complex connections were: Inservice training in areas such as teaching responsibility, teaching social skills, an experiential component incorporated into more education courses, parental and administrative support for inquiry based learning, more opportunities to experience different teaching strategies, adequate content preparation, and ways of obtaining funds for the supplies and equipment needed to implement interactional pedagogy.

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A COMPARISON OF ELEMENTARY SCHOOL SCIENCE METHODS WITH EMBEDDED PRACTICUM AND EMBEDDED IN A YEAR-LONG INTERNSHIP PROGRAM

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Over the last three decades the Faculty of Education at the University of Victoria has experimented with a variety of organizational structures for the five-year B.Ed. program and the two-year post-degree certification program. The number, length, and calendar placement of student teaching practica during the professional- year have been changed frequently from three-week periods at three different times, two periods of six weeks each, a two-week period plus a ten-week period, and a longer internship with coordinated instruction lasting 38 weeks. These student teaching practica have been articulated with one or two other limited clinical experiences in preceding years. Each variation in organization attempted to lengthen the student teaching component while balancing the instructional components in a meaningful way.

This paper describes the two professional year options leading to certification (currently year 4 of the B.Ed. program and year 2 of the post-degree program). The first option called the "Normal" program consists of an instruction-practicum-instruction-practicum sequence referred to in the title of this paper as the science methods with embedded practicum. The second option called the "Internship" program consists of instruction-internship-instruction-internship sequence referred to in the title of this paper as the science methods embedded in a year-long internship. Students from both the five-year B.Ed. and two-year post-degree programs are enrolled in each option. This paper provides the theoretical background for the programs, description of overall program, descriptions of the two professional year options, evaluative data, and a comparison of the two options.

<u>Background</u>

Many elementary school science teacher educators have spent the last 35 years (1960-1995) trying to identify basic instructional strategies and curriculum materials that address a variety of post-Sputnik science education goals—knowledge, processes/skills, thinking, attitudes, and science-technology-society. Kennedy (1990) suggested that many professional education programs can be categorized into two different classes—teaching a body of knowledge and teaching thinking. Furthermore, within teacher education there was little agreement on the content knowledge and the type of thinking to be taught. In recent years it has become apparent that the basic assumptions of the current reforms (*AAAS–Project 2061, NRC–National Science Education Standards, NSTA–Scope, Sequence and Coordination*) are equally related to the dual objectives of educating elementary school teachers as well as to educating elementary school students. The basic assumptions include: focus on big ideas, less is more, prior knowledge is a major influence on learning and it may include misconceptions, there is no single best way (avoid either/or approaches), meaningful reform is no quick fix, habits of mind are central to science literacy, and doing science is hands-on and minds-on. These seven ideas have guided the development of the University of Victoria's Elementary Teacher Program and the Elementary School Science Curriculum and Instruction courses described here.

Schulman (1987) identified the critical components of a teacher education program as involving three areas: content knowledge, pedagogical knowledge, and content-pedagogical knowledge. Frequently, Faculties of Education have little control over the courses and disciplines used to address the content knowledge and Departments of Science Education have little influence on the general learning theory and curriculum and instruction courses used to address the pedagogical knowledge. The lack of articulation and coordination of these two components in the early years of a teacher's education results in great diversity of prior scientific and pedagogical knowledge amongst preservice teachers entering the science methods courses in most teacher education programs (Anderson & Mitchener, 1994). The use of selection procedures, entry standards, prerequisites, and specific program requirements have had mixed success because of the myriad of political agendas and competing philosophies (Roth & Pipho, 1990). The diversity of backgrounds or the lack of prior science knowledge and pedagogical knowledge make it extremely difficult for science education professors to address the content-pedagogical knowledge required to become an effective elementary teacher of science.

Province-wide surveys of elementary teachers (BC Science Assessments, 1978, 1982, 1986, 1991, 1995) indicate that practicing teachers believe they lack appropriate content knowledge especially in the physical sciences and earth-space sciences. These surveys also indicate that practicing teachers do not value their preservice science education and that they want inservice education to address current science education reforms. These reflections indicate that science education courses in preservice 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 classroom conditions, do not provide depth of understanding, and most importantly do not convince preservice teachers of their value.

An analysis of science education methods course outlines would likely indicate that university science educators are promoting the most recent reforms, trends, and goals and are attempting to remediate content, process, and learning theory weaknesses. But a visit to these classes may indicate that we are not demonstrating a commitment to "less can be more," "knowledge construction is a private, personal act supported by a sociocultural context," and to the fact that "preservice teachers are not experts". Methods courses must respect the realistic conditions of today's classroom, appreciate that many contemporary science education theories and goals are fuzzy and are not well understood by practicing teachers, that science in the elementary school curriculum is assigned a low priority, and that a well-developed basic "tool-kit" is likely better than a comprehensive survey of strategies. Anderson and Mitchener (1994) stated "science methods courses act as a bridge between many areas": the program, the university, the school, and the professor (p. 17).

Still, content-pedagogical knowledge focuses on "educating" not "training". Science teacher educators must realize that there is likely a discrepancy between the ideals of the methods course and the reality of the classroom (Goodlad, 1990). Student teachers frequently do not apply or test ideas promoted in their campus-based coursework, rather they adapt to the expectations and practices of the classroom teacher. This is a major dilemma with the traditional apprenticeship approach. Substantive rationales consisting of declarative, procedural, and conditional knowledge and opportunities to apply and manage instructional strategies in a supportive cognitive apprenticeship are needed if methods courses are to be more effective. The match between the expectations of the methods course professor, the university supervisor, and the cooperating teacher is a critical attribute in the success of science methods courses. Compatibility is the end result of collaboration, awareness of cultural differences, and mutual respect among school, district, and university personnel.

Yager and Penick (1990) identified some of the immediate problems facing science teacher education as the relative value of methods courses and practicum experiences, the nature of an effective methods course, and the role and placement of clinical experiences. Teacher education programs at the University of Victoria have tried to address these issues using the work of John Goodlad and Lee Schulman. The major principles guiding program development are:

1. Collaborative planning among the Teachers' Association, the College of Teachers, the University's Academic Departments, and the Faculty of Education.
2. The B.Ed. program will have a variety of clinical experiences ranging in duration, focus, and placement; and the Professional Year will have student teaching practica of at least 12 weeks.
3. Preservice teachers will have a general background in all areas: arts in education, physical education, reading education, language arts education, science education, social studies education, and mathematics education.
4. Preservice teachers will have a strong background in educational psychology, evaluation, and social foundations and will demonstrate communication skills.
5. Allied faculties, the School of Physical Education, Department of Arts in Education, and Department of Social and Natural Sciences will provide the content knowledge required.

6. Educational Psychology and Professional Studies will provide the general pedagogical knowledge required.
7. Content-pedagogical knowledge is provided in the discipline-specific methods courses and fifth-year major courses.

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, and art) coursework, and a short two-week clinical experience at the end of the year. The fourth year is the professional year with further methods courses and the 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 on to complete the fifth year, since it provides a higher salary and teaching positions are presently in short supply.

The post-degree program is a two-year program leading to certification and a B.Ed. degree after receiving an undergraduate degree in Arts and Science, Fine Arts, or another professional faculty. The program is essentially the same as the third and fourth year of the regular B.Ed. program with minor exceptions to allow for completion of a second degree. Graduates of this program do not have a teaching concentration but come into the program with an appropriate degree, which gives them their content knowledge expertise. Some prerequisites such as mathematics and laboratory sciences may need to be remediated in the summer prior to entry into the post-degree program.

The science education component of these programs ranges from the basic core to two levels of specialization: a concentration and a teaching area (Figure 1). 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 requirement 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 the physical science, earth-space science, and biological science concepts found in the K-7 elementary school science curriculum. These courses focus on content knowledge, science processes, and inquiry science but also illustrate appropriate content-pedagogical strategies.

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 content 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 STS, technology application, upper-level instruction, and curriculum courses.

Within the regular and post-degree programs, two distinct schedules for the professional year component of the Elementary Teacher Education Program are used. Figure 2 indicates the time periods and sequence for courses in each program. The Normal option of the professional year program provides an 8-9 week instructional term (September-October), a 6-week November-December practicum, an 11-week instructional term (January-March), followed by a 6-week April-May practicum. Most methods courses are split by the intervening November-December practicum. The Internship option is operated in conjunction with a local school district. Students teach nearly full-time for 9 weeks in the fall and 16 weeks in the spring term completing some courses during the preceding summer (July-August) and other courses during a 6-week instructional period in November and December.

Figure 1
Science Education Component of the Elementary B.Ed. Program

ELEMENTARY SCIENCE EDUCATION PROGRAMS

University of Victoria

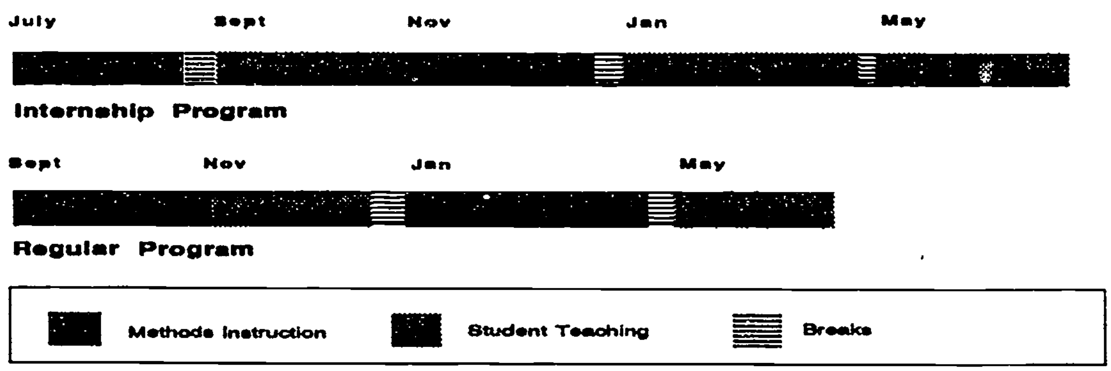
	Core	Concentration	Teaching Area
Year 1/2	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science

* If Grade 11/12 Science, requirement reduced. Most frequent courses SNSC-E 145A (1.5) - Physical Science, SNSC E 145B (1.5) - Earth Science, SNSC E 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
TOTAL	Core = 5 - 6.5 units	Other Sciences / Core + 9 units	Other Sciences / Core + 15 units

1.5 units equals 3 semester hours or 4.5 quarter hours

Figure 2
Calendar Placement and Direction of Instruction and Practica
in the Normal and Internship Programs



Normal Option

The elementary school science methods course (ED-E 745) is a 2-unit course that meets three hours per week during 19 weeks spread over two semesters. 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. It is the placement of the first practicum that makes this methods course unique. This practicum provides an authentic classroom experience in which to test ideas, to establish relevance, and to build a foundation for further study. The overall structure of the course models a guided inquiry approach with the first term serving as a pre-experience, the November-December practicum serving as an experience, the second term serving as a post-experience, and the April-May practicum serving as an authentic evaluation.

The philosophy of science education methods (ED-E 745) is heavily influenced by applied cognitive science, and curriculum and instruction are linked to an interactive-constructive perspective of teaching and learning. No textbook is required, but contemporary articles from professional journals and provincial curriculum documents are used to elaborate the classroom activities and discourse. Most often the educational idea under consideration is used to demonstrate the idea itself. Therefore, activities from the curriculum materials that are interesting and challenging to adult learners are used to illustrate the attributes of the 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 application and associated teaching strategies/skills are described.

Goals and Instruction

The student will be able to:

1. define the nature of science and technology, describe the nature of the learner and outline the needs of the society, and state how these factors should be reflected in the elementary school science, goals, curricula, and instruction;

2. demonstrate proper use of the science processes, science skills, and thinking strategies and state how these are learned by children;

3. demonstrate knowledge about and application of the elementary school science curricula and instructional resources;

4. develop and apply instructional strategies, teaching skills, and support materials that are compatible with the nature of science and technology, interactive-constructive learning model, nature of the learner, needs of society, and stated outcomes;

5. demonstrate an understanding of science and technology knowledge, motor skills, thinking, and attitudes involved in elementary school science program;

6. demonstrate knowledge about and applications of creative problem solving, plausible reasoning, writing-to-learn, and content reading strategies in science.

These goals are addressed with a series of one-hour discussion and two-hour hands-on classes. The topics addressed are outlined in Figure 3. The first eight weeks are problem-centered and focussed on the November-December practicum in which each student is required to teach a science unit. Cooperating teachers are advised of this requirement and most (+90%) comply with the requirement.

The first part of ED-E 745 serves as pre-experience for the practicum experience and provides a problem focus, motivation, and a limited "tool kit" containing an understanding of the BC Elementary School Science (K-7) Integrated Resources Package (1995), basic science process, and teaching skills related to the four-part guided inquiry (pre-experience, experience, post-experience, assessment). The fall assignment involves the progressive development of a science unit (overview, Lesson 1, Lessons 2-5, and summative evaluation) and a reaction paper

Figure 3
Tentative Topic Schedule for the Normal Option

September 11 - 15	Course Overview & Evaluation Nature of Science and Technology
September 18 - 22	Interactive-Constructive Learning Model Science Process (Observing)
September 25 - 29	B.C. Science (K-7) Integrated Resource Package (1995) Science Processes (Inferring and Communicating) Assignments: Reaction Paper #1 and Science Unit Topic, etc.
October 2 - 6	Basic Teaching Strategy: 4-Part Guided Inquiry Science Process: (Classifying) Assignment: Unit Overview
October 9 - 13	Thanksgiving Holiday (Oct. 9) Science Process (Measuring) October 16 - 20 Lesson Introduction and Experiences Science Processes (Predicting and Formulating Hypotheses) Assignment: Lesson #1
October 23 - 27	Post-Experience Discussion Science Process (Interpreting Data)
October 30 - November 3	Basic Assessment Strategies Individual help/materials preparation Assignment: Unit Plan
January 8 - 12	Reflections on Science Unit (Fall Practicum): Critical Attributes of Effective Elementary Science Teachers Science Process (Controlling Variables)
January 15 -19	Concept Mapping Science Process (Formulating Models)
January 22 - 26	Learning Centres Science Process (Experimenting) Assignment: Reaction Paper #2
January 29	Introduction to Project Wild
February 2	Project Wild Activity (T.B.D.)
February 5 - 9	Project Wild: Using the teacher guide Project Wild Activity (T.B.D.)
February 12 - 16	Other Environmental Education Resources Reading to Learn or Computer Applications Assignment: Reaction Paper #3
February 19 - 23	Assessment Alternatives (Reading Break February 21-23)
February 26 - March 2	Assessment Alternatives (continued) Reading to Learn or Computers (continued)
March 4 - 8	Write to Learn Science Assignment: Learning Center (set-up Friday a.m./take down Monday class time)
March 11 - 15	Presentation of Learning Center Review
March 18 - 20	Assignment: Examination (TBA)

of a journal article. This limited view was selected to address the "less is more" assumption and to closely approximate classroom practice while building the foundation for a more contemporary perspective and richer "tool kit" in the second term.

The second part of ED-E 745 serves as a post-experience for the practicum and is designed to address the needs of a reflective teacher, to build upon their teaching experiences, and to expand their instructional and curricular tool kit. Again, the expansion is very strategic and only those strategies not considered in other courses that have substantive research support are addressed (learning centers, read to learn,
write to learn, creative problem solving). Spring assignments involve two additional reaction papers of journal articles, a reflective analysis of the fall practicum, the development of a learning center or alternative instructional resource, and a final examination.

Internship Option

The internship program consists of a ten-month commitment from July through April. Methods courses are delivered in concentrated periods during the summer and a six-week period in November-December (Figure 4). Practical experience in the schools begins in September and, with a six-week break beginning in November, runs until the end of April. This provides for a total of 25 weeks of practice teaching in a school setting throughout the year. Students may spend the entire time in one classroom or in two separate classrooms at different levels depending on the school and placement.

The elementary school science methods course (ED-E 745) is concentrated in a six-week period beginning in early November. The course meets for two hours each day while students are taking two other courses during this period. Students in the internship option differ from the normal option in that they have completed nine weeks in the schools prior to science methods and about a third have done a minimum of science teaching prior to science methods, usually assisting the regular teacher in a unit or observing.

Figure 4
Tentative Topic and Schedule for the Internship Program

NOVEMBER

5 - 6..............What is Science?
7 - 8..............What should we teach students about science?
9..............How should we select the science content we teach?
11 - 13..............What resources do schools have for teaching science?
14..............What learning is of most value?
15 - 19..............How do children learn science?
17..............Overview of Unit
20 - 21..............How do we find out what children know or believe about a topic?
22 - 23..............How do children become motivated to learn science?
26..............How do effective teachers teach science?
27..............What are some barriers to teaching science and lesson plans?
28 - 29..............How can we emphasize critical and creative thinking in science?

DECEMBER

1..............Field trip to Science World
3 - 5..............What are some strategies for asking appropriate questions?
6 - 10..............How do we evaluate student progress in science?
8..............Learning Centre
11..............What are appropriate in-class and homework activities?
12..............How can we get parents more involved in student learning?
13..............Review
14..............Examination

The philosophy of the internship science methods course is influenced by the same factors as the normal course with the normal variance expected between two professors who have worked together for 25+ years. The instruction stresses hands-on/minds-on inquiry and attempts to build on and reflect the facts that the students have completed three closely aligned methods courses (language arts, mathematics, social studies) in the July-August instructional block and have 9 weeks of diverse classroom experience.

Goals and Instruction

The goals and objectives of the methods course have been jointly developed by instructors in both the Normal and Internship options (Figure 2). Generally the Internship science methods course follows the same content and sequence of topics (Figure 4). The concentrated methods course allows for a bit more flexibility of scheduling, which permits use of field trips and group projects, but suffers from a lack of time for reflection and general reading in the science teaching area.

Results

The ED-E 745 courses were evaluated each year by the students using the departmental teaching effectiveness form and written comments. In 1994 a special triad evaluation form was used to evaluate students' (Normal option only) perceptions of specific topics, assignments, and activities.

Quantitative Results The departmental teaching effectiveness form requests students to evaluate the course instruction on 15 dimensions using a five-point Likert scale. The following three items provide direct or indirect perspectives on the course's content:

1. Assignments, labs, seminars, and discussions were well integrated with the lecture material.

   (0) Not applicable (1) Strongly disagree (2) Disagree
   (3) Agree (4) Strongly agree

2. The instructor made good use of examples, illustrations, and demonstrations to help clarify the material in the lecture.

(0) Not applicable (1) Strongly disagree (2) Disagree
(3) Agree (4) Strongly agree

3. For my preparation and ability, the level of difficulty of this course is:

(1) Too elementary (2) Somewhat elementary (3) About right (4) Somewhat difficult (5) Very difficult

The 1995 results (Table 1) clearly indicate that students believe that the course's activities and examples are well integrated (3.27 to 3.58 out of 4.00), realistic and practical (3.59 to 3.76 out of 4.00), and the difficulty is reasonable (2.91 to 3.26 out of 5). Generally the teaching effectiveness of the professors involved in the two options is rated well above average. The primary-focussed (K-3) students have a slightly less positive assessment of difficulty than the intermediate students (4-7). This is likely influenced by their prior experiences, content background, and self-concept. Frequently, preservice teachers planning to teach the primary grades have a very limited background in science, negative experience with high school science, and high anxiety about science learning. Furthermore, their image of science teaching is very limited and their expectations of primary learners are below their actual ability.

The 1994 students were also asked to evaluate 16 different topics, activities, and assignments on the degrees of importance (critical to teaching science), satisfaction (satisfaction with the presentation of the topic, etc.), and value (worth the effort and time devoted to topic, etc.) ascribed each using a five-point Likert scale. Students were asked to assess each dimension as a 5 (very ____), 4 (somewhat ____), 3 (neutral), 2 (somewhat un-____), or 1 (very un-____). The results and pair-wise *t*-Test of differences are summarized in Table 2.

These results indicate a high degree of importance ascribed to all topics, activities, and assignments except reaction papers. The degree of satisfaction and value were also high except for health activities and reaction papers. Generally, students rated the importance significantly higher than satisfaction and value in most cases. The ratings of satisfaction and value were mixed.

Table 1
1995 Students' Evaluations for the Normal and Internship Options of ED-E 745

ITEM	NORMAL OPTION M, SD, f	M, SD, f	INTERNAHIP OPTION M, SD, f	M, SD, f
1. Integration	3.57, .51, 21	3.44, .51, 25	3.58, .58, 24	3.27, .67, 26
2. Examples	3.76, .44, 21	3.67, .56, 27	3.71, .55, 24	3.59, .51, 27
3. Course Difficulty	2.91, .43, 22	2.93, .39, 27	2.92, .28, 24	3.26, .59, 27

It appears that students believe that (a) greater depth should be given to a more limited array of topics, (b) assignments and activities should be crafted to be more efficient, and (c) the evaluation system needs to be redesigned to more closely reflect the effort and time involved.

Qualitative Results. Students were encouraged to make written comments about the course content and instruction on the teaching effectiveness evaluation forms. Between 50 to 90% of the students provided written comments about the content, instructor, personal beliefs, etc. These comments were analyzed using a key idea analysis to determine common trends and assertions. Actual comments were selected to illustrate the intention of each assertion.

Table 2
Descriptive Statistics and Pair-Wise *t*-Test Results for the 1994 Student Evaluations of the D-E 745 Activities and Assignments

Activity/Assignment (t-Test Results)	Importance (M, SD, f)	Satisfaction (M, SD, f)	Value (M, SD,f)
Curriculum Overview (*,**)	4.72, .53, 53	4.21, .72, 53	4.40, .84, 53
Interactive-Constructive Model of Learning (*,**)	4.63, .53, 48	4.29, .71, 48	4.44, .65, 48
Guided Inquiry (*,**)	4.78, .47, 50	4.64, .56, 50	4.66, .63, 50
Pre-experience Activities (*,***)	4.88, .32, 52	4.58, .57, 52	4.77, .51, 52
Experience Activities (*,***)	4.94, .24, 51	4.75, .44, 51	4.88, .33, 51
Post-experience Strategies (*,**,***)	4.88, .38, 52	4.46, .73, 52	4.73, .60, 52
Unit Planning (*,**,***)	4.78, .42, 50	4.10, 1.11, 50	4.42, .97, 50
Basic Science Processes (*,***)	4.76, .44, 45	4.31, .63, 45	4.76, .44, 45
Integrated Science Processes (*,***)	4.75, .44, 44	4.23, .68, 44	4.61, .58, 44
Guided Imagery	4.17, .83, 46	4.20, .81, 46	4.04, .97, 46
Concept Mapping (*,**)	4.64, .53, 45	4.38, .65, 45	4.42, .66, 45
Project Wild	4.60, .65, 45	4.56, .81, 45	4.89, .90, 45
Health Activities (*,**)	4.24, .64, 46	3.78, .79, 46	3.91, .87, 46
Learning Centre (*,**)	4.61, .58, 46	4.39, .68, 46	4.28, .91, 46
Reaction Papers (**)	3.87, .89, 45	3.73, 1.03, 45	3.62, 1.11, 45
Writing-to-learn and Reading-to-learn Strategies (*,**,***)	4.64, .65, 45	4.13, .79, 45	4.40, .72, 45

* denotes $p \leq 0.05$ between importance and satisfaction, ** between importance and value, and *** between satisfaction and value

Normal Option

Relevance. **Students believed this course, topics, activities, and assignments were very important, practical, and representative of effective practice.** They were generally satisfied with class presentations, activities and assignments, and believed that they were worth the effort invested. The degree of importance, satisfaction, and value was slightly lower with second semester topics, activities and assignments and among primary preservice teachers. Some students believed that the range of topics, activities and assignments should be decreased and greater depth provided (less is more).

> *You gave us a lot of relevant and useful information and a lot of practical ideas and strategies.*
>
> *I found all the assignments worthwhile, particularly the unit plans and center. At times the [reaction papers] seemed tedious...I still learned from them.*
>
> *I enjoyed this class as it provided me with hands on activities that can be [used] in my classroom.*
> *I feel this course is very 'in tune' with our practicum because most of the assignments that we do help to prepare us for our practicum and the work we do can be actively used in the classroom.*
>
> *The second semester of the course didn't seem as useful as first [semester]. I didn't [think] a lot of the information relevant.*

Self-confidence. **Students expressed a greater self-confidence about science, an increased willingness to teach science, and a more authentic view of science.** A large number of elementary school preservice teachers are very anxious about science, view science as a body of facts about nature, and believe science teaching is telling the students the right answer. Much of these prior beliefs are based on their high school science experience, since few students can remember any elementary school science experiences.

> *[This course] provided a non-threatening environment for those who are a bit afraid of science, made some less exciting parts of science more interesting, [and gave] a sound base and format to use as lesson guidelines.*
>
> *I feel much more confident in [this] area of teaching after taking this course.*

Before this year began, I thought I would be best teaching math, but now that it is over, I have to say that I feel best about science.

I liked [science methods] so much I changed my [teaching] concentration [to Science].

[This] course has helped me to feel excited to teach science.

[This course] took the fear out of teaching science for me and I now look forward to teaching it.

Through this class I have learned how to enjoy teaching science and make it meaningful.

Organization. **Students generally supported the topics and activities but suggested deletion of the final examination or the inclusion of a midterm examination, rescheduling the due date for the learning centre, and reallocation of time and marks among the assignments.** Students also suggested that the addition of reference materials was needed and emphasis on some topics. University grading systems influenced by the traditions of Arts and Sciences cause unnecessary evaluation problems for professional programs that are more interested in clinical performance than declarative knowledge. Many of the student comments included in this assertion appear to be related to test anxiety. Professors could benefit by realizing that many students today are non-traditional, mature students with financial problems.

The centre is worthwhile, but to expect us to invest all this money over and above tuition fees at this time of year when personal budgets are tight is ridiculous.

Please caution next year's students about high cost involved in constructing a learning centre.

Maybe [you] could have [the learning centre] due earlier in term, not at the end.

Have assignments completed before the last 2 weeks of class.

I think it would be better if there was some sort of testing prior to final.

The exam at the end of the year causes some concern as we have not been tested in [this course] before -- perhaps a midterm in December would give some reassurance.

Specific assignments were not too many, [manageable] over the year, debriefed well in class -- not just left to fade from memory after the marks were returned.

Relevant assignments, [but] more assessment strategies would be helpful.

We would have possibly covered more assessment in regards to science specifically.

Please suggest possible titles of books that would be good resources for science teachers.

I find it hard to follow and take notes [and] because I have no notes I can't refer back to 'what did I learn', it is hard to study for the exam.

Internship Option

Relevance. **Students believed that the activities and ideas considered were illustrative of effective science instruction in the elementary school classroom.** Students directly mentioned the "special" activities (field trips, games, guest speakers, etc.) that are normally part of effective science classrooms as good examples and contributing to their appreciation and learning.

I appreciated the "Special Days," field trips and guests. I felt the marking was not fair, as the criteria were not always clear. It will be a useful course in my teaching.

I enjoyed the class and the many good examples that were given. The comments on the assignments were helpful.

Enthusiasm. **Students identified the importance of enthusiasm, excitement, passion and emotional disposition in effective teaching.** Students consistently mentioned how much positive impact the personal attributes of a teacher has on their motivation and imply that they believe it would have equal impact on their students. The implication made is that they did not see similar passion in their internship settings.

I very much enjoyed this course and the enthusiasm of the instructor. The motivation ideas were excellent.

I have enjoyed science. It's refreshing to have a professor who not only has a passion for the subject but tries to instill that passion in us.

The instructor was very approachable. He was always well prepared for classes and put his effort into teaching. I aim to model myself after his teaching.

I enjoyed all aspects of this class except one. His enthusiasm was much appreciated.

The instructor was most personable. He shows genuine interest and dedication to making us want to be effective, enthusiastic science teachers. I appreciate his excitement and his generosity.

Comparative Results

Students within the Internship option generally rate their overall program experience more positively than those in the Normal option program, although both groups rank their overall experience as a positive one. Both groups rate their science methods classes highly, generally higher than other content methods courses. The fact that the Internship students must apply specifically for the program, be interviewed by the cooperating school district, and are selected by school principals for specific placements skews the data collected in ways that are not well understood. Interns have somewhat of an elitist perspective due to the selectivity of the internship option and they believe they are better teachers on average. However, these perceptions may be only that, as observational data are difficult to clearly interpret.

A questionnaire regarding student experiences and perceptions was administered to the interns following the initial fall practicum experience and prior to the methods course instruction. Twenty-nine of the thirty-one students enrolled completed the questionnaire that was designed to determine what science teaching they had seen or done during the first nine weeks of their practicum and various attitudes they had developed prior to the methods course in science.

Only three (10%) of the twenty-nine students responding taught a science unit on their own, and all were in primary (K-3) classrooms. Five students (17%) helped the regular teacher teach a science unit, and seven additional students (24%) were able to observe science lessons being taught by the regular teacher or another specialist science teacher at a middle school. Thirteen students (45%) did not see any science teaching during their initial practicum of nine weeks! One wonders if these cooperating teachers teach much science at all, even though the provincial elementary school curriculum guide mandates the teaching of science for a minimum of 80-120 minutes per week. When asked to explain why they had not seen any science teaching, most of the students noted that the teachers were waiting for the interns to prepare a unit in their methods course and teach science during the spring term. A few noted that there was a specialist science teacher in the school (particularly in middle schools), and they did not observe science due to the fact that they remained with their cooperating classroom teachers.

The central assumption of the Internship option dealing with coordination between classroom practice and university course work appears to have "backfired." In the Normal option (no change) over 90% of the students teach a substantial science unit during their first practicum while only 55% of the interns report either seeing, helping or teaching science in their September-November internship. At least for the 13 interns who did not even see science lessons the methods instructor is not burdened with the need to break bad habits gained during the first practicum. However, the model that cooperating teachers set of avoiding science instruction altogether generates concern.

A synthesis of the data about the two options and our experience of teaching in the two options indicates several advantages and disadvantages of each option. The following ideas were identified as the major advantages and disadvantages:

Advantages of the Normal Program.

1. The students have some science methods instruction prior to attempting to teach science.
2. The students have an opportunity to reflect and debrief their initial practicum teaching assignment in science.

3. The methods instruction occurs over the entire year, allowing for more time to think about and complete assignments.

4. A second science unit is able to be critiqued based on the first assignment and experience.

5. The influence of the methods instructor is likely to be greater on the students than the influence of the cooperating teacher.

6. Bad habits gained prior to methods instruction are rare and do not need to be remediated.

Advantages of the Internship Program.

1. Students come to the science methods course with some experience in teaching, although it may not be in science.

2. There is a much longer period of student teaching, which allows students to get an extended time for teaching more than one unit in science.

3. With only three courses involved, it is easy to arrange for full day field trips and the use of other informal teaching strategies.

4. Classes that meet every day can sustain instruction based upon group and individual projects.

5. The students are both self screened and district screened, thus providing a certain Hawthorne effect regarding the morale and self-esteem of the group.

6. Students from the Internship option are often sought out by school districts for hiring in the belief that these students have more experience, and have already been screened.

The disadvantages for each program are simply the corollaries of the above list of advantages. It is possible that both programs may prove to be valuable for certain students, but it is not known if the present selection procedures naturally select for the program that best suits individual student's needs.

Conclusion

The questions surrounding which pattern of instruction and practicum better meets the objectives of the program and the needs of students are not able to be answered clearly from the quantitative and qualitative data collected to date. However, the opportunity to explore these questions further remains and the advantages and disadvantages of each pattern need to be considered when planning new programs or making changes to established programs. Two central ideas about elementary school science teacher education would be seamlessness and compatibility. Preservice teachers must perceive that there is a seamless transition between their general-liberal education, their campus-based teacher education and field-based teacher education and amongst their various education courses. Realistically this may be impossible! But if a strong rationale is established, shared and constantly reiterated for content knowledge, pedagogical knowledge, content-pedagogical knowledge, and experiential application, the barriers will fade. Furthermore, all stakeholders in the professional year activities must present a unified view. Any discrepancy among the methods professor, university supervisor, and the cooperating teacher will under-mine the basic academic foundation of the teacher education program. Preservice teachers will default to the cooperating teachers' position when faced with differences in opinion and are less likely to value the methods professor's opinion. Close examination of such discrepancies would support this, since preservice teachers believe that the cooperating teacher represents the "profession" while the university professor represents some "idealization," and the preservice teacher and the cooperating teacher establish a very strong personal/professional alliance. It is hoped that these considerations may be useful to other program and curriculum planners.

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USING SCIENCE, TECHNOLOGY AND SOCIETY INVESTIGATIONS TO ENGAGE DIVERSE LEARNERS IN SCIENCE

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Using STS Investigations to Engage Diverse Learners in Science

Changing demographics and the movement toward inclusion are bringing a diverse student population into K-12 classrooms across the country. Represented are students with disabilities, students labeled "at-risk," and students from diverse cultural and ethnic backgrounds. Many diverse learners who learn best by doing often feel left out, do not participate, lose interest, and fail school as a result. There is a great need to engage these students in their own learning and to empower them to take charge of and be responsible for their own lives.

Many science teachers have little or no experience teaching students with diverse learning needs, and many of those trained to meet the needs of these students have little or no exposure to science. Regular and special education teachers rely on the textbook and utilize direct instruction to teach science (Brophy & Good, 1986; Rosenshine & Stevens, 1986). The learning differences of these students may best be addressed by activity-based methods of teaching science (Atwood & Oldham, 1985; Bay, Staver, Bryan & Hale, 1992; Choate, 1993; MacDougall, Schnur, Berger, & Vernon, 1981; Morocco, Dalton, & Tivnan, 1990).

Science, Technology and Society (STS) Investigations are an effective method for regular and special education teachers to use to engage and teach science to diverse learners. STS instruction is characterized by (a) an emphasis on societal problems and issues, (b) practice with decision-making strategies, (c) attention to relevant local and community issues, and (d) an emphasis on the applications of science. Other characteristics include emphases on (e) cooperative work on real problems, (f) multiple dimensions of science, (g) career awareness, and (h) evaluation based on the ability to get and to use information rather than simply to retain it. This focus meets many needs of diverse learners to be actively involved in their own learning, to learn problem solving, to work cooperatively and to present what they know through such authentic measures as project presentations.

Classroom teachers in the Rio Grande Valley of Texas and the San Joaquin Valley of California participated in university courses specifically designed to train teachers to use science, technology and society issues to teach science to diverse learners in special and regular education classrooms. Teachers were given a questionnaire at the beginning of the course to determine what training they had to teach science and what information they had about STS instruction. Special education teachers were asked if student behavior interfered with learning and if so, what specific behaviors.

Pre-Course Questionnaire Results

Teachers from the Rio Grande Valley were middle and high school science teachers; those from the San Joaquin Valley were K-12 special education teachers. Regular education teachers reported having had a science methods course. Most of the special education teachers had received no training in science. Special education teachers reported using primarily direct instruction to teach science. These same teachers also reported that students' behavior problems (e.g. inattention, off-task behavior) often interfered with learning. Most of the participants were unfamiliar with STS instruction.

STS Course Goals for Participants

Participants attended several weeks instruction in the theory and practice of STS to teach science. Sample STS lessons were modeled. The Learning Cycle Model was presented as a guide to develop lesson plans which include the important components of STS. Specific course gaols were:

1. Demonstrate the integration of STS themes and activities in the curriculum.
2. Increase teacher knowledge base regarding current STS-related topics through reading of related books and journal articles.
3. Practice methods to stimulate higher order thinking and curiosity by relating material to students' own lives.

4. Design STS module appropriate for particular grade levels in regular and special education settings.
5. Implement a series of STS lessons in the classroom.
6. Present modules to peers in university class.

Evaluation of STS Instruction

Teacher reports indicate that the STS focus to teach science to diverse learners was successful in engaging student interest and minimizing behavior problems. Teachers were excited to learn about the STS approach and pleased with the level of student achievement and engagement in activities. At the end of the course teachers reported their perceptions about the value of using STS to teach science, the benefits to students, and the observed behavior of students during STS activities. Questions and common responses are listed below.

What aspects of STS instruction did you find most valuable in teaching science to your students?

1. Lessons are relevant to students
2. New ways of presenting lessons
3. Problem solving
4. Tie-in to technology
5. STS activities can be used with any ability level and focus on the individual learner
6. Personal approach to problem solving allows for greater retention of concepts
7. Allowed students to drive their own learning, to feel okay about asking questions and giving answers
8. Easy to do alternative assessment
9. Students get involved in doing research, making presentations, evaluating ideas, resolving conflicts, working together as a group

What do you believe your students gained from the experience with STS?

1. Hands-on experience, awareness, and social interaction
2. Insight into the social issues around them

3. Began to ask questions and show concern for the environment

4. Civic awareness and community participation

5. Higher order thinking was enhanced

Briefly describe the behavior of your students during STS activities.

1. All were interested and involved, enthusiastic and cooperative

2. Students were on-task and behavior problems were almost eliminated

3. Students were sharing ideas and working together as a team

4. Students seemed to enjoy taking about controversial topics

Discussion

Participant responses would indicate that teachers found many benefits for both themselves and their students in using STS to teach science. During STS activities students were actively engaged in meaningful investigations of their choice and few behavior problems were noted. A more detailed description of the courses and results, implications for research and for practice are discussed in a paper submitted for publication in the Journal of Science Teacher Education.

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CASE STUDIES BY A GROUP OF COLLABORATING EDUCATORS: HOW DO STUDENT AND TEACHER QUESTIONS FACILITATE LEARNING?

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Akiko Kurose, Seattle School District
Dorothy Simpson, Mercer Island School District
Emily van Zee, University of Maryland at College Park
Judy Wild, Sacred Heart School, Bellevue, WA

This workshop exemplifies one approach to the theme of this conference, "Teachers and Science Educators: Partners in Restructuring Science Teacher Education." We are a group of collaborating educators who teach in elementary schools, a high school, and a research university. With the support of the National Science Foundation, we have been developing case studies of student and teacher questioning from data collected in our own classrooms. Our intent is to document and analyze examples of dialogues in which student are actively engaged in learning. We recommend directing explicit attention to such dialogues in science teacher education programs. Engaging teachers in dialogues about dialogue seems to us to be essential in efforts to implement educational reforms advocated in documents such as Benchmarks for Science Literacy (AAAS, 1993).

In this paper, we begin by briefly describing the collaborative relationship that has evolved during our project. Next we review some of the interpretations we developed in our case studies of student and teacher questioning in our own classrooms. Then we summarize ways in which these case studies may be used in courses for teachers and researchers. We also describe how this work has influenced the design of a science teaching methods course taught by the university researcher. We close with some recommendations for ways in which conferences such as this one can be made more accessible to teachers.

Collaborative Relationships among Teachers and University Researchers in Studies of Questioning

This project illustrates changes that have been occurring in ways in which researchers collaborate with teachers. Most studies of classroom discourse in general and questioning in particular have been conducted by university researchers (see Cazden, 1988; Carlsen, 1991;

Dillon, 1988; Gall, 1984; Lemke, 1990; Sinclair & Coulthard, 1975). For such studies, collaboration with teachers may have involved simply gaining access to classrooms to collect data or, in experimental studies, training teachers to execute particular questioning techniques designed by the researchers. Results typically were presented in tables that combined data from unnamed teachers' classrooms or in descriptive accounts that referred to teachers with pseudonyms. As the subjects of such studies, teachers rarely attended the conferences or read the journals where researchers reported these results. Teachers participating in interpretative studies sometimes attended research conferences but generally they sat in the audience while the researchers presented the analyses from the podium.

Recently some researchers have collaborated with teachers in ways that engaged the teachers as more active participants in the research. For the university researcher who designed this project, for example, collaboration initially involved many hours of videotaping in the teachers' classrooms, interviewing teachers and students, selecting and transcribing events of interest, discussing these video clips and transcripts with the teachers, and many cycles of writing analyses, discussing these with the teachers, and revising. Rather than using pseudonyms, the university researcher included the teachers as co-authors of papers reporting on the project. She also chose formats such as roundtables and data analysis sessions in which the teachers could join her as colleagues in discussing our findings at research conferences (e.g., van Zee & Iwasyk, February, 1994; van Zee & Kurose, April, 1993; van Zee, Wild, & Flanagan, 1993). In undertaking this interpretative approach, the university researcher was building upon research practices she had developed earlier when she had collaborated with a teacher who was also a prominent researcher (van Zee & Minstrell, in press).

Currently, the teachers participating in this project have assumed responsibility for conducting their own research. Last spring, participating teachers reported their findings as first authors or sole authors at a national meeting for educational researchers (Iwasyk & van Zee, April, 1995; Kurose & van Zee, April, 1995; Schnabel, April, 1995; Simpson, Minstrell & van Zee, April, 1995; Wild, April, 1995). They also are participating in joint presentations of their work at conferences for researchers, (Iwasyk, Kurose, Simpson, & van Zee, March, 1996b), teachers (Iwasyk, Kurose, Simpson & van Zee, March, 1996a), and science educators (this conference). For the university researcher who initiated the project, collaboration now involves facilitating the teachers' research by discussing progress with them individually and in meetings of the group. This shift in ownership of the collection and interpretation of data occurred fortuitously when the researcher moved to a new institution and the teachers were willing to continue our collaboration with only occasional face-to-face meetings. Although such long-distance collaboration has inherent difficulties, we believe that the outcome has been beneficial. These teachers are now reporting upon questioning phenomena that occur in their classrooms from their own perspectives, with emphasis and interpretations that are shaped by their perception of what will be useful to other teachers.

Summary of Interpretations from Our Case Studies of Student and Teacher Questioning

Appendix A summarizes the objectives, settings, participants, and data sources for our case studies. The settings include science activities conducted in elementary school classrooms, a high school physics course, and an undergraduate seminar in education for majors in mathematics, science, and engineering. Students range from kindergartners to college students. Data sources include videotapes made by the university researcher in the early years of the project, audio-tapes and video-tapes made by the teachers themselves more recently, copies of student written work, and the participants' observations and reflections. The interpretations reported below have been developed by the teachers, in consultation with the university researcher and other members of the group.

Study of Questions Primary Children Asked to Help Each Other

Marletta Iwasyk is a primary teacher who teaches her students how to ask questions so that they can help others think about a problem and how to solve it. She believes that children are capable of being teachers too and while engaged in the teaching process, they reinforce and solidify their own learning. In her study, she documented children modeling questioning skills that she had taught as a way for the children to help each other without giving answers. She audio taped conversations among children who were working on arithmetic problems at a computer station. She observed that early in the year it was very important for some of the children to get the answer first and make sure that the rest of the class knew they had. Later in the year, some of the children were making a great effort not to tell the answer but instead were asking questions to help another child figure out the problem. She also observed changes in ways that a special education student interacted when the student was working on her own at the computer during an unstructured activity time.

Study of Student and Teacher Questions during Conversations about the Moon on the Playground, in Class, and at Home

Akiko Kurose is a first grade teacher who uses science as a focus for learning reading, writing, mathematics, social studies, art, and music. She documented and analyzed questions that she asked her students, that they asked her, and that they asked of each other while engaging in "eyes on" science. She and the students frequently went out to observe the moon at different times of day so that the children could view the moon in a variety of phases. She found that first graders' questions about the moon indicated their interest and enthusiasm in the process of observing. They were able to share what they had learned with their families, as well as with the other students. Some of the children became interested in learning about the way the moon looks at different places on the earth, and also the way it appears away from the earth such as on the sun. Several children were also curious about how the earth appears from the moon. These experiences engendered thoughts about the moon from different places, granting the students the gift of a global perspective. Engagement in this type of abstract thinking and questioning became part of the class culture, in which virtually all of the children participated.

Study of Questions Asked to Elicit Fourth Grade Students' Reasoning about Electrical Circuits

Judy Wild is a fourth grade teacher who has assisted colleagues in undertaking inquiry approaches to teaching science. She also has taught science methods courses for future elementary school teachers at a local university. She documented ways of asking questions to elicit student reasoning during class discussions and conversations with individual students about electric circuits. She found that including a sequence of questions for discussions as part of the lesson plans was helpful during the lessons, especially when trying to help students develop a model for interpreting the brightness of bulbs in various circuits. Questioning the students about responses, especially asking why, helped her to determine how the students were reasoning and to evaluate their conceptual development. She also documented some of the difficulties students encountered in working with batteries, bulbs, and wires, in making predictions about whether various arrangements would light a bulb, and in drawing wires to connect components in a circuit diagram in ways that would light a bulb. Although lesson plans for the unit were developed prior to the first lesson, they needed to be reevaluated and modified each day based on the progress of the students.

Study of Student and Teacher Interactions which Encourage Student Questions and Logical Thinking

Dorothy Simpson is a high school physics teacher who believes that students who actively think and discuss ideas will be empowered to reach logical conclusions about the physical world and to change their original conceptions to fit their logical conclusions. She analyzed student and teacher interactions which encouraged student questions and logical thinking during a group discussion about the force(s) acting upon a tossed ball. She found that students were willing to risk putting forth tentative ideas which might not be physically accurate. Some of the students' confusions related to exactly what is shown in a force diagram, what might be considered a 'force', what 'momentum' is, and what Newton's laws really mean. As the students talked together about what they were thinking, they reached a better understanding of the concept of inertia. As more students became involved with the 'brainstorming,' they helped each other focus their ideas. In this kind of conversation with the teacher and with each other, they were able to reach some logical inferences about the situation which refuted their preconceptions.

Study of Student Questioning during Conversations about the Moon in an Undergraduate Seminar on Science Education

Emily van Zee is a university faculty member who believes that student-centered dialogues can help students to develop a deeper understanding of a topic than a teacher-led discussion, recitation, or lecture. She documented and analyzed a group discussion in which the students collaborated in developing their understanding of the phases of the moon during an undergraduate seminar on science education. She found that students asked conversational questions of each other as they tried to work out an understanding of what one of the students had said. During 26 turns of talk without interruption by the instructor, for example, they referred to each other's thinking, reflected upon the use of particular words, offered alternative descriptions, checked the details of their understanding of what each other said, made up examples to clarify their meanings, explicitly questioned each other's meanings, summarized their understanding of what had just been said, articulated their confusions, contributed to making sense of each other's ideas, conceived of unexpected possibilities, and offered observations as evidence in considering a classmate's question.

Anticipated Use of the Case Studies in Courses for Teachers and Researchers

In conducting a research project, we primarily are intending to contribute to knowledge about questioning processes rather than to develop materials for use in courses and workshops. However, we believe that it is important to provide examples of research studies conducted by teachers in courses and workshops for both teachers and researchers. For each case study, therefore, we have prepared a data handout, discussion handout, and paper that instructors can use as the focus for discussions in such settings.

The data handout includes a short summary of the context of the case study, presents some data (usually an excerpt from a transcript of a discussion), and poses several questions that an instructor can use as prompts for discussion of the data. The intent of this handout is to provide experience in reading transcripts of classroom discourse, formulating claims based upon these data, and backing these claims with evidence in the form of specific quotes drawn from the transcripts. The paper can be handed out after the session to provide a more detailed account of the context of the study and the teacher's interpretation of these data.

The discussion handout articulates an important issue relevant to the case study and several focal questions that an instructor can use as prompts for a general discussion of this issue. The paper can be handed out before the session to provide background reading for a discussion that draws primarily upon participants' beliefs and experiences rather than upon the data from the case study.

In addition, each case study includes figures from which instructors can make transparencies to introduce the study. These include a title page, summary of objective, perspective, setting, participants, and data sources; and summary of interpretations.

Influences on the Design of a Science Methods Course for Future Elementary School Teachers.

The university researcher has used some of these case studies in her science methods courses for future elementary school teachers. More importantly, her collaborative experiences through this project greatly influenced the way in which she designed these courses. She opens her science methods course with the metaphor of teacher as researcher and makes assignments in these terms. Her students conduct research in three contexts. They write weekly observations of science learning in progress and reflect upon factors that foster science learning in these instances. At the end of the course, the students analyze their written commentaries to identify common themes and develop three to five recommendations for science teachers based upon their analyses. Her students also document their own learning throughout the semester as they make observations, identify patterns, and develop an explanatory model for the changing phases of the moon. In addition, her students also do research projects in which they select topics that they can teach in their school placement settings, review ways that various science curricula have presented these topics, read literature on student understanding about the topics, interview adults and children to explore common knowledge about the topics, and design, conduct, and reflect upon lessons (which we call "conversations") about the topics.

As principal investigator for this project and as a university instructor, the university researcher retains responsibilities for providing leadership and resources. In both contexts, however, she views her role as an organizer of learning events and as a facilitator of research conducted by others rather than as the transmitter or sole producer of knowledge herself.

Recommendations

We recommend that individuals planning research conferences give explicit attention to ways that researchers and teachers can engage in more collaborative discourse. These might include physical changes, such as placing chairs in circles rather than rows, format changes, such as adding more informal data analysis sessions, and policy changes, such as developing explicit guidelines for presiders, presenters, and participants to foster more productive discussions. Increasing the number of teachers who participate in research conferences would help provide the perspective of teachers during small group conversations and large group question/answer periods. Perhaps information can be sent to local teacher organizations with coupons for free registration. One-day registration fees would make possible the exploration of a research conference by interested local teachers. A reduced registration rate for precollege teachers may make full participation in the conference more feasible. We also recommend that funding agencies encourage university researchers to include funding in their budgets to enable teachers participating in their projects to make presentations at national conferences.

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Appendix A

Case Studies by a Group of Collaborating Educators

Author	Title	Objective	Setting	Participanats	Data Sources
Marletta Iwasyk	Kids questioning kids: "How can you find out" vs "The answer is..."	To document children modeling questioning skills taught by the teacher as a way to help each other without giving answers	computer station where children can choose math disks from many different levels	two 1st graders in urban school	audio-t
Akiko Kurose	"Eyes on Science": Asking Questions about the Moon on the Playground, in Class, and at Home	To document and analyze questions that a teacher asks her students, that they ask her, and that they ask of each other while engaging in "eyes on" science	conversations about the moon on playground in class and at home	21 1st graders in urban school	
Judy Wild	Attempting to Understand 4th Grade Students Conceptual Development of Electrical Circuits: Asking Students Why	To document and analyze ways of eliciting student reasoning during class discussions and during conversation with individual students	small group science activities and group discussions	27 4th graders in a suburban parochial school	videot
Dorothy Simpson	Student and Teaacher Interactions which Encourage Student Questions and Logical Thinking	To document and analyze student and teacher interactions which encourage student questions and logical thinking	class discussion about forces on a thrown ball	physics students in a suburban high school	

Appendix A (continued)

Author	Title	Objective	Setting	Participanats	Data Sources
Emily van Zee	Student Questioning during Conversations about the Moon in a Seminar in Science Education	To document and analyze a group discussion in which students collaborate in developing their understanding of a topic		undergraduate seminar in science education	math, science and engineering majors

COMBINING DEMONSTRATION CLASSROOMS AND INSERVICE FOR SCIENCE TEACHERS

Julie L. Wilson, University of Arizona

Introduction

Inservice that promotes change is especially critical for elementary teachers of science. The quality of elementary science instruction have been discussed in several national surveys. For example, Weiss's (1987) National Survey of Science and Mathematics found that only 27% of the elementary teachers felt well qualified to teach life sciences, 15% felt well qualified to teacher physical sciences, and 15% felt well qualified to teach earth/space sciences. National Assessment of Educational Progress (NAEP) researchers found that only 15% of fourth graders had done experiments with five/six types of common scientific materials and equipment (Jones, Mullis, Raizen, Weiss, & Weston, 1992). In addition, most teachers teach facts and definitions from the science textbooks, with little emphasis on application of knowledge or development of higher-order thinking skills (Gallagher, 1987; Stake & Easley, 1978; Yager & Penick, 1983). Finally, 80% of elementary teachers are less than 50 years old; thus they have many years of potential service remaining (Weiss, 1987).

As educators look for ways to improve their instruction they will seek out a variety of professional development strategies; such as, conventions, workshops, institutes, inservice programs, and academic coursework. Each year a substantial amount of funding will be allocated to support such programs, and each year science teachers will enthusiastically participate in these programs. Yet current inservice practices are minimal at best. Math and Science Eisenhower funds, for example, are spread thinly and provide only short term inservice training experiences, with the average inservice being about six hours per year per teacher (U.S. Senate Committee on

Appropriations, 1992). School-district led inservice predominates the inservice community, even though the results following teacher participation is often dismal (Fullan, 1991). Fullan (1991) concludes that the failure of inservice programs stems from a less than adequate experience for teachers, the inservice being created and supported by personnel other than teachers, the lack of development within individual schools, the failure of inservices to meet long-term instructional needs (often offering quick fixes instead), and the lack of funding and commitment (time, administrative support, and support personnel) provided.

In recognition of elementary teacher needs, and in recognition of the current status of inservice programs an alternative model of inservice was developed. This article briefly outlines an inservice practice that was developed from teachers' requests; specifically, the Problem Solving Demonstration Classroom inservice program. This article provides a brief overview of the Problem Solving Demonstration Classroom inservice format, the participants who were involved, the methods used to assess the program, and a brief discussion about the results from the evaluation. The primarily goal of this paper is to share findings about a possible alternative form of inservice for the professional development of teachers.

The Problem Solving Demonstration Classroom Program

Demonstration Classroom Program

The Problem Solving Demonstration Classroom (PSDC) inservice program was designed in response to teacher requests to learn about Search, Solve, Create, and Share (SSCS) problem solving (see Pizzini, Huber, & Shymansky, 1988). It was structured according to effective inservice practice (Joyce & Showers, 1995; Olrich, 1989; Sparks, 1983; Wade, 1984; Yeany & Padilla, 1986), peer-centered practices (Bey & Holmes, 19o2; Garmston, Linder, Whitaker, 1993; Glatthorn, 1987; Joyce & Showers, 1995; Little, 1982), and the practice of clinical supervision

(Acheson & Gall, 1992; Glatthorn, 1984; Glickman, 1985; Sergiovanni & Starratt, 1993). It is acknowledged that several other areas could have been emphasized, but this program relied heavily on peer-centered practices as a mechanism to enact long term change.

The PSDC inservice program consisted of the following:

1. Preprogram--Prior to the first week of school, teachers participated in a week-long inservice that provided practical experiences with problem solving, while providing information related to the important aspects of successful implementation (e.g. cooperative learning, questioning, and classroom management). The sessions were held for four hours in the morning at the school-district office.
2. Classroom implementation--Teachers were encouraged to implement some aspect of the problem solving model in their classroom. The district staff developer was available to assist teachers in planning for their use of the SSCS model in their class.
3. PSDC visitations-- During the fall and the spring a two week demonstration classroom was available for teachers to visit. The two-week schedule of classroom events was distributed prior to the demonstration classroom so that teachers could schedule days that they were most interested in experiencing. Teachers were encouraged to visit two days within each two week-period.
4. Follow-up--A follow-up session was held in the fall and the spring at the District Office after the conclusion of the demonstration classroom. The topic of the session was selected in response to the questions that teachers asked during the post-conference and following their demonstration classroom visit.

A preprogram, implementation, and follow-up are elements of a typical inservice program, while visitations to observe the inservice methodology is unique.

As unique as the demonstration classroom, was the structure of a demonstration classroom visit. A typical visit was composed of consisted of three components:

1. Previsitation conference--The preconference provided an opportunity for teachers to hear about lesson they would experience, the decisions the demonstration teacher made prior to enacting the lesson, and the demonstration teacher's personal concerns about enacting the lesson. Visiting teachers were encouraged to ask questions of the demonstration teacher, and they were provided a simple form to keep notes on as they experienced the demonstration classroom.
2. Visitation--Teachers made notes about student actions (in response to teacher actions), observed student groups, and discussed observations with fellow teachers in the demonstration classroom.
3. Postvisitation conference--Processing, explaining, and discussing were the focus of the post-visitation conference. Visiting teachers were provided opportunities to explore their observations and what they meant to problem solving instruction in their classroom. These sessions were highly interactive and provided multiple opportunities for teachers to have professional discourse, while understanding the nature of their own practice.

Participants

Thirteen teachers participated in this study, and a majority of the teachers worked in a self contained setting. Two of the teachers held specialized assignments; one in math, the other in science. More than half of the teachers in the group actively taught in the 5th and 6th grade. All of the teachers in this study held a K-8 teaching certificate in an area other than science or math. Any teacher, regardless of years of experience in the district, could participate in this inservice. As a result the years of teaching experience fell into two groups 0-9 years and 15 + years. Most of the teachers who did attend were active professionally, and all attended two or more workshops, conferences, or inservices during a year.

Assessment

There is limited information available about demonstration classrooms held in conjunction with inservice programs. To determine the effects of a PSDC held in conjunction with an inservice program three areas were explored: changes in attitudes and beliefs of the participants during the inservice, actual implementation of the problem solving process in participant's classrooms, and teacher's salient perceptions about a PSDC inservice. These areas were picked because of the holistic and focused view they provide about this alternative inservice structure. The emphasis of this study is to examine the attitudes and beliefs, the actions, and the perceptions of participants involved in a PSDC inservice

To better understand the change in attitudes and beliefs and the degree of SSCS implementation among participants, quantitative methods were used. Attitudes and beliefs were assessed through a one-group time series design (Isaac & Micheal, 1981) using the Laboratory Approach to Teaching Elementary Science (Good, 1971) and the Attitudes Towards Teaching Science (Hall, 1992) instruments. Measures were taken at the beginning of the inservice program, prior to the first demonstration classroom visit, following the first demonstration classroom visit, prior to the second demonstration classroom visit, and at the conclusion of the inservice program. An analysis of variance (ANOVA) was used to reveal the significant changes in either participants' attitudes or beliefs. The implementation of problem solving in the classroom was assessed through a one-group pretest-posttest design (Isaac & Micheal, 1981) that used the SSCS Implementation Assessment (see Wilson, 1994). The one-group series design specifically allows for multiple pretesting and posttesting. Measures were taken prior to attending the first demonstration classroom in the fall, and following the last demonstration classroom in the spring. Dependent t-tests were used to assess the difference in instruction among participants.

Wilson (1977) states that qualitative research is beneficial when there have been no previous studies, previous studies have lacked significant findings, or there is the need to provide a framework for understanding. Furthermore, qualitative methodologies are used because of the limitations of experimental settings (Cronbach, Glesser, Nanda, & Rajaratnam, 1972). This study used a qualitative approach in designing an implementation instrument, and obtaining salient perceptions about the PSDC inservice. Specifically, the qualitative portion of this study was composed of in-depth interviews, participant observations, and document analyses (Marshall & Rossman, 1989; Bogdan & Biklen, 1992).

Results

Quantitative Results

The results of the attitudes ANOVA are in Table 1.

Table 1
F-ratios, Probabilities, and Significant Pairs for Components in Attitudes Towards Teaching Science

Component	F-ratio	Probability	Significant Pairs
Science Equipment	1.19	0.32	
Need for Science	1.90	0.14	
Time to Teach	1.60	0.20	
Ease and Comfort	2.31	0.09	T2 vs. T4

The results of the beliefs ANOVA are located in Table 2.

Table 2
F-ratios and Probabilities for Components in Laboratory Approach to Teaching Science

Component	F-ratio	Probability
Laboratory Oriented Science	0.40	0.75
Specific Science Components	0.24	0.87
Structured Science Teaching	0.19	0.90

The results for the SSCS Implementation Assessment dependent t-test are in Table 3.

Table 3
Results of Dependent t test for SSCS Implementation Assessment Groups (2 tailed, 0.10)

Pairwise Comparison	t-value (df=6)
All Components	6.09***
AI - Time in Groups	1.92
AII - Teacher Approach	-0.82
AIII - Group Cohesiveness	2.52**
AI, AII, AIII Learning Groups Work Cooperatively	1.40
B - Students Actively Participate	3.35**
C - Unique Role of the Teacher	2.00*
D - Students Communicate	1.71
E - Students Generate Their Problem and Action Plan	2.24*
F - Students Manage Materials	0.93

*$p < .10$ **$p < .05$ ***$p < .01$

Qualitative Results

The constant comparative method revealed salient propositions from the teachers who participated in the PSDC inservice program. These propositions are located in Table 4.

Table 4
Qualitative Propositions

1. By attending the PSDC teachers addressed their personal instructional needs pertaining to problem solving.
2. During the PSDC teachers focused on specific teaching strategies inherent in the problem solving process.
3. Teachers identified constraints to implementing problem solving and integrated math/science curricula in their classroom.
4. The PSDC catalyzed participant reflection.
5. The PSDC provided opportunities for professional dialogue.
6. The PSDC and classroom implementation allowed teachers to redefine their understanding of the SSCS model.
7. Teachers developed a contextual view of students during SSCS cycles.
8. The level of math/science integration through problem solving differed among teachers.

Discussion

Completing both qualitative and quantitative assessment techniques allowed for a more comprehensive view of the program, as other authors have noted (Lawrenz & McCreath, 1988; Swift, Weber, Beyerbach, Gooding, & Swift, 1994). In instances where certain results had no effect, other results presented findings of interest. For example, the lack of significance in certain quantitative measures could have been explained from the results of the qualitative findings. In either case, both types of assessment provided a more comprehensive view of the inservice program.

Attitudes and Beliefs

Given the previous body of literature on change, attitudes, and beliefs (Bruce, 1971; Halverson, 1979; Guskey, 1985; Abell, 1988; Fullan, 1991) it is interesting there were limited significant findings in the attitude measures and no significant findings in the belief measures.

Of the four components that were examined in the attitudes analysis, only one had a significant effect. Ease and Comfort with Teaching Science was significantly different at the 0.10 level. Need for Science in the Elementary Classroom was the only other measure that was close to significance ($p < 0.14$). A closer look at this component reveals an increase, then a decrease in attitudinal change. Teachers reported greater Need For Science following the demonstration classroom, but by the end of the year the Need For Science decreased. It appeared that teachers felt some Need for Science, but the effect was short lived.

The significant effect found in Ease and Comfort in Teaching Science appears to have been more long lasting. Over the course of the inservice, teachers continually reported more ease and comfort with the teaching of science. Scheffé follow-up tests revealed significance between predemonstration classroom and the end of the year scores ($p < 0.05$). The beginning of the year and the end of the year comparison suggested that some effect might have been present, although not significant ($p < 0.10$). The change in Ease and Comfort in Teaching Science score could be attributed to several factors: teacher experience in the classroom with the model, seeing the effectiveness of the model, and talking about the model with other teachers.

The lack of findings pertaining to the beliefs of teachers is interesting. Beliefs should change, but they did not. The lack of significant findings in specific areas may be due to a mismatch between the instrument and what is being measured (Munby, 1983), or a small of amount of change may not be measured as significant, but it actually might be significant to the teacher (Good, 1983). In either case, it is surprising that beliefs did not change.

As teachers tried the model, and tried it repeatedly, they began to feel more comfortable and at ease with the teaching of process based science. They saw the instructional impact it had on students, and they also began to understand their role in problem solving instruction. This provided clarity into an instruction practice, which enhanced their Ease and Comfort with Teaching Science. Guskey (1985) would say that as participants saw the effects of their teaching their attitudes began to change.

Teacher Behaviors

Eleven of the thirteen teachers implemented SSCS problem solving in their classrooms, with seven teachers implementing SSCS problem solving before the first PSDC and after the last PSDC. For these seven teachers attending the PSDC resulted in significant changes in how they used SSCS problem solving in their classroom. The significant difference between the overall pre and post cycle was measured at the 0.01 level; this exceeded the original proposed significance level of 0.10. Dependent pair-wise comparisons in categories revealed that four out of eight categories were significantly different: Learning Groups Working Cooperatively-Group Cohesiveness, Students Actively Participating, Unique Role of the Teacher, and Students Generating Their Problem and Their Own Action Plan.

Given that the goal of inservice is to change classroom practice, these findings from the PSDC inservice suggest three main points; a) teachers did change in their implementation of SSCS from pre to post demonstration classroom visits, b) most teachers experienced first order or changes (Cuban, 1988), and c) certain categories may be dependent upon instructional style or dynamics of the classroom verses the implementation of SSCS.

Interviews

The in-depth interviews that were conducted during the school year provided insightful findings. Responses given by the participants during these interviews led to the formation of eight salient beliefs about the PSDC inservice. These beliefs provide insight into the importance of the PSDC classroom that were not detected by the quantitative data. These eight beliefs are embodied in three broad summary areas that have implications for PSDC inservices. These areas are: personal need, peer-centered professional development, and instructional practices.

In terms of personal need, teachers came to the PSDC inservice with their own levels of personal and instructional need. During the inservice and the demonstration classroom, teachers were able to address their most relevant and personal needs. For some teachers this meant seeing the use of cooperative learning in the science classroom, while for others this meant seeing the effect of problem solving on students.

In terms of peer-centered professional development, the PSDC classroom clearly provided the opportunities that teachers needed to support their own success. Teachers spoke to one another about classroom practices, the failure of the SSCS cycle in their classroom, how the demonstration teacher was doing in the class at that time, and what SSCS instructional practice meant to them. In addition to the collegial discussions, teachers were also able to have conversations that were mentoring in nature. Several teachers asked questions and asked for help from fellow teachers who are regarded as experts in SSCS problem solving.

In terms of instructional practices, teachers saw two types of instructional practices. They saw practices that were curriculum-centered and they saw instructional practices that were teacher-centered. Curricula-centered instructional practices included math mini lessons, science instruction, math/science integration, and the use of the SSCS problem solving model. Teacher-centered instructional practices included questioning strategies, cooperative learning, and management techniques.

Teachers experienced both instructional practices through the inservice and the demonstration classroom. They felt that one complemented the other, often presenting a holistic picture of the SSCS problem solving model. The inservice provided the mechanics for SSCS problem solving, while the demonstration classroom showed the effects.

Conclusions

Several positive effects were noticed as teachers participated in an inservice that contained a PSDC. The attitude measure indicated that teachers Ease and Comfort with Science Teaching increased over the course of the inservice. Teachers felt significantly more comfortable and at ease teaching science between the first demonstration classroom to the end of the inservice. As teachers participated in the PSDC inservice, their classroom instruction of SSCS problem solving also changed. Teachers demonstrated an overall improvement of their SSCS problem solving instruction; specifically learning groups demonstrated more cohesiveness, and students actively participated in their learning. Finally, teachers felt that the PSDC allowed the teachers to meet their personal needs for SSCS instruction, participate in an environment that professional dialogue was fostered, and receive clarification of the instructional practices that were used with SSCS problem solving. These results indicate that the demonstration classroom could be a viable supplement to inservice and is worth further exploration.

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Acknowledgments

This study was in part a result of a grant funded by the Iowa Board of Regents, with Eisenhower funds. The research described herein, including the interpretations, does not necessarily represent the view of the Iowa State Board of Regents.

PREPARATION AND EVALUATION OF THREE VIDEOCASES IN SCIENCE TEACHER EDUCATION

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Many science educators are familiar with the use of case method in science teacher education. Some case material specific to issues in science teacher education is available, however the majority of case material focuses on general issues of teaching and learning. Most case materials have been prepared in a written format. This project was funded by the National Science Foundation (NSF grant DUE 9254635) to evaluate one central question: Can science educators with no video experience and a very limited budget produce video case material which other science educators regard as useful? If so, then perhaps it is possible to work towards production and dissemination of a relatively large set of useful videocase materials without relying on heavily-funded and centralized science videocase production projects.

This paper reports on the production and evaluation of three videocases in secondary science. This paper has been written to summarize a session at the January, 1995, AETS meeting in Seattle. The presentation itself involved viewing and discussing one of the actual videocases. Therefore this paper is not a representation of the actual presentation, but a summary of some of the points made in the session.

The three videocases were produced during the 1994-95 academic year. The cases were constructed from unrehearsed events which were filmed in typical public schools over three class periods for one of the cases and during one class period for the other two cases.

During summer, 1995, volunteer reviewers were solicited via the AETS listserve. Ten reviewers were selected from among the eighty university faculty members who responded to an invitation to review posted on the listserve. The reviewers were selected on the basis of their ability to review the cases by October, 1995, and because they represented diverse situations in teacher education. Each reviewer received a cassette containing the videocases and a ten-page instructors guide to the structure and use of the cases. By the end of October, 1995, all ten reviewers had used the cases in at least one setting involving science teacher education. All the reviewers provided a written analysis which responded to a number of evaluation questions which I supplied along with the videocases and instructors guide.

The rest of this paper provides a brief background on case material, including background on the three cases developed in this project; a summary of reviewer reactions; my own analysis of the cases and of the reviewer reactions; and a brief summary of some technical details involved in videocase production.

Review of Case Methods in Teacher Education

For years professional education in law, medicine and business has used cases successfully as a fundamental core of the curriculum. Although cases are used somewhat differently in each of these fields, they all share some common characteristics. A case is a fairly detailed description of an event or situation, usually written in narrative form. The event or situation is complex and context-dependent and highlights important principles or issues. The case may or may not present an explicit problem to solve, but it does include aspects which are open to various interpretations or responses. The pedagogy may also vary, but teaching with cases generally means that students read the case (and perhaps an accompanying commentary), discuss it in small or large groups under an instructor's guidance, and often write about it.

The main rationale for teaching with cases is that it helps prospective practitioners understand and respond to the complexity and subtlety of their discipline in its real-life context. Case methods are typically used in the professions, where complex interactions in particular circumstances call on the lawyer, doctor, or businessperson to make reasoned judgments and decisions rather than to apply rules and principles in fixed ways. In 1986 Lee Shulman pointed out the obvious applicability of case methods for teacher education, as a natural consequence of the movement toward viewing teaching as situated cognition, decision-making, reflection, and related aspects of teacher knowledge. Since then a number of authors (e.g., Merseth, 1991; L. Shulman, 1992; Sykes & Bird, in press) have firmly grounded and amply justified this new direction in teacher education.

The actual work of implementing, analyzing, and assessing case methods in teacher education has just begun. Several researchers have developed collections of cases, used them in practice, and studied the process. Rita Silverman, William Welty, Sally Lyon, and colleagues have established the Center for Case Studies in Teacher Education at Pace University in New York. They have produced a casebook for teacher problem solving (Silverman, Welty & Lyon, 1992) and have also designed and taught entire courses such as "Effective Teaching Methods" and "Learning and Development," using case-based instruction. Their research shows that about 1/4 of students take to the case method naturally and thrive in it, 1/3 to 1/2 gradually grow into it, and 1/4 remain uncomfortable with it but come away with a greater awareness of their own weakness in analysis and problem solving (Welty, Silverman & Lyon, 1991). Judith Kleinfeld at the University of Alaska Fairbanks, working in conjunction with the Center for Cross-Cultural Studies, has helped her students write and publish several long cases dealing with some of the problems peculiar to teaching in rural Alaska, and she has used these in her teacher education classes. Her research indicates that students enjoy the case method (though not more than they do a well-taught lecture course) and that this method produces an advantage over traditional instruction in developing analytic and problem-solving skills (Kleinfeld, 1991).

At Mills College in California, Vicki LaBoskey and Anna Richert have been asking both their credential-level and masters-level students to write cases as a means to develop the ability to reflect about themselves as teachers. Examples of these cases (LaBoskey, 1992; Richert, 1992) illustrate clearly how successful this enterprise is. Carne Barnett, working first at the University of California, Berkeley and later at the Far West Laboratory, has also asked students to write cases—but unlike the cases mentioned previously, these focus on the teaching of mathematics. She has used the cases (Barnett, 1992) to explore her students' stages of development as mathematics teachers in light of the new NCTM Standards (1991), and she is working to compile an integrated case-based curriculum specifically for mathematics teacher education (Barnett, 1991). Several other authors have recently published casebooks for use in general teacher education (Greenwood & Parkay, 1989; Kowalski, Weaver & Henson, 1990; Schön, 1991).

Much of the existing work on case methods in teacher education has been both stimulated and tied together by Judith Shulman and her colleagues at Far West Laboratory. They published two of the first casebooks in widespread use (J. Shulman & Colbert, 1987; J. Shulman & Colbert, 1988) and have continued to develop and field-test more cases. Far West Laboratory has also hosted a series of conferences over several years to bring together researchers in case methodology. A new book (J. Shulman, 1992) sums up the current status and direction of the movement toward case methods in teacher education.

Rationale for this Project

Except for Barnett's work in mathematics (cited above) and isolated examples in other subject areas (e.g., Wilson, 1992, in history, and Small & Strzepek, 1988, in English), the cases developed for use in teacher education have focused on such generic aspects of teaching as classroom management, teacher decision-making, and teacher reflection. This is especially ironic given L. Shulman's special concern, and the interest that he has evoked throughout the teacher education community, regarding the importance of subject matter in instruction (see, e.g., L. Shulman, 1987). Indeed, the recent emphasis on pedagogical content knowledge has made it clear that what a teacher must understand in order to teach content -- the subject matter itself, the students' own understanding, instructional strategies and materials, instructional contexts, and how all of these interact to form new knowledge -- is at least as complex, particularized, and important as the knowledge of how to manage a classroom. As we in the research community experiment with case methods, we must also explore how these can be used to develop teachers' ability to teach subject matter (Barnett, 1991; P. Hutchings, commentary in AERA session, April 22, 1992). The need for subject-specific case material is the first need that this project is designed to meet.

The second need addressed by this project is to explore further the use of videotape as a vehicle for introducing cases for discussion. Much of the value of cases lies in their ability to contextualize discussions of teaching and learning, and video is a natural medium for enhancing the sense of context and realism. A few researchers have already begun to explore the video/case connection. Harry Broudy at the University of Illinois has developed 15 videocases in generic problem areas for teaching, such as motivation, tracking, and parent-school relationships (Broudy, 1985). Shari Saunders studied the process of students discussing videocases at the University of Michigan. One interesting result was that the cases engaged students and stimulated discussion effectively, but that what the students actually derived from the cases depended strongly on the course instructor's goals in using them (Saunders, 1992). At the University of Arizona Virginia Richardson developed a set of videocases of classroom instruction in reading, then examined several aspects of teacher education students' responses to the cases. She found that for the most part students moved from a critical, "teacher deficit" appraisal toward a greater appreciation of what the teacher on the videotape was trying to do, and from simple behavioral descriptions toward more functional and analytical descriptions of teaching (Richardson, 1992). Researchers at the University of Virginia are creating and using a set of videocases for multicultural education and are doing a nice job of documenting the development process and attendant issues as they proceed (Herbert, White & McNergney, 1992). Finally, the work that Deborah Ball and Magdalene Lampert are doing at Michigan State University—videotaping their own teaching of mathematics and math education and using the tapes as a stimulus for discussion—is clearly relevant to this line of inquiry, even though they are not representing the tapes as "cases." The potential of videocases is evident in general, but we need more examples of them to appreciate their specific strengths and uses.

Background on the science videocases developed in this project

Refraction is a five-minute case which shows a middle school teacher explaining a simple observation concerning refraction to her seventh grade class. While referring to a diagram, the teacher states, incorrectly, that light goes from the eye to an object. She then realizes her error and corrects herself. She makes a brief effort to check whether her students have been confused by her correction then goes on with the lesson. The case concludes with an interview with the teacher in which she reflects on this episode. This case, which is strongly connected with the case *Penny in* *a cup*, raises issues of (1) teachers' understanding of subject matter, (2) the efficacy of explanatory teaching, and (3) teacher decision making.

Penny in a cup involves the same lesson on refraction. Here, the teacher challenges her students to explain the Penny in a cup trick in which a penny in a cup becomes visible only after water is added to the cup. The students try the Penny in a cup trick and then make a drawing illustrating their understanding of the phenomenon. They are asked to use concepts of refraction which they have discussed and experienced in hands-on activities for the three previous days. Most of the case involves interviews with students as they explain their interpretive drawings. Almost all students give evidence of the misconception that light goes from the eye to the object seen. This case raises issues of (1) student misconceptions about light and seeing and (2) the goals and method of inquiry, or constructivist, teaching.

Peanuts is a longer case which was recorded over a three day period in a ninth grade physical science class. The teacher explains to the class how to burn a peanut under a can of water in order to measure the calories given off per gram of peanut oil burned. The teacher explains the ideas, holds class discussions, models the calculations and provides an opportunity for the class to practice the calculations. The students also work in the laboratory to burn several peanuts and record the data necessary to make the calculations. Subsequently several students are interviewed concerning the concepts implicit in the activity and the calculations. Students give evidence of widespread misconceptions about heat, energy, and the nature of this experiment. This case raises issues of (1) the goals and methods of science teaching, (2) student understanding of particular key science concepts, and (3) the relationship of student thought to students' intellectual development.

Reviewer reactions

Where and when were the cases used?

The cases were used with students in middle school and secondary teacher preparation programs and with experienced 5th-8th grade teachers in a biotech summer institute. Two reviewers used the cases on the first meeting of a methods class. These reviewers commented that they were interested in beginning their courses with an activity which raised real issues in a realistic context. The other reviewers used the cases during the semester, with one reviewer using the same case twice at different times in a methods course to make two sets of points.

Pedagogy of case use

The reviewers used the cases in a variety of ways. Some used one or more of the cases on the first day of a methods class. Students in these classes viewed a case together and then responded to questions raised by the methods class teacher. These responses were sometimes written and sometimes in group discussion. The questions were sometimes from the videocase instructors guide or were designed by the methods class instructor in order to bring out issues he or she felt were important. Other reviewers used the cases during the methods class. One reviewer prefaced the use of the actual cases by having students perform the experiment recorded in the case before viewing the case. Another reviewer asked her students to consider how they would teach the specific subject, for instance teaching about the idea of energy in a peanut, before viewing the case, *Peanuts*. One reviewer used the cases as part of a summer workshop for experienced teachers. After the entire group of teachers viewed the videocase, he asked for volunteers who were interested in considering the case more deeply.

Regardless of the specific pedagogical approach to the cases, every reviewer noted that he or she used the cases to raise issues around the goals and methods of science teaching. Some reviewers used the questions provided in the teachers guide, while others developed original questions. In addition, however three reviewers used the cases to focus discussion of issues for which the cases had not been expli. itly designed. These reviewers used the cases as examples of questioning strategies, as examples of gender-equity/verbal-nonverbal interactions, and to provide a context for students to practice a verbal interaction coding scheme which they had been taught previously.

How did reviewers react to the videocases?

The reviewers responded, without exception, that the videocases were successful in providing a realistic, shared classroom experience for teachers. The reviewers also noted that the cases often provoked a lively interchange as students debated the goals and methods of the teachers and classrooms depicted in the videocases. A few quotes give the flavor of this reaction: "The cases provide access to a variety of settings and experiences. This kind of shared experience is hard to get through direct classroom observation." The cases "provoked heated discussion on which no consensus was reached." The cases provided "realistic classroom scenarios which provide accurate depictions of what life is like in classrooms."

The reviewers, with one exception, stated that the authenticity of the videocases was enhanced considerably by videotaping unrehearsed events in actual classrooms. Both future teachers and experienced teachers viewed the videocases as authentic representations of real classrooms and events. The reviewers felt that this sense of reality added considerably to the ability of the videocases to provoke genuine discussion and debate among the viewers.

Several reviewers stated that their students were shocked by the lack of understanding of students interviewed in the videocases. Evidently, beginning teachers had not previously confronted the quality of student learning resulting from any particular lesson. Also, several reviewers said that the student teachers were somewhat critical of the two experienced teachers appearing in the videocases. Students expressed that they would like to see exemplary teachers in other videocases. Thus, many student teachers appear to have focused on what they perceived as shortcomings in both teaching and learning. This deficit focus has also been reported by other researchers (Richardson, 1992). It is interesting to note that the two experienced teachers appearing in the videocases have both won awards for their teaching and are regarded as superior science teachers. Perhaps teaching is harder than it appears to be?

The reviewer who worked with experienced teachers noted that these teachers reacted very strongly to the teachers appearing in the cases. Some teachers were very supportive of the videocase teachers while others were somewhat critical of the practice they observed. One teacher said that the videocase teachers must have been very brave to let the world see their classrooms.

How did reviewers react to the introductory written materials?

Reviewers reactions to the written materials varied considerably. One reviewer felt that he did not need to consult the written materials because he interpreted the videocases for himself. Others used the written material as background to help understand the cases. Reviewers used the questions provided in the instructors guide as prompts for writing and discussion assignments. Some reviewers added their own questions to the set of questions supplied in the instructors guide materials.

Reviewers' suggestions for improvement/future work

As I have stated previously, the audio and visual quality of the videocases was found to be acceptable. Indeed, some reviewers implied that this less-than-broadcast quality may have added to the authenticity of the videocases. One reviewer did note that the sound quality was sometimes not sufficient to pick out comments from students working in groups. Some reviewers also stated that the videocases could profit from less camera time spent on the teacher (in *Peanuts* especially) and more camera time on students' reactions to the teacher's comments.

Several reviewers commented that the videocases should contain a time clock or some other marker visible on the screen so that viewers could quickly refer to particular instances. For similar reasons, two reviewers suggested that written transcripts of the cases would facilitate close analysis of verbal interactions.

One reviewer suggested that the questions presented in the instructors guide was predominantly theoretical in nature and that questions of a more practical nature would be helpful in discussions involving preservice teachers. An example might be If you were to re-teach this lesson tomorrow, what changes would you try to make?

Analysis of reviewer feedback

The three videocases produced appear to have been used to good benefit by the reviewers. It seems clear that the answer to the basic question addressed by this project -- Can science educators with no video experience and a very limited budget produce video case material which is regarded as useful by other science educators? -- is "yes." The balance of this analysis considers two questions: First, what makes these videocases successful?; and, second, did the reviewers actually use the videotapes as *cases of something*?

My impression from the reviewers' comments is that the videocases were used largely as realistic "slices of life" from classrooms. These videos allowed groups to share a common experience as they view events in a real classroom. In addition, the viewing can be repeated or specific events can be reviewed to make specific points in discussion. In addition, time is compressed by the editing out of many repetitive or uninteresting classroom events. As noted previously, some of the reviewers used the videos for diverse purposes: as material on which students could practice an interaction coding scheme; as examples of questioning strategies; and as examples of gender equity in the classroom. None of these uses had been considered in the development of the videocases. Other researches have also found that instructors will use the same videocase to make largely different points (Saunders, 1992).

Apparently, one of the characteristics of videocases, at least the cases produced in this project, is that the video medium is so rich that it is possible to use a particular videocase in a wide variety of ways. This richness of evidence allows videocases to be used to meet a variety of goals in teacher education.

The second question revolves around the issue of these videocases as *cases of something*. My tentative impression is that most of the reviewers did not use the videos as sharply defined cases raising specific issues of practical or theoretical importance. That is, I am not sure that the videocases were used in a manner consistent with the notion of cases as defined in the literature reviewed in the background section of this paper.

There are several possible interpretations of my impressions concerning whether the videocases were used as sharply focused *cases of something* or as more general *slices of life* in a classroom. First, the data collected from the reviewers was rather informal and it is possible that my impression is not correct. However, it may be informative to speculate further about my tentative conclusion as it may shed some light on case method in teacher education.

(1) *Perhaps the videocases produced in this project were not very good examples of case material.* Readers of this paper would need to work with the videocases themselves in order to evaluate this possibility. I think, however, that there are several interesting possibilities which remain to be discussed. These have to do with the nature of the video medium and the nature of science teacher education.

(2) *It may be true that videocases are more difficult to restrict to a small set of theoretical or practical issues than are written cases.* The video medium is very dense with information and this allows videocases to be used in a variety of ways. For instance, reviewers used the videocases to raise issues of questioning strategies, gender interactions, and nonverbal interactions. These may all be important issues, but it is interesting to note that they are not the issues intended to be addressed by these videocases. It may be that written case materials are easier to focus onto a particular limited set of issues than are video case materials since writers can create and edit written material more easily than can video producers.

(3) These particular videocases were designed to (a) raise issues of student, and teacher, thinking with regard to learning very specific scientific concepts; and (b) probe issues of learning which may be important, or even challenging, to those interested in a constructivist interpretation of learning. Reviewers seemed to use the videocases to focus more generally on the goals and methods of science teaching and to focus on issues of classroom interaction. *It may be that science educators working with preservice teachers or inservice teachers in summer workshops do not want to, or are not able to, raise issues which are focused very sharply on specific instances of student thinking.*

Technical details of production

The production of these videocases involved rather simple videotape techniques. These notes are provided to help other video novices who might be interested in producing their own video case material.

A standard consumer quality VHS camera was used to record all the videotape. Image quality is adequate, but it should be kept in mind that every copy degrades image quality and thus it is important to begin with fairly high-quality images. For this reason, formats with high initial image quality are desirable. Audio recording, which is a technically difficult task, was accomplished with a remote mike on the teacher and a pressure-zone microphone (PZM) or on-camera mike used to record sound with groups of students. Other more elaborate systems involving microphones on booms or mixing imputes from a variety of mikes was avoided in order to keep the system simple.

A university student camera operator did the taping. While this arrangement worked out well enough, it seems that it would be better if the camera operator had some sense of the nature of the material being filmed. The camera operator often needs to make decisions on the spot and it is desirable if he or she understands something about classroom events and how they might be developed into a case.

For two of the videocases (*Refraction* and *Penny in a Cup*) only one camera was used, while in *Peanuts* two cameras were used with one following the teacher and the other recording students' reactions. As a novice video producer I preferred the use of one camera only, since editing and the logistics of cameras in the classroom are both simplified.

Two to three hours of raw videotape was recorded to produce each of the cases. This raw videotape was edited into final form using conventional reel-to-reel techniques. This technique, long standard in videotape production, is rapidly being replaced by computer aided editing. These new, more flexible, techniques will allow case developers to experiment much more quickly with variations on particular cases.

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SCIENCE EDUCATOR PERCEPTIONS: INCLUSION IN SCIENCE CLASSROOMS

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Inclusion is integrating diverse student populations into general education classrooms at every grade level across the country. Students with disabilities are being placed in science classrooms with general education teachers, many of whom feel ill-prepared to teach these learners. Some classroom teachers have voiced concerns about integrating students with learning and emotional disabilities and mental retardation, due to lack of training in managing the behavior of these students and in instructional strategies to meet the needs of these students.

Many teacher educators are concerned about the preparation of general education teachers regarding inclusion strategies and instructional methods to teach our diverse student populations. However, not all teacher educators have the training or consider it a priority to assist K-12 science teachers in integrating students with disabilities into their science classrooms.

AETS Committee for the Inclusion of Challenged Populations in Science

The term Challenged Populations, as defined by members of the AETS Committee for Inclusion of Challenged Populations in Science, represents those who are underrepresented in science and includes students with disabilities, at-risk students, students with limited English proficiency, females, and members of ethnic groups other than white. One of the charges for the AETS Committee for Inclusion of Challenged Populations is to develop recommendations on ways to improve pre- and inservice science teacher preparation in working with learners who are challenged.

Focusing on students with disabilities, the 1994 AETS Board approved funding for the AETS Committee for Inclusion of Challenged Populations in Science to conduct a national survey investigating practices and attitudes relating to the instruction of students with disabilities in science. In October of 1994 the survey instrument was mailed to 100 elementary teachers, 100 middle school science teachers, 100 high school science teachers, and 100 university science educators. The survey inquired as to teacher preparation, experience, needs and attitudes with regard to teaching science to students with disabilities in inclusive classrooms.

Survey Results

The percentage of respondents to the survey was: elementary teachers 23%, middle school science teachers 40%, high school science teachers 28%, and university science educators 31%. Results are summarized in the following statements.

(1) The categories of students with disabilities represented in the highest percentages of respondents' classes were students with learning disabilities and students with emotional or behavioral disorders.

(2) For each level of teacher and for each of selected topics, a higher percentage of university science educators than teachers reported training in undergraduate teacher education programs pertaining to teaching science to students with disabilities.

(3) Following the established pattern, a higher percentage of university science educators than teachers reported required courses related to teaching science to students with disabilities in undergraduate teacher education programs.

(4) Elementary teachers rated themselves as more prepared than the other groups of educators to teach students with all types of disabilities. Middle school teachers rated themselves as less prepared than the other groups to teach students with physical or health impairments, orthopedic impairments, visual impairments, hearing impairments, and cognitive impairments. University science educators rated themselves as the least prepared to teach science to students with learning disabilities and students with emotional and behavioral disabilities.

(5) Each group of educators rated the amount of training needed by themselves as much lower than that of other educators.

(6) Overall, elementary teachers were perceived the least in need and university science methods and science content instructors the most in need of training related to teaching science to

students with disabilities.

(7) The concerns most often mentioned with regard to teaching science to students with disabilities focused on inadequate preparation and training, limited knowledge and a lack of time.

Teacher Comments and Concerns

Each respondent was asked to list three concerns regarding teaching science to students with disabilities. Comments were pleas for help. Elementary teachers made these comments: "Teachers are not trained to work with students with disabilities. I have no training. Train us!!!" and "Special children take valuable teacher time away from the other 20-30 children in the room. Their education should not be so casually compromised. Lower class size will be needed - a costly item!"

Middle school science teacher comments were equally as revealing: "More effort needs to be put in training of teachers to prepare them for teaching students with disabilities" and "More funding needs to be available for staff development, science materials, and additional staff to meet the needs of students with disabilities." High school teacher comments were similar: "Time and support - Help! Will this be in to everything else? Where will the money come from? We don't have what we need for regular students." University science educators voiced their own concerns, including "Every student is different and it is unrealistic to expect precious time devoted to a broad preparation for all "special" circumstances. Time is limited and there is so much to do as it is now. What do we omit? I'm not willing to discuss add without subtract."

Discussion and Conclusions

Limitations of the study included a small sample size, and the fact that the teachers and the university educators were not necessarily associated with the same teacher training programs. The sample group was selected from membership rosters of professional organizations in science teaching, and thus may not represent the opinions and experience of other teachers and university science educators. However, the results must be considered and further examined. The comments made by the teachers and university educators should be taken seriously.

Inclusion of students in general education classrooms is preceding the establishment of appropriate training and assistance for teachers and support personnel. It is time for science educators to collaborate with special educators in implementing teacher education programs designed to assist teachers in science instructional methodologies appropriate for students with disabilities. Elementary teachers and secondary science teachers should receive training related to teaching students with disabilities. Special education teachers should receive training in science education. Ideally, preservice education classes should prepare special education and regular education teachers together. Inservice workshops should be offered in which special educators and science educators learn to work in teams.

New models of education are emerging in response to the need for collaborative training of special and general education teachers. California State University, Fresno, is in its second year offering a program called Teachers in Inclusive Education Settings (TIES). The TIES program prepares preservice teachers to work collaboratively in serving the needs of an increasingly diverse student body. Preservice teachers take both general and special education course work toward a multiple-subject elementary credential. Science is a required course in the program along with special education courses in Introduction to Special Education, Mainstreaming, Behavior Management, and Trends and Issues in Special Education. The preservice teachers in the program participate in intensive field work at two elementary schools in Fresno currently practicing full inclusion. General education and special education teacher trainers collaborate to teach in this program. A focus is on serving students with special needs in the general education classroom.

The University of Texas at Brownsville has a program to prepare teachers to teach science to students with disabilities in inclusive settings. This program is in its first year and is funded by the National Aeronautics and Space Administration (NASA), the Lyndon B. Johnson Space Center in Houston. Participating preservice teachers take two undergraduate courses: (a) Teaching Children with Disabilities in Inclusive Settings and (b) Teaching Science to Special Populations.

The courses are taught by a special educator and a science educator. Preservice teachers in the courses participate in field experiences in Brownsville schools, and they work with cooperating teachers to lead science activities for students with disabilities in inclusive classrooms. An emphasis is placed on the contributions to the field of science made by individuals with disabilities and particularly those from minority backgrounds. Year two of the program (1996-97) will include graduate courses in special education and in science education, designed to assist practicing elementary and secondary teachers as they teach science to students with disabilities in inclusive settings. Long term, this project is designed to increase the participation of persons with disabilities in science, engineering, and technology studies and careers related to NASA research in these fields.

THINKING, WRITING, AND SHARING: TEACHER AND STUDENT VIEWS OF STARTING SCIENCE AND MATHEMATICS CLASS WITH OPEN-ENDED QUESTIONS

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Writing is often promoted as a tool for science and mathematics concept learning (e.g. Abell, 1992; Ammon & Ammon, 1990; Butler, 1991; Kober, 1993; Koeller, 1982; National Council of Teachers of Mathematics (NCTM), 1989; NCTM, 1991; Sturtevant, 1994; Wood, 1992). Kober (1993) justifies the use of writing in science:

> When students are asked to write about their observations, results, reasoning processes or attitudes, they are forced to pay closer attention to details, organize data more logically, and structure their arguments in a more coherent way. In the process, they clarify their own understanding of science and hone their communication skills. (p. 45)

The NCTM (1989) considers student writing and thinking creatively about problems as integral to mathematics instruction. Writing about mathematics helps students clarify their thinking and deepen their understanding.

Despite the many advocates of writing-to-learn approaches, many have noted there is little research evidence to show their effectiveness in learning science and mathematics (Holliday, Yore, & Alvermann, 1994; Moore, 1993; Peasley, Rosaen, & Roth, 1992; Rivard, 1994). Existing evidence is mainly anecdotal (Moore, 1993). "The links between writing to learn and conceptual change, and writing to learn and critical thinking have not received sufficient attention. Carefully designed studies, both qualitative and quantitative, are still required to provide data from a variety of perspectives" (Rivard, 1994, p. 969).

This paper describes a writing-to-learn method for learning science and mathematics that uses class time and teachers' time efficiently. The approach was implemented with urban eighth grade students. Data from this implementation regarding student and teacher attitudes toward the approach are reported.

The Write Now Approach

While teachers may understand the benefits of writing-to-learn methods, many middle school science teachers have not infused writing into their curricula because of shortages of class time and the demanding task of routinely marking hundreds of student essays. Many teachers view writing in content areas to be "'frills' in an already packed curriculum" (Sturtevant, 1992, p. 174). "The potential value of writing-to-learn is offset by the additional burden placed on the instructor in terms of evaluating students' efforts" (Liss & Hanson, 1993, p. 342).

The Write Now Approach was developed by the researchers as a class time efficient method to promote daily writing and higher level thinking without requiring the teacher to read and grade huge stacks of student essays (Cleland, Rillero, Zambo, & Ryan, 1996). When students walk into class they read and answer an open-ended writing question focusing on learning from the previous day's class. After sufficient time has been allocated, selected students verbally read their responses to the class. Teachers are encouraged to call on volunteers and non-volunteers to share responses. It is stressed that students should read their written responses and not simply provide an oral answer to the question.

Implementation Evaluation

Exploratory research was conducted to study the implementation of the Write Now Approach with eighth grade mathematics and science teachers and students. The findings respond to the research question: How do participants feel about using the Write Now Approach?

Research Design and Participants

This research was conducted in an urban middle school in Phoenix. Two eighth grade science teachers and two eighth grade mathematics teachers participated in the study. During a staff development afternoon, these four teachers were educated about the philosophy and method of the Write Now Approach.

The population at the middle school is comprised of students with diverse multicultural backgrounds; twelve language groups are spoken as the primary home languages. Sixty percent of the students receive free or reduced-cost lunches.

Following a model proposed by Slavin (1992), within-teacher random assignment of classes was undertaken.

> In schools with departmentalization, where teachers have more than one class in the same subject, it is often possible to have teachers serve as their own controls by randomly assigning two or more of their classes to experimental and control conditions. (p. 29)

The study used a quasi-experimental control group design, where teachers used the Write Now Approach in randomly selected classes and their other classes served as controls. There were 353 student subjects in the project.

The quasi-experimental design was used to compare treatment and control groups on several variables including content attitude and achievement. These results have been previously reported (Rillero, Cleland, & Zambo, 1995). The quasi-experimental design was not used to collect evidence of participants feelings toward the approach.

A questionnaire was used as one source of information about students' feelings and attitudes toward the Write Now Approach. As recommended by Patton (1990), interviews with students and teachers were conducted to explore the personal perspectives and experiences of people involved in the program. These interviews were recorded, transcribed, and subjected to content analysis procedures to identify assertions and emergent themes. Another source of data on student attitudes towards the approach are students' written answers to Write Now questions. The effort in formulating responses was qualitatively compared to the type of question asked. An additional source of data is students' written responses to a question about the Write Now Approach.

Results

Quantitative Data

Students in the treatment groups completed a questionnaire containing 36 Likert items about their experience with and feelings toward the approach. A five item scale was used with five indicating strong agreement and one indicating strong disagreement. The instrument was designed to evaluate students' attitudes toward the Write Now Approach in general and towards the Write Now Approach specifically in helping students learn and value science or mathematics.

Factor analysis indicated loadings on five factors. For students answering the questionnaire in the treatment science classes (n=71), the factors (means and standard deviations in parentheses) were as follows: Enjoyment of Approach (M=2.73, SD=.85), Writing Improvement and Attitude (M=2.41, SD=.87), Subject Learning and Attitude (M=2.77, SD=0.81), Views of Sharing Responses (M=3.30, SD=.84), and Effort and Participation Levels (M=3.23, SD=.87).

For students answering the questionnaire in the treatment mathematics classes (n=94), the means and standard deviations for these variables were: Enjoyment of Approach (M=2.69, SD=.81), Writing Improvement and Attitude (M=2.60, SD=.72), Subject Learning and Attitude (M=2.80, SD=.70), Views of Sharing Responses (M=3.11, SD=.74), and Effort and Participation Levels (M=3.26, SD=.73).

Qualitative Data

Students' Written Responses

All written responses were reviewed and analyzed in an effort to identify any generalizations. A major theme did emerge as it became evident that some responses reflected greater thoughtfulness than others; the term "rich responses" will be used for these more thoughtful answers. At first it seemed that a simple teacher variable was responsible for the noted differences, as certain teachers tended to elicit more rich responses than others. Upon further investigation, however, it became clear the true source of difference was the quality of the question asked. Questions that elicited rich responses required one or more of these three thinking skills: use of imagination, expression of personal opinion, and justification for one's answer. Individual students' writings across time were checked in an effort to support or reject this assertion. As previously mentioned, teacher by teacher comparisons showed more instances of rich responses for certain teachers. Comparisons of responses within each teacher's classes, however, supported the generalization; the type of thinking required affected the richness of the responses. The following example shows four responses from one student responding to a given teacher's questions. Three questions contain the characteristics identified as stimulating rich responses and one requires simple factual review.

Question [requiring imagination]: What do you think the "edge of space" looks like?
Response: I think that the edge of space is very cold. You can see out and it is all bright. You can't break out of the barrier because it is too thick. When you look straight at it you are automatically blinded.

Question [requiring personal opinion and justification]: If you were a farmer and could grow ONE crop, what would it be and WHY?
Response: If I were a farmer the one crop that I would like to grow an apple crop because you can make apples in anything and they are good to eat. They also stay good for a while so you don't have to worry about growing them that often.

Question [requiring personal opinion and justification]: What do you think is the SINGLE most IMPORTANT discovery in the world of science and WHY?
Response: I think that the single most important thing ever discovered in science is the new way of fueling cars. The reason that I say this is because by doing this we can greatly reduce the amount of carbon monoxide and help the level of pollution to save the ozone layer.

Question [requiring factual review]: Describe what a polymer is and give at least 2 uses for polymers.
Response: A polymer is a large molucle formed by 2 or more small molucules. 2 examples of a polymer are plastics and metal or slime.

It appears that this student, like her peers, was motivated to generate richer responses when asked to imagine, express an opinion, and justify her answers.

In an unexpected source of data, students gave further insight into their views of the approach. Midway through the project, one of the teachers opted to ask this Write Now question to open his class: "How do you feel the Write Now project is working? Is it helping?" This may be a leading question, however, the student responses merit analysis. The responses included seventeen positive and nine negative reactions. These specific positives were listed: encouragement to think about one's work, stimulation of imagination, aid to grasping meaning, relevance to daily life, and opportunity for peers to exchange ideas. Most of the negative comments failed to give the sources of dissatisfaction. Only two specifics were included: a sense that the activity was boring and a dislike for having to read answers aloud.

Interview Data: Students

Eight students were individually interviewed at the end of the ten-week Write Now project. Teachers were asked to identify students who were highly involved in the process and students who seemed only marginally involved. Two students per teacher, one highly and one marginally involved, were interviewed. Thus interviews were conducted with two highly involved science students, two marginally involved science students, two highly involved math students, and two marginally involved math students. As expected from this purposeful selection, students' responses to the open-ended questions reflected extreme opinions of the Write Now Approach, although there were some cross-over answers in both directions. The following generalizations show recurrent patterns across all responses and are categorized as benefits and problems.

Benefits of Approach

The interviews corroborated student views about the Write Now Approach discussed in "Students' Written Responses" above and extended upon them. Students highlighted five benefits of the approach. First, they stated that it made them think more deeply about the previous day's concept and this enhanced memory. One student stated, "I like to do some thinking...because it makes you remember longer."

Second, students felt the approach gave them opportunity to express their own personal opinions, a high priority for adolescents, as shown in comments like these: "I think it's good to get the students' point of view." "It gave us a chance to express our own feelings." "I liked telling the class...what I thought."

Third, while some students admitted that they didn't listen carefully to their peers' answers, most valued hearing the thoughts of classmates and at times learning from them. One student said, " I liked to hear the way other people think about things." Other students indicated similar feelings.

> If I do algebra one way and they [peers sharing their Write Now answers] do it an easier way, then I'll say, "That's easier, so I'll change."

> If it asked me a question like I have no idea, then I can listen to the other people and they can help me without me asking.

Fourth, students enjoyed questions that stimulated their imaginations. They viewed them as fun rather than work, but the learning value was recognized. Some students identified the benefit of the Write Now questions in extending thinking beyond the walls of the classroom. One student described a favorite question in which the teacher "asked us if we were...stranded on an island and we could get any one element of unlimited supply [what that element would be]. That was pretty neat because it dealt with school at the same time as it did with another place." Another student captured an essence of scientific investigation by stating that the Write Now Approach "can make your imagination explore."

Fifth, students identified the value of writing to refine thinking. Although the requirement that the response be written and read as written received mixed reviews, the awareness of the need for writing was apparent.

> It did show me that I had trouble writing down exactly what I wanted to say...; I wasn't aware of...that.... [I]t could make me be a better writer.

Other students were grateful for the think time. Having their answers pre-written gave them confidence when they were called on.

> It's easier because it's on paper. You don't have to think it out [while you talk]. You don't have to be embarrassed.

Problems With Approach

The students who did not like the Write Now Approach were far less articulate about their reasons, making general comments about finding it boring or simply choosing not to participate. Two specifics, however, did emerge across the interviews. The themes were similar to the two negative aspects identified in the class response to the Write Now question about the Write Now Approach discussed in the section above on "Students' Written Responses." Some students felt that it shortened the class period, reducing the amount of instructional and practice time available. Others expressed dislike for having to share in front of their peers when they had not volunteered.

Interview Data: Teachers.

All four participating teachers were individually interviewed after the implementation of the Write Now Approach. Two teachers were science teachers (Ms. A and Mr. C) and two were mathematics teachers (Ms. B and Mr. D). Open-ended questions were used to guide the interviews. Emergent themes from the interviews are presented in three clusters: Benefits of Approach, Problems with Approach, and Strategies for Increasing Participation.

Benefits of Approach

Three of the four teachers viewed assessment as a powerful benefit of the approach. Two teachers focused on the assessment of prior knowledge and the retention of information from previous classes.

> I was surprised to the extent that they didn't have the knowledge base that I would think by eighth grade that you would have and I'm not talking about something like organic chemistry. I'm talking about basic terminology, basic facts that I thought they would know. (Ms. A.)

> It was a good way to begin the class for the students to reassess what they did before and to get their mind back on the topic. (Ms. B.)

> I thought it gave me a great deal of insight into what the children had retained since the previous lesson.... I did have to re-teach a couple of times and I was grateful for that. That didn't bother me at all. (Ms. A.)

The third teacher focused more on assessment of students' understanding steps of problem solving.

> Probably the main thing is their real understanding of it because I'm not just asking them to solve a problem, but I'm asking them more to tell me what steps they are going to take to solve a problem. At least that's what most of my questions were based on; whether or not they understood the steps it takes to solve a problem. I'm finding out where the error parts lie. If they don't understand one step of it, or if it is the whole thing that I taught the day before. Was it really clear to them at all? It is real obvious when I look through their Write Now questions. (Mr. D.)

All four teachers commented that the approach was useful for classroom management.

> It is a very good way to start the class because it gets them settled down immediately and gives them something to do when they walk into the classroom. (Ms. B.)

> It gives me time, which is something that I need. Until this I hadn't done warm-ups [beginning of class exercises]. I tried to do my attendance as fast as I could and jump right in to the lesson. In the two classes that I use the Write Now question it runs much smoother because while I'm taking attendance or doing whatever, when I'm busy they are

> busy and are already getting their mind set into math. It kind of forces them into it. (Mr. D.)

Three of the teachers suggested the approach had benefits because it made the subject matter more relevant.

> It kind of reminded me to keep everything in relation to their lives and to motivate them by making it relevant to them. The questions I have tried to come up with makes it a little bit more relevant to them. (Mr. C.)

A couple of teachers commented that the approach helped focus the students on the upcoming subject.

> They... are already getting their mind set into math. (Mr. D.)

A couple of teachers suggested the approach was beneficial for thinking and learning.

> They like the questions more than the dry five daily review that I usually gave them. I like giving them the open-ended questions. Like I've told them all year I don't want to stuff their heads full of facts figures and formulas and stuff. I just want them to learn how to think. (Mr. C.)
>
> I 'd say that it does nothing but help the students. If you think of it, it is such a simple idea. It wasn't like it was any kind of a great revelation or whatever, but to put a label on it and just to structure it to always going back to the previous days lesson is just perfect and from what I've seen it does exactly what it is supposed to do. (Mr. D.)

Problems With Approach

Lack of classroom time for using the method was a major problem for two teachers. One of the teachers (Ms. A.) stated, "That was my trouble this year and definitely I have days where there is not the time because we do not allow our classes adequate class time." A transcript excerpt follows from the other teacher.

Interviewer: What might prevent other teachers from using this approach?

Ms. B.: Time. It is a lot more time consuming. Five minutes doesn't do it. It takes ten minutes to twelve minutes at least and our classes have been cut down to forty minutes as it is, so I find that there just isn't enough time in the day to always do this.

It is noted that time as a problem was mentioned by the two teachers who viewed the primary benefit of the approach as an assessment tool for recall of information. Time was not mentioned by the other two teachers who viewed the approach as a method for learning and a method to assess understanding of problem solving steps.

Three of the teachers viewed writing effective questions as a major difficulty in implementing the approach.

Interviewer: What do you find to be the hardest part about the Write Now approach?

Mr. C.: Just coming up with good questions. Because I do want the questions to relate directly with what we had just talked about the day before and sometimes it had to be a totally off the wall subject or question or topic. Just coming up with one that they really would have to think about.

Strategies to Increase Participation

The teachers used the willingness of students to share their ideas as motivation to do the writing. But to include all students in the process, they employed punitive strategies to motivate students to write and share their answers.

Interviewer: What strategies do you use to increase participation?

Ms. B.: I tell them that they will be graded on it and that they will get points and credits for it and if they didn't do it their grade would suffer. Otherwise they wouldn't have taken it seriously. They tend to take it seriously at the beginning, but after they have done it for a few weeks it gets a little more everyday type and they get lackadaisical about it.

Interviewer: What strategies do you use to increase participation?

Mr. C.: I make them put their pencils down when we are ready to begin sharing because I have experienced a lot of students that were waiting to hear an answer and then they would just jot that answer down. I would normally ask for three volunteers and then one non-volunteer, but I always played it unpredictably. Sometimes I would go around and get an answer from every single student and so they never knew if they were going to be picked. This increased their chances of being caught without an answer.

Teachers tended to believe that students are motivated to write because they might be called on even if they do not volunteer. This pressure—plus a desire for other students to want to share—is what helped Mr. D. get high levels of participation.

> I have some students that just basically demand to read theirs. Which to me is great because they are obviously motivated enough that they want to read their question. Motivation is ninety percent of it in education. The other students know that I'm also going to ask them possibly because I always choose a couple of students who don't have their hands up. I just tell them how interested I am in hearing what they have to say and if they don't read them or if they don't read them loud enough I make them come up in front of the room and read them there. That creates that little bit of tension, knowing that they might have to come up in front of the class and read their answer. Usually everyone is involved in it. I'd say the participation level that I have is about 95%. (Mr. D.)

Discussion of Results

How do the urban eighth grade students feel about the writing-to-learn approach described in this paper? The group means for the Write Now Questionnaire indicated students tended not to agree (i.e. the class mean was below 3.0) that the approach was enjoyable, improved their writing, and helped their content attitude or learning. They tended to agree (i.e. the class mean was above 3.0) that they enjoyed and valued sharing responses with each other. They tended to agree that they were motivated to work on answering the questions.

The students participating in the study tended to be motivated to write richer responses when the Write Now questions required them to use their imaginations, express their personal opinions, and justify their answers. They seemed to recognize the value of the approach as a stimulus to thinking more deeply about concepts, an opportunity for peers to exchange personal opinions, a time to let their imaginations soar, and a strategy for using writing to articulate thinking.

The teachers participating in the study tended to view the approach favorably. Teachers felt the approach was useful for assessment of learning and to help with classroom management at the beginning of classes. The approach also helped focus students on what they were about to learn. Problems experienced by the teachers include class time and difficulty writing effective questions. Class time is indeed short for these teachers; working in 40 minute periods requires time efficiency. It was previously noted that teachers who viewed assessment of prior learning as a major benefit were the ones who indicated time as a problem. Perhaps if they primarily viewed the approach as a learning tool rather than as an assessment tool, they would be more willing to use the class time.

Strategies used by the teachers to encourage participation seemed effective to the teachers. One teacher reported a participation level of 95% and another teacher reported "99% participated perfectly." The high rates of participation for a new program are encouraging.

All innovation takes time. With only 10 weeks' intervention time, this study is indeed only exploratory in nature; but it has produced results that encourage continuation of efforts in this direction. The approach appears to be acceptable to teachers and the vast majority of students participated in this writing-to-learn method. As teachers master the technique of developing effective questions, perhaps student enjoyment of the process and learning from the process will increase.

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USING CHILDREN'S IDEAS AND LITERATURE TO HELP TEACHERS LEARN SCIENCE: THE SCIENCE PALS PROJECT*

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This paper outlines an inservice program to enhance the science background and instructional expertise of elementary school teachers by building on student ideas using in-class and at-home language arts, hands-on activities, and parent partners to facilitate the enhancement activities. Referred to as the "Science PALs" program (Science, Parents, Activities and Literature), this program builds substantially on the teacher enhancement work of Shymansky, Woodworth, Norman, Dunkhase, Matthews, & Liu (1993) in which the idea of using students' ideas to focus teacher enhancement activities at the middle school level was developed and researched. In the Science PALs approach, students' ideas again are used to focus the enhancement activities but are combined with a language arts component to capitalize on the power of children's literature and parents as partners to promote science in the elementary school curriculum.

Figure 1 illustrates the basic principle of conceptual change teaching/learning on which the Science PALs approach is based. At the heart of the approach lie the learner's ideas about a selected science topic (represented as C_i, C_2, . . . C_3) and the scientifically accepted ideas (C_f). What a student understands at any point in time reflects the organization of ideas. Understanding progresses, regresses, or remains unchanged (reflected by the jagged line). Changes in understanding occur when students' ideas are challenged and extended through hands-on activity and as they interact with others and study and reflect on their own ideas. The teacher trying to facilitate conceptual change must know how to access and evaluate students' ideas over time and be able to select and design instructional activities to challenge and extend those ideas. Figure 2

* Funding for this project provided by the National Science Foundation under Grant 9353690. Any opinions, findings and conclusions or recommendations expressed in the paper are those of the author and do not necessarily reflect the views of the National Science Foundation.

Figure 1

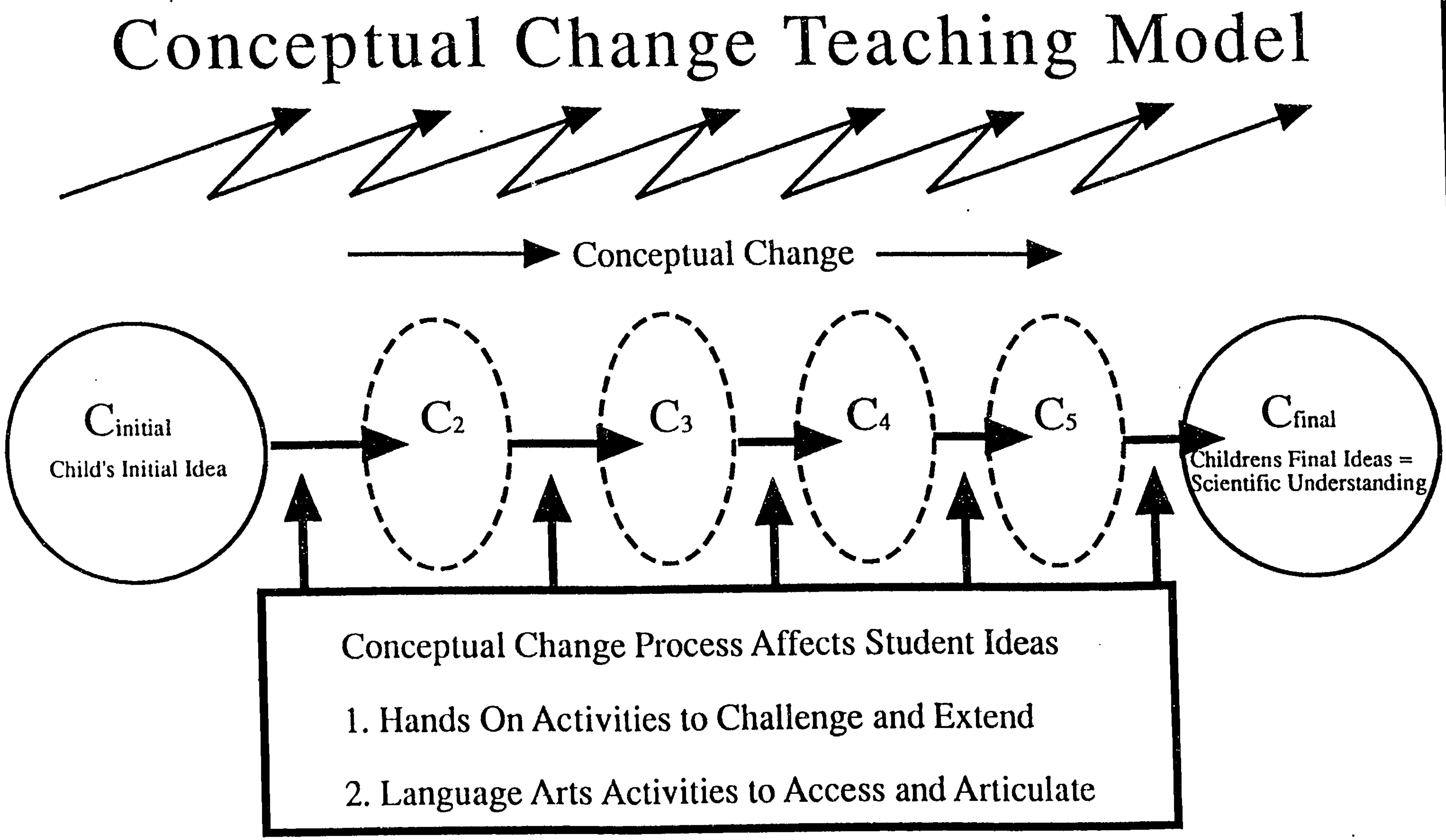
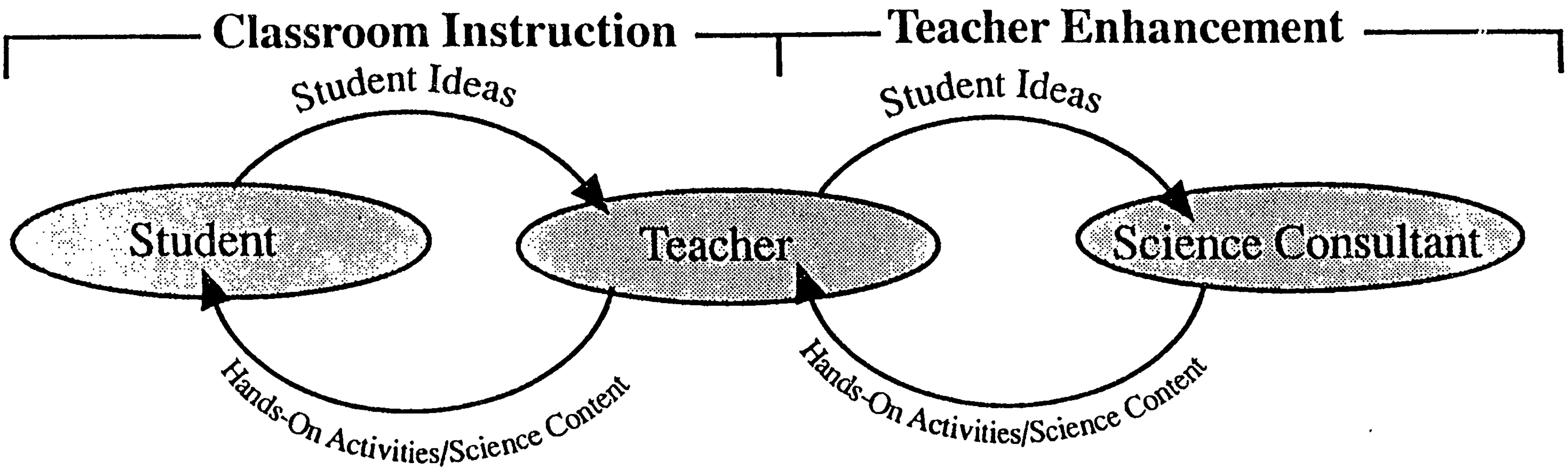

Conceptual Change Teaching Model
Conceptual Change
Cinitial
Child's Initial Idea
C2
C3
C4
C5
Cfinal
Childrens Final Ideas =
Scientific Understanding
Conceptual Change Process Affects Student Ideas
1. Hands On Activities to Challenge and Extend
2. Language Arts Activities to Access and Articulate

Figure 2

Teacher Enhancement Focusing on Childrens Ideas



Science Content-Activities-Strategies

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illustrates how those student ideas are used to connect teacher inservice to classroom instruction in the basic FOCIS approach.

The Science PALs approach has several strengths: By using student ideas about science to focus enhancement activities, we shift attention from what the teachers don't understand about specific science topics to what their students don't understand; by using language arts and children's literature to pique students' interest and access their ideas, we draw new instructional time for science from language arts in the primary grades and play to the instructional strengths of the majority of teachers K-6; and by involving parents in the process, we take advantage of their natural interest and enthusiasm in their children's education.

Background

Why Focus on Students' Ideas?

There is a considerable body of research evidence that suggests that students come to school harboring explanations and ideas about science that differ from those held by scientists (Osborne & Freyberg, 1985). These ideas are more or less resistant to change based on how central a given idea is to a student's thinking (Linn, 1986). Teaching strategies aimed at effecting "conceptual change" in students necessarily require that a teacher know how to access, challenge, and extend a student's central ideas.

How well a teacher understands the science ideas related to a topic effectively places an upper limit on the conceptual level at which he/she can engage students in that topic. While it is true that subject matter knowledge alone does not a good teacher make, without a deep understanding of a topic, a teacher is hard-pressed to do much more than "manage" the science classroom (Linn, 1987). The advantages of doing hands-on activities are greatly enhanced when a teacher understands enough about the topic to pose challenging questions and probe student ideas. It follows that preservice and inservice teacher education should focus on helping teachers learn how to access, challenge, and extend student ideas specific to the topics being studied.

Student ideas related to topics targeted for instruction provide the ideal vehicle for helping teachers better understand the science they are expected to teach. Using student ideas for teacher enhancement is efficient (inservice activities can be targeted to the science topics and ideas that teachers plan to teach) and non-threatening (teachers are more willing to work with a science expert on what their students don't understand than on what they themselves don't understand). In effect, the students' ideas serve as the "straw man" through which the problems in teachers' understanding can be addressed.

Why Use Language Arts in Science?

What student can resist a good adventure with some puzzle to be solved or mystery to be unraveled? The elementary school science classroom is a natural setting for adventure because so much in the immediate environment is a mystery to young students. Data from National Assessment of Educational Progress studies consistently have shown that student interest in science is very high in the early grades but drops off dramatically by late middle school. Though the reasons for the drop in interest are surely complex, the usually dry, expository text materials and often-times seemingly pointless, cook-book, hands-on activities are likely culprits in the turn-off! Introducing science ideas in more exciting, personally relevant formats has the potential to provide both the context and motivation for doing hands-on activities and seeking additional information and explanations from expository sources both inside and outside the classroom (Butzow & Butzow, 1988; Coonrod, Rusher, & Miller, 1991; Kinghorn & Pelton, 1991; Martin & Miller, 1990); Smardo, 1982).

Using language arts activities (reading, storytelling, drama, etc.) to provide context for learning science is supported by research in both language arts and science education (Yore & Shymansky, 1991). Elementary school-aged children are often exposed to new ideas through written, oral and visual media and tend to use these forms of expression as a way of providing structure to ideas (Lawrence, Skoog, & Simmons, 1984). Young students need to learn how to think about, work with, and express science ideas through a variety of language, visual, and tactile modes; and they need to do these things early and often!

There are other reasons for using language arts activities to access and challenge student ideas and stimulate hands-on science activities. It is well documented that:

1. Elementary school teachers spend almost six times as much time on language arts as on science in a given school day (Goodlad, 1984);

2. Language arts is often an area of strength for an elementary teacher, providing a "comfort zone" from which the teacher can deal with the more intimidating area of science (Butzow, 1989); and

3. Elementary school teachers state that they would like to do a better job of teaching science, but feel that of all the instructional areas, science is the one they are least prepared to teach and most intimidated by (Weiss, 1987).

The reality of elementary school life is that language arts is perceived as the most important area of the curriculum. Even those teachers who are enthusiastic about hands-on science often don't feel they have enough time to do science. And when they do use hands-on activities, they often over-structure them to save time. If K-6 teachers can be shown how hands-on science activities can be used in conjunction with language arts activities to develop skills of problem focus, identification of main ideas, argumentation patterns based on evidence, example, contradiction, etc., skills which are critical in reading, writing, and forms of verbal and visual expression, we submit--and others (e.g., Saul, Baker, Bird, & Mandel, 1990) agree--that teachers would be less reluctant to take time from language arts to do more hands-on science.

Why Use Parents as Partners?

"The Whole Village Educates the Child"

--an old African proverb

It is well known that parents play a key role in children's success in schools especially at the elementary school level. Parental involvement in a child's school experience dramatically and positively affects a child's motivation and attitude and increases academic achievement (Chavkin, 1989; Edwards, 1990; Fullan & Stiegelbauer, 1991). Not surprisingly, these positive results have been observed in a wide range of socioeconomic, racial and ethnic groups (Davies, 1991; Edwards, 1990). As the earliest and most influential teachers, parents are a source of strength for schools. In the words of one expert, "Trying to educate the young without help and support from the home is akin to trying to rake leaves in a high wind" (Gough, 1991).

Though there is general consensus that teachers appreciate parent involvement, research suggests that very few teachers make a systematic effort to establish specific learning goals with parents or provide special instructions to help them be more effective (Fullan & Stiegelbauer, 1991). The teacher's attitude and willingness to provide direction makes the difference in whether parents are productive partners in their children's education (Epstein, 1988). Given directions from teachers, parents can be very effective instructional partners (Fullan & Stiegelbauer, 1991).

The Science PALs Model

Inservice Goals

The interactive constructivist perspective of Science PALs emphasizes concrete experiences, prior knowledge, and interaction with others in the construction of knowledge. The "desired image" of a teacher in this model is to survey the construction site, make preparatory adjustments, plan the construction goal, "scaffold" the construction process, and enhance the learner's strategic abilities and metacognitive skills. Operating from this perspective, the Science PALs project has the goal of providing enhancement activities in which teachers grow and develop in four areas:

1. Understanding of the specific science concepts and the important "big ideas" or benchmarks that can be defined as learning outcomes for each science unit undertaken.

2. Awareness of possible "prior knowledge" and/or "naive understandings" that the learners bring to the classroom regarding these concepts and benchmarks. This awareness may come from summaries of the "misconceptions" literature on this topic provided for them by the project or more significantly from alternative assessment strategies designed to monitor their own students' understandings.

3. Use of strategies such as reading children's literature in the classroom and at-home readings with parents as a vehicle for students to talk about and summarize their prior ideas about

target science concepts. Other strategies may include concept mapping, student journaling, student interviews, and class discussions.

4. Ability to plan classroom instruction that includes hands-on activities, debate, discussions, investigations, etc. These facilitating strategies emphasize the identification and discussion of evidence that supports or doesn't support various student understandings in the class, challenges the learners to critically evaluate their understandings, and encourages students to rethink these understandings towards those that are better supported by evidence that reflects the way in which science operates.

How Science PALs Inservice Is Structured

The Science PALs inservice is "topic-specific," that is, it focuses on units already in use or planned for use. The Science PALs approach recognizes that teachers simply do not have the time to ponder theoretical or philosophical issues at the expense of practical classroom strategies. Thus, the inservice activities focus on things that allow teachers to use materials (i.e., hands-on activities, available print materials, and other instructional technologies) and strategies (e.g., embedded assessments, cooperative learning) to accomplish an agenda that is do-able and consistent with current science r form standards. Here is what the Science PALs "topic-specific focus on student ideas" teacher inservice involves:

1. Teachers gather and review student ideas related to a topic/activity and analyze them for their scientific merit and relationship to national science standards--a process that enhances the teachers' science backgrounds.

2. Teachers develop strategies and activities for challenging and enhancing student ideas--strategies and activities that effectively become teaching plans for a topic or activity.

3. Teachers develop strategies for accessing student ideas and monitoring changes in those ideas--strategies that inform instruction, empower students, and document student performance.

Many years of teacher inservice work have taught the education community that professional growth and development demand continued support across time. In the Science PALs approach, we understand that teachers need an intensive workshop where they can give their undivided attention to developing activities and learning new ideas and receive the needed expert support and collegial interaction during the school year as they are trying to implement the new activities and ideas. In Science PALs, a two-stage inservice program is utilized. The first stage involves an intensive (summer) workshop, and the second stage involves intermittent workshops scheduled as teachers are trying out new activities and ideas. In Science PALs, teachers work in teams to develop and implement new activities and ideas--recognizing both the need for a "critical mass" of teachers and the strength of collegial interaction and support.

Impact of the Inservice

A variety of documentation activities have been conducted to gauge the impact of the Science PALs inservice. Anchored in the "Professional Growth Matrix" (PGM), an evaluation system developed especially for the Science PALs project (Shymansky, Jorgensen, Chidsey, Henriques, Dunkhase, & Yore, 1995), impact evidence was gathered from a case study, video tapes of classroom teaching and teacher responses to a variety of questionnaires. However, for this paper only the results obtained from the analysis of the "teacher resource binders" are discussed since they best reflect what teachers actually do in the inservice and how the literature and parent components come into play.

Teacher Resource Binders

The teacher resource binders (TRBs) provide an estimate of teacher content-pedagogical knowledge gained from the inservice. Teachers must utilize their content insights and instructional insights on specific topics to revise, elaborate and enhance ICCSD science units from various sources (e.g., FOSS, EDC, NSRC, regional education agency). The resulting effectiveness of the inservices can be indirectly assessed by evaluating the TRBs against pre-determined attributes referenced to the desired image of teaching outlined under the project goals.

These characteristics are captured in the Professional Growth Matrices 1-9: Goals, Materials, Instructional Strategies, Instructional Time, Instruction Connections, Instruction

Evaluation, Instruction Resources, Reflective Planning and Science Component of the Science PALs framework (Shymansky et al., 1995).

The target science units for the 1994-1995 phase of Science PALs were assessed according to these dimensions. The Iowa City Community Schools' (ICCSD) version (1993) served as the basic reference frame for curriculum, instruction, and assessment prior to the start of Science PALs. The unit notebook (1994) developed by the teachers represents the initial impact of the 1994 summer institute. The revised version (1995) reflecting the 1994-1995 teaching experience and days 1-3 of the summer institute represents the impact of the first full cycle of Science PALs. These three versions of a sample unit (Floating and Sinking) were qualitatively evaluated in terms of the Science PALs desired image and quantitatively evaluated using the scoring rubrics associated with items under "Organizes Instruction" on the Professional Growth Matrix:

Floating and Sinking (Pre-Inservice, 1993): Teacher's Guide (NSRC)

Goals: The goals are teacher guide-based objectives; they dictate teacher's thinking. Goals are the same for the whole group (e.g., "Through a brainstorming session, students have opportunities to discuss what things float or sink and to pose questions about the phenomenon . . . . Students observe an object that both floats and sinks, record their observations, and record their ideas about how this could happen.")

Materials: All are teacher-directed, cook-book experiments. Some small group activities planned (e.g., "Discuss with students what they observed . . . . Ask students to share the observations that surprised them as well as the outcomes they expected.")

Strategies: Instructional strategies are teacher-selected learning experiences. These strategies (preparation, procedure, final activities/extension, evaluation) are stated in a way that dictate teachers' thinking (e.g., "First, conduct a class brainstorming session . . . . Ask students to respond to the questions listed on the newsprint sheets . . . . Ask students to observe what happens as you place the acrylic object in each of the tubes.")

Time: Each lesson is forced into uniform timetable (45 minutes). Planned teacher talk time is high.

Connections: There are some inter-disciplinary connections as in Lesson 4: "As a math exercise, ask student to weigh sheets of paper by hanging them from a punched hole . . . . Ask students to predict and test the weight of four sheets, two sheets, and one sheet . . . . Ask students to draw a design for a boat. Ask students to write and illustrate an advertisement for fishing bobbers."

Evaluation: Assessment is linked to teaching. Mid-unit assessment used to maintain effort and inform progress (e.g., "Check to see whether students are including reasons for their predictions . . . . Look for the level of detail and consistency in their reasons . . . . Look to see whether students include multiple reasons for their predictions.")

Resources: There are not any suggestions for resources.

Reflective Planning: Lessons are made in advance and no changes are made. Assessment information can't be used to plan instruction.

Science Component: Brings in some examples of the history of science (e.g., The story of Archimedes on p. 90).

Floating and Sinking (Post Phase 1 of Inservice, 1994): Unit Notebook

Goals: Goals are still based on content coverage established by a commercial unit, but are being taught with a developing awareness of the related Benchmarks and about what ideas/misconceptions students may hold as evidenced by the Content and Misconception sections in the Unit Notebook.

Materials: Additional enhancement/expansion activities are linked to commercial unit to support and elaborate science understandings. Some activities are teacher and student generated as in Lesson 7, Activity 10, where students are challenged to use what they have learned about making clay boats to investigate the amount of cargo that various clay boat designs will keep afloat.

Strategies: Teacher still selects activities for student to become involved in, but has now added to commercial unit to make a "menu" of activity selections. Some instructional variety introduced to the basic teaching approach through the use of literature and math connections to reinforce and stimulate science understandings.

Time: Science PALs teachers have increased their instructional block to teach Floating and Sinking from four weeks to six - twelve weeks to allow for further in-depth explorations (some student generated) and curricular connections. Students are given additional time to focus on student interest on the context of "Big Ideas," i.e., making marbleized paper (art) to explore why oil floats on water.

Connections: Science lessons are often related to past and future lessons by the continual use of student predictions and testing, all directed by the teacher. Literature and math connections are infused throughout the unit as evidenced in the Teacher Guide Practical Matrix. Contemporary STS issues are being explored as in Lesson 15 and the reading of *Spill! the Story of the Exxon Valdez.*

Evaluation: A limited variety of assessment techniques are used, i.e., lab-practical tests and summative tests. Assessment is a basic part of each NSRC unit lesson, but no reference is made to student feedback.

Resources: Parents are used as an integral step to identifying selected student misconceptions about displacement through the use of the Parent/Student Science Bookbags. Parent connection is only used once in the unit.

Reflective Teaching: The Theoretical and Practical Teaching Matrix were added to the Unit Notebook Teacher's Guide as a direct result of the reflection of a group of Science PALs teachers who pilot taught the unit after being inserviced in the unit to modify their teaching strategies. Reflective changes are based on practical experience, misconception research, and personal theory of learning.

Science Component: Over the past two years, the ICCSD has moved to cover fewer topics in greater depth as noted on the District Curriculum Guide. In Grade Level 4 teachers are asked to teach a core five units during the school year. In the past, teachers have taught their "favorites." Important science understandings are tied to Benchmarks as noted on the

Theoretical Matrix, Teacher Guide. Emphasis is placed on understanding the concepts. Teacher selected activities are chosen to challenge student misconceptions and further science understanding in 9 out of 16 unit lessons.

Floating and Sinking (Post Phase 2 of Inservice, 1995): Science PALs Unit

Goals: Identifies "Big Ideas" from Physical Setting and provides definition of key conceptions. Unfortunately, little attention is given to Nature of Science, Technology, Mathematics, the Designed World, the Human Organism (learning), Common Themes, and Habits of Mind. Furthermore, floating and sinking are limited to a "liquids" event rather than applying generally to fluids" (hot air balloons, helium filled balls, etc.).

Materials: The NSRC unit is the basic guide. This unit uses small group (N<4) structured inductive inquiries, with some attempts to use prediction-focused inquiries (hypothetical-deductive inquiry). Little use of other information sources (CD-ROM, videodisk, expository text) and student-designed inquiries.

Strategies: A sound basic introduction, experience, final activities/extensions, and evaluation. Little variety evident for accessing exploring, challenging and applying. Learning centers are recommended in the teacher guide, but they are not fully developed or resourced.

Time: A significant amount of time allowed over 30 days for 16 lessons that were originally designed to be covered in 12 hours (45 minutes/lesson).

Connections: Practical Matrix mentions lesson-specific connections to mathematics, language arts or social studies. The mathematics connections are specifically developed, but language arts connections are implicit or in progress and social studies connections are not explicitly provided.

Evaluation: Embedded evaluation is an integral part of the NSRC unit. An up-date supplement has been added and the post-instructional summative assessment is drastically improved to include a test, interview and self-evaluation. Little evidence of expanded formative techniques, likely due to limited goals (knowledge and process).

Resources: No evidence of outside resources (people, trips, etc.).

Reflective Planning: Addition of Practical Matrix to supplement the NSRC unit.

Science Component: Concrete, interactive but little consideration of society's influence and the constructive, hypothetical-deductive epistemology resulting in temporary constructs.

Floating and Sinking (1993, 1995 & 1995): Quantitative Results

The evaluation framework (Matrices 1-9) were applied to the qualitative results. Table 1 summarizes the scoring decisions. Growth in the direction of the Science PALs desired image became progressively more evident across the ICCSD Edition (pre-inservice), Science PALs Unit Notebook (post Phase 1 of inservice), and Science PALs Edition (post Phase 2 of inservice):

1. Connections to the misconception literature are apparent in the later units, but these ideas do not appear to have influenced lesson design and actual instructional recommendations of the original units. The 1995 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 unit 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. Units contain evidence of a strong hands-on experience but still are weak in specific strategies for scaffolding the construction of understanding.

4. As judged from the ultimate users' perspective of a generalist classroom teacher, the unit modifications to date still have work to be done. Comprehensive lesson plans should be provided illustrating the Science PALs desired image, or the FOSS teacher's guide should be modified with margin notes to highlight important changes and new strategies.

Concluding Remarks

The Science PALs approach to elementary school teacher inservice is both powerful and innovative. It is powerful because it targets the weak science preparation of K-6 teachers by working through their strongest area--language arts. It also draws power from its focus on student ideas about science. Student ideas--what the students do and don't understand about science--

Table 1

Summary Ratings for the Three Versions of Floating and Sinking

Unit Considered Floating & Sinking	Goals	Materials	Strategies	Time	Connections	Evaluation	Resources	Reflective Planning	Science Component
1993 version	1	1	1	1	2	2	0	1	2
1994 version	2	3	2	3	3	2	0	3	3
1995 version	2	3	3	3	3	3	0	3	3

become the "straw man" in the Science PALs approach allowing teachers to address deficiencies in their own science backgrounds in a non-threatening, low-stress inservice context.

The Science PALs approach is innovative in its use of parent-partners to serve as sources of information about children's ideas and as inservice team members. Parents (especially parents of K-6 students) historically have been active supporters of school programs. In the Science PALs approach, parents have an opportunity to be supportive of teachers and to impact their children's science learning in substantive and meaningful ways.

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THE ROLE OF TECHNOLOGY IN AN ALTERNATIVE ELEMENTARY TEACHER EDUCATION PROGRAM

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Introduction

Technology is being used more and more in educational settings including preservice teacher education programs. Similarly, computers and multimedia tools are finding their way into the classrooms for instructional use. Teachers are beginning to use video recorders, laser discs, televisions, and integrated computer aids in the classrooms, to name a few examples. This paper will describe the integration of technology into an elementary preservice teacher education program during one year in the life of a co-hort. The purpose of this paper is to investigate how participants in a co-reform elementary teacher education program incorporate technology as a theme into the program.

Sixteen preservice elementary teachers participated in an Alternative Teacher Education (ATE) program which focused on technology as one of four themes woven throughout courses and other experiences. One of the assumptions of the ATE program was teacher and student learning would ultimately be enhanced through intensive exposure to experiences with technology infused throughout the program.

Technology

While technology is a universally accepted word in society, there is no one accepted definition or meaning of the word that prevails. Philosophers have defined technology as "the practical implementation of intelligence" (Ferre, 1988). Educational technologists have defined technology as "an idea technology" (Rieber, 1991). Critical theorists believe technology "embodies the values of a particular industrial civilization, especially those of the elite that rest their claims to hegemony on technical mastery" (Feenberg, 1991). With multiple definitions of technology, it would seem bothersome if a shared meaning of technology is not negotiated when it is used as a major theme in an elementary teacher education program.

Jackson (1994) has shown that elementary classrooms are especially prone to the non-use of technology, such as software and computers. Accordingly, it follows that preservice elementary programs should provide teachers with many technology-related experiences. Loucks-Horsley et. al. (1990) stated that "most teachers who feel unprepared to teach science feel even less prepared to teach about technology." It is therefore important to encourage preservice teachers to learn about technology, in this case computers, as part of their preparation in becoming science teachers. The article "Teacher Education: One Dean's Perspective and Forecast on the State of Technology and Teacher Prep" (1993) reported that the current state of preservice and inservice teacher education with respect to the use of technology in the classroom is mediocre, and in the elementary sector it is poor. Okey (1992) stated that there is a need for technology instruction in preservice programs so that teachers will be better prepared to use technology once they are in the classrooms. He also stated that teachers had to be ready to incorporate technology with different subjects. Technology is an integral part of teaching and learning, but teachers have not been adequately prepared for the implementation and use of technology in their classrooms.

A previous ATE co-hort responded to a survey on technology (Survey, 1994). The results showed that eighty percent of the prospective teachers in the cohort used computers. Most students used the Macintosh computers and Microsoft Word-processing software. None of the respondents indicated that they were advanced users of the computers or software. Only two individuals indicated that they used spreadsheets, databases or e-mail. When asked how computers could be used in the schools, no one mentioned that science teaching and learning could be enhanced with a computer.

The survey was developed from the preliminary thinking that led to the inclusion of technology as a theme into the ATE program. The document *Alternative Teacher Education Program Student Teaching Considerations and Negotiable Expectations* stated that "students should use technology during student teaching (1994)." No additional explanation or direction was given. An ATE Progress Report (1992-1993) stated that "a major effort has begun to bring technology into all aspects of the Education Initiative." This initiative was instigated by the Dean, and the responsibility to infuse technology into the preservice program fell into the hands of the ATE Program Director. The Progress Report also stated that "work with technology will follow the co-reform principle that has guided other aspects of the project." The use of technology did not start with the participants, but was mandated by others outside of the co-reform initiative.

The preservice teachers in the ATE program received an introduction to common technologies, including computers, during their first three quarters in a multimedia class, just like other elementary teacher education programs (Schrum, Dahooney, & Hogle, 1995). Students usually wait until their last quarter to take this class. Computer labs, video recording machines, and other electronic technologies are accessible in the College of Education, but these technologies are not readily accessed or used by the students for class work, or used by the faculty in their courses for instruction and assignments. "The use of educational technology to enhance teaching and learning is often confused with technology education. But technology is more than hardware" (Loucks-Horsley et. al., 1990). One of the professors stated, "the ATE program implemented technology to mean the use of computers."

Research Questions

This study focused on three questions and three corresponding assertions. As data were analyzed in reference to our assertions, the research questions and assertions were modified to include new understandings about the use of technology in the Alternative Teacher Education program. The first three questions were: (a) What preconceived ideas and notions do ATE participants bring with them that facilitate or constrain their use of technology?; (b) How did the participants in the ATE program react to the top-down technology mandate from the Dean?; (c) How would technology be received by the participants?

The corresponding assertions are: (a) There would be a lack of consensus and shared understanding of the role of technology; (b) Participants' perspectives would be polarized with respect to the direct mandate to include technology in the program; (c) The implementation of technology as a theme would be slow and confusing due to the participants' prior experiences with and beliefs about technology. These assertions emerged from two researchers who were involved as instructors in the ATE program.

Analysis from the initial interviews and documents allowed us to add a new research question and assertions. The additional question was what role would technology as computers play in prospective teachers' science curriculum planning and instruction? The corresponding assertions were: (a) Technology as computers would not be used as a major component of the prospective teachers' science curriculum planning and instruction, due to their lack of knowledge and use of computers and science; (b) Computer use would not necessarily aid all the participants in developing a greater understanding of teaching and learning science.

Alternative Teacher Education Program

The Alternative Teacher Education Program at Olympic University was part of an educational initiative funded by a grant from a major foundation. The ATE program was a co-reform initiative. Co-reform is based upon the principle of collaboration between local schools and the university. Carriuolo (1991) provided a definition of collaboration as the unique quality of co-reform which includes a range "of activities honoring the skills, knowledge, and talents of individuals from both institutions" (p. 20). This type of collaboration enables the dynamics of learning and teaching to be shared by multiple stakeholders in the university and the schools (Cochran-Smith & Lytle, 1990).

The ATE co-reform project involved teachers from three elementary schools and their three representatives, faculty from six departments within the College of Education, and preservice students and their student representatives. Co-reform in the ATE program involved shared decision making processes involving all participants. The participants were able to raise concerns, make recommendations, and participate in dialogues that influenced the evolution of the ATE program.

The ATE program was set up as a collaborative program in which the education of preservice teachers was the responsibility of the university, public schools, and public school elementary teachers. Preservice students took a four quarter sequence which was modeled on the competency-based approach (Zeichner, 1983) of teacher education. The traditional competency-based program consisted of three quarters of classes followed by one quarter of student teaching, and field experiences during the third quarter. The ATE program differed, because the program required the students to participate in field experiences during all three quarters (Allexsaht-Snider, Deegan, White, 1994). Cochran-Smith believed that early field experiences gave students opportunities to make linkages between what they learned in class to the culture of elementary schools and classrooms (1991).

Throughout the four quarter sequence student representatives, professors, and teacher representatives met at biweekly planning meetings to discuss planning, problems, ideas, and issues pertaining to the program. A second unique aspect of the program was the direct involvement of professors from different subject matters. The professors stayed in contact with the students and teachers throughout the four quarter sequence. This provided an interdisciplinary approach to the learning of elementary teaching methods. A third unique aspect was that the preservice teachers stayed together as a co-hort throughout their class sequence, field experiences, and student teaching.

Initially, all participants selected three integrated themes to serve as a philosophical core for the program: constructivism, reflectivity, and multiculturalism. At the beginning of the third year of the program, educational technology was mandated from the Dean's office as the fourth theme. The program received money to purchase twenty-seven Apple

Macintosh Powerbook 520c computers equipped with a modem and an integrated software package. These computers were given to the pre-service teachers to use during the program. The extra computers were given to the professors to use. The acquisition of the computers gave the program a means for implementing the fourth theme.

Once technology was introduced as a theme and computers subsequently obtained, we became interested in how this theme was developing and evolving in the ATE program. The prospective teachers, as well as many of the other participants, did not know what to do with the computers, or how to use them. Our research explored how technology became integrated into this preservice elementary program.

Theoretical Framework

Science educators are recognizing the importance of examining teachers' pedagogical beliefs about science teaching and learning. Pajares indicated that "teachers' beliefs can and should become an important focus of educational inquiry" (1992). "Beliefs are the best indicators of the decisions individuals make throughout their lives" (Pajares, 1992). We believe that one's belief structure influences how one will change an attitude toward the use of technology.

Science educators also have become aware of the external or hidden forces which direct a preservice program. Critical theory provides the opportunity to study the use of technology in a preservice elementary program, because it also provides a means by which we may ask the question: Whose values have determined the extent of technological use in the ATE program? Teachers' beliefs and critical theory serve as the theoretical frameworks for examining how classroom teachers, prospecitve elementary teachers, and university professors make sense of technology and the role it should play in an alternative education program.

Teachers' Beliefs

In recent years science teacher educators have begun to realize the importance of examining the beliefs of preservice teachers' beliefs about teaching and learning. Ernest

(1989) examined how two teachers teaching the same math class could teach differently. He suggested that beliefs were a powerful predicting device to how teachers make decisions. We used this theoretical framework, because over the course of the ATE program, teachers' beliefs helped to inform us about the role of technology in the ATE program.

We make an assumption that the actions of the preservice teachers reflect their beliefs, and that these beliefs are the best indicators of the decisions the participants in this program make during the preservice experience. The beliefs the participants have about technology may be unyielding, but they provide personal meaning. Whether their beliefs change through exposure to experiences with technology is not as important as what the beliefs tell the researchers about the implementation of technology.

Critical Theory

Critical theory falls under the broad heading of social transformation theory. This theory states that there must be empowerment, voice and emancipation when a culture transforms. A culture transforms when it disrupts and challenges the status quo. The culture in this study is the ATE program, and it has challenged the traditional preservice elementary program and the mandate from the Dean. Giroux (1988) stated that schools or programs can become liberating when forms of knowledge and social relations are taught for the purposes of educating people for critical empowerment. To understand critical theory, one must be concerned with the need to raise people's awareness about how the hegemony shapes them. The research in this paper is based upon one out of seven assumptions made by Kincheloe and McLaren (1994): power relations are socially and historically constituted.

The researchers draw upon critical social theory to help them employ their understanding of the participants' roles in the program hierarchy to reconstruct the assertions. Social theory in this case allows the participants to transform their situation in the spirit of co-reform. The research then becomes transformative, because the researchers view the process of integrating technology into a co-reform program as potentially emancipating and liberating.

Critical theory allows for the emic perspective to guide the transformation process. Co-reform allows the practitioners to better legitimate their knowledge of technology and science, because they are closer to the purposes, cares, and interests of teaching. The emic perspective allows for the voices of the participants to be heard.

Critical theory is one lens through which the researchers examined the effect of the mandate of technology upon the participants of the ATE program. Co-reform allowed the participants the freedom to make decisions about their program, but the mandate could be considered a social injustice to the participants of the group. In order to understand how this affected the participants, their beliefs were used as the other lens through which the researchers could ascertain the outside influence of the hegemony.

Methods

Nature of the Study

An interpretive research approach was used to examine the role of technology in the ATE program and to infer participants' beliefs about technology (Gallagher, 1991). Critical researchers maintain that the meaning of an experience is not self-evident. The interpretation of an experience depends upon the definition of the experience by the researchers (Giroux, 1983; McLaren, 1986). Critical interpretation does not follow the empiricist tradition that posits data as irrefutable facts. Kincheloe (1991) stated that the facts "represent hidden assumptions-assumptions the critical researcher must dig out and expose...What we call information always involves an act of human judgment. From a critical perspective this act of judgment is an interpretive act."

Interpretive research provides a tool to better understand social phenomena in the science milieu. In this study, the researchers sought to understand how the participants were able to make and share meaning (Erickson, 1986). "The intent is to understand, in depth, teachers' actions and the knowledge, beliefs and values that lie behind them"

(Gallagher, 1991). By understanding the social interactions, teachers' actions, and teachers' beliefs, we can better inform the participants about their social ecology so that they may become more reflective.

An important aspect of an interpretive research approach is to build theory from knowledge acquired with one set of data, and incorporate it as a base for the next phase (Tobin & Tippins, 1993, p. 16). In our study two members of the research team were actively involved in the data framing and interpretation needed to construct new knowledge. Each member of the team brought to the study his/her own socio-cultural perspectives. These two members of the team generated the first set of assertions before analyzing the initial interviews. After the data were analyzed, the two members developed a second set of assertions. Later, three members of the team discussed interpretations, analyzed the data, and considered evidence to support or refute the second set of assertions.

Participants

The participants in this study were 16 white, female preservice elementary prospective teachers, six university professors from different education departments, and three white, female elementary teachers. The prospective elementary teachers varied in terms of their experience with technology. Most of them had used a computer for typing papers and word processing. Most of them did not feel comfortable with computers, and none had used them for any instructional purposes prior to the program. There was a continuum for the use of computers among students that ranged from no use of a computer and networks to high use and being comfortable with using word processors and networks.

The seven university professors came from different departments: Elementary Education, Reading Education, Educational Leadership, Language Education, Science Education, Math Education, and Social Studies Education. Like the prospective teachers, the professors had varying degrees of experience and use with computers, but the professors tended to have more experience with the communication and networking aspects of computing due to the computer system in place at the university. The professors represented the extremes of usage, just as did the students. One professor rarely used the computer, while another used it for communicating and desktop publishing of a news letter.

The three teacher representatives worked at different schools and had access to differing aspects of computer technology. All three teachers had a computer in their classrooms which they used for grading, communication, letters, games, and interactive software. One school had a computer lab for writing. Only one of these teacher representatives had extensive experience in science. She worked with Foxfire, and was the science coordinator for her school. She taught fourth grade, and had extensive computer experience related to science through her participation in the Galaxy Program and use of Kidsnet. The other teachers in the schools had some access to the computer lab and classroom computers, but used them sparingly for instructional purposes.

The research team consisted of three people: a Science Educator in the ATE program, a graduate student involved with the ATE program, and another graduate student who was asked to help analyze and triangulate data. Two members of the research team were actively involved in data framing and interpretation for both phases. The third member was actively involved in data interpretation for phase II.

Procedure

Data Collection

The research project took place over a year's time that included three quarters of the students' four quarter program. During the second quarter, one professor and one graduate student became concerned with the initiation of technology into the ATE program. The students were to receive their laptop computers at the end of the second quarter, and there was much talk, preparation, and discussion about computer technology. Interviews were conducted, and documents were collected during the second quarter. E-mail correspondence was collected in the third quarter during the students' field experiences. A survey was administered and collected at the end of the student teaching experience in the last quarter. Two follow-up interviews with two students occurred after the students had graduated.

The collection of data involved the use of a multiple data sources. Data sources included the following: 1) personal interviews with teachers, prospective teachers, and university professors; 2) e-mail correspondence; 3) tapes of biweekly planning sessions; 4); documents pertaining to the expectations and goals for the program, and 5) a survey of the prospective teachers. These sources allowed for triangulation of the data, and provided a multiplicity of views and comments.

An initial interview protocol was designed to probe university professors and prospective teachers' prior beliefs about technology (Appendix A). "Grand tour" and "Mini-tour" questions were used in the initial interviews (Spradley, 1979). Follow-up interviews were conducted by phone and e-mail to elicit deeper meanings when necessary, based upon responses to initial interview questions.

Copies of e-mail correspondence between a professor and her students and biweekly ATE team planning sessions were also analyzed with regard to the research questions of interest. A survey was administered at the end of the student teaching experience, and was designed to examine how prospective teachers translated their understanding of technology into practice. The survey questions were developed based upon a second set of assertions. These assertions were developed during the analysis of the interviews and the transcriptions from the professors, students, and teachers.

Data Analysis

The interviews were considered the primary data for the first phase of the study. The e-mail correspondences and surveys were regarded as the primary data for the second phase. Secondary data (e.g., documents, biweekly meetings, and informal conversations) were collected to help support the primary data sources. The interviews were evaluated in terms of the research questions and assertions. The e-mail correspondences and surveys were evaluated in terms of the first and second set of questions and assertions.

In the first phase, two researchers evaluated the data independently by completing two tasks: 1) reading through the interviews once; and 2) rereading the interviews for evidence to support or refute our assertions. Data analysis for the second phase involved three researchers who completed the earlier tasks separately, and came together to discuss and compare what was being learned and to resolve differences in interpretation. In completing these tasks, each researcher looked for key linkages connecting similar instances of the same phenomenon (Goetz and LaCompte, 1984).

Results and Discussion

Phase I

In Phase I of the study interviews were conducted with five university professors (two female and three male), four preservice teachers, and one fourth grade teacher. These individuals were asked a set of semi-structured questions dealing with the implementation of technology into the ATE program.

Question 1: What preconceived ideas and notions do ATE participants bring with them that facilitate or constrain their use of technology?

The professors as a group had more experience with computers than the teachers and prospective teachers. Because the professors had more training and background, they were more eager to incorporate technology. "I was a graduate student at Atlanta State University in the early seventies, and was involved in some of the very first computer assisted instruction that took place in the nation; I enjoyed it (Dr. James)." Dr. James also programmed mainframe computers, and edited a newsletter. His background knowledge has helped him realize the benefits of technology. Dr. James stated that "the classroom should have capability to show and use technology." Dr. Megan stated that her computer learning "has taken place at my job." She believed that "having access to it" gave her a comfortable self efficacy about technology.

The students as a group had less background in the use of technology than the professors. Beth believed that she "didn't have a good education and introduction" to computers. Beth and Steph took one class educational technology outside of the ATE program. They "learned a little word processing and MacDraw there." A survey conducted at the beginning of the prospective teachers' program asked what their background in computers was. Seventy-five percent of the prospective teachers used the computer for word processing. Twenty -five percent did not use a computer.

Some students believed that possibly the best way to learn to use computers and feel comfortable is to learn on the job. Edna "learned the most just being out in the schools here." Beth became excited with the use of computers when she saw a teacher use the computer in an instructional manner in school. "Ms. Houser had a program and she had a close up of the cells and you can click on those, and you can get more detail...but you can do a ton of stuff on the computer on the human body (Beth)."

The preconceived ideas and notions originated from the use or lack of use of computers for both the professors and the prospective teachers. Those who used the computer believed the computer would facilitate their learning. Those who did not use the computer felt intimidated. "I sure could of used some help when I got that laptop; I felt really dumb at times, but I learned along the way (Beth)."

Assertion 1: There would be a lack of consensus and shared understanding for the role of technology.

The Dean at this institution decided that technology would be an important theme in teacher education programs throughout the school of education. The ATE program was told to incorporate technology as one of its themes. Dr. Jason believed that "we should have been using more technology all along." He was referring to computer technology. "We are slow in picking up the capabilities (Dr. Jason)." Steph believed technology needed "to be real and for real purposes. That was their problem for a very long time. They were just holding a session on something, just to say they were doing technology." Dr. Megan gave a philosophical statement for the role of technology:

> I do think that having experiences with technology and being comfortable with it and knowledgeable about it and developing a critical view of technology that is knowledge based, not just coming from the outside is an important part of teacher education.

Some of the students believed that technology needed to be modeled by the professors. Steph believed that the students needed "to see some representation from the professors. Beth explained that it " has helped having professors who know a lot about it." The professors were expected to be able to supply the knowledge of computers. Steph saw "Dr. James using technology in that he always had his notebook or laptop with him, and we would go over and do some great things in it."

The prospective teachers had to attend technology sessions which included instruction in many forms of multimedia for the classroom. Steph believed that "technology with a lot of our people is that dreaded class." Technology was not understood to be computers until a grant was awarded to the program to supply them with laptop computers. All of a sudden the role of technology became understood as the use of computer technology for teaching and learning. "Exposure to an education about technology is really important, and I think education should not be forced upon you (Steph)." Dr. Lula believed that "there should be an imposition that would require them to attempt to become familiar with and try it out, absolutely."

The lack of consensus and shared understanding did not stop when the computers were introduced into the program. The role of the computers was nebulous. Dr. Lula believed that the computers should be used to "facilitate communication...and thinking." She believed the role of technology to be communicative and "for finding information", but she never stated how this was to be done. Dr. Jason believed that "e-mail should have already been up and running." Many of the professors and students welcomed technology, but there were a few who did not like its influence. Dr. Jack believed that technology should not take "precedence over other themes in the ATE program." Dr. Jack was also the professor with the least amount of computer experience in the group.

There was an overall agreement that technology was beneficial for the program, and that the computers could serve as tools for instruction. Dr. Megan believed that the ATE program "should have as many tools as possible; as many different kinds of technology for students to really explore in pretty open ways." Dr. Lula believed the computers could be used as "a vehicle for going out and finding information." She also believed that the computer could "help students learn and create products and to communicate with e-mail." Dr. Megan stated "that if we prepare our students, that they might be one of the people who could go out there and have some purposes and understandings and some ways to use technologies that are available." All participants mentioned how technology or computers would effect them, but no specific examples were given; especially when asked to explain how technology could be used to teach science.

The role of technology was never fully agreed upon by the participants in the ATE program. The participants did agree that computers would be used. Steph was critical of the use of technology in the ATE program and the lack of consensus and leadership; "most people are using them in the elementary school for math tutoring and word processing, and here they are using it for e-mail and paper writing."

Question 2 and 3: How did the participants in the ATE program react to the top-down technology mandate from the Dean? How would technology be received by the participants?

The answer to theses questions were described by providing evidence for the second and third assertions. The mandate to use technology and the reaction by the participants were inter-related. The preconceived beliefs and ideas of technology would influence the use of technology and would determine if the computers were seen as a good addition to the ATE program or not. Those who were dissatisfied with computers originally were the ones who objected to the mandate. The following two assertions provide this evidence.

Assertion 2: Participants' perspectives would be polarized with respect to the direct mandate to include technology in the program.

There were two aspects of technology being used as a theme in this program that warranted attention. The first was that the participants were polarized with respect to implementing technology; and secondly, technology was mandated and imposed upon the program, not generated from within. "There is a lot of money behind it now (Dr. Jack)." Funding was a major incentive for incorporating technology into the program. Dr. Jack stated that the Dean "became aware of the enormous push and funding behind technology, and he was anxious to instill that in this college when he came back." Dr. Jason saw a polarization for embracing technology:

> I would say that virtually everyone was, well I guess I would divide people into two groups. Those that said OK, I'm already using some technology, I would put myself in that category. And those who saw it as an intrusion into their normal routine.

Dr. Jack believed that the other professors had "whole heartedly embraced it." Dr. Jack on the other hand was not receptive to technology; "We have a number of people who enjoy it enormously, and see it as valuable and meaningful...that would not intrigue me." The students were also split. Some did not like technology at first due to the technology sessions, but warmed to the idea as time progressed. Steph believed that technology was "something that would benefit, and its across the curriculum."

Those students who did not like technology, thought that technology itself was good to learn, but did not like the fact that it was imposed upon them. "I think education should not be forced upon you (Steph)." Many of the professors agreed that technology carried a bad label due to its imposition. "I think it's basically imposed. I don't think it emerged from the students. If we were thinking of the whole group as stake holders, in a sense it could have emerged from the schools (Dr. Megan)." The political mandate from the Dean forced a polarization to occur within the group.

<u>Assertion 3: The implementation of technology as a theme would be slow and confusing due to the participants' prior experiences with and beliefs about technology.</u>

The prior experiences of the participants varied greatly. Those with a poor background in computers believed the computers to be nonessential for the program. "The Dean has just come back from Washington, and he is going to make technology an emphasis. We don't have technology in our program, let's put it in (Dr. Jack)." Dr. Jack had the least amount of background in computers, and reflected it in his statement. The implementation of technology as a theme occurred quickly, but the actualization of technology as a theme occurred more slowly. "Following the Dean's experience in Washington...he was anxious to instill that (technology) in this college (Dr. Jack)." Politically it was a fast decision to include technology, but practically it was a slow process to integrate computers into the existing ATE program. "Could you imagine the political ramifications if this college said that they weren't going to promote technology (Dr. Jack)?" Dr. Jack saw no significance in getting computers to use for e-mail and communication when a cheap phone would work just as well.

The students had their own beliefs that hindered the quick implementation of technology. Steph felt that students should "have a choice in what they want to learn about, and how far they want to go with certain things." If the students were given more ownership in the decision making process for technology, then the learning process would have increased. "I don't think one person can make that decision. I think the teachers together (Beth)." Beth believed that teacher input was valuable to the process. Steph believed that the powers to be needed to find "out what the needs and interests were of the students before becoming a them (computers)." Edna wished she "had a better understanding of them." With a better understanding of computers and ownership of how to use computers, the implementation would have occurred more quickly.

Another constraint to the implementation of technology was computer errors. "You get a huge computer and phone line, and no one can make their e-mail work. I think that that's what it is. Lack of expertise, lack of software and machines (Dr. Jason)." The students felt that this was a major constraint in their use of the computers. Susan stated that her "track pad was broken, then my keyboard was locked up; so my computer was out of commission."

Time was another aspect associated with these problems. Beth complained during her student teaching that she had no time to teach and learn the computer and its applications with her cooperating teacher. Kendra stated that "there wasn't enough time, and I'm not sure how I would use it." Glenda stated that "there only seems to be only so much room in the school day and getting together this equipment and learning how to use it all takes extra time." The problems and lack of expertise influenced the slow implementation of technology:

> People need time, they need training. They need motivation for using this stuff. And if you are missing any of these three components, it's going to be a slow go. So if the ATE program wants to pump up the technology, they are going to have to provide time, motivation, and training for these students. (Dr. James)

Phase II

In Phase II, fourteen of the sixteen preservice teachers responded to a survey that was more focused to science and technology teaching and learning.

Question 1: What role would technology as computers play in prospective teachers' science curriculum planning and instruction?

The evidence in the following two assertions show that the computers were mainly used for word processing, e-mail communication, and organizing. Karen stated that she used the computer for "word processing and homework problems." "I have not incorporated it (the computer) into instruction other than using some CD ROM programs (Susan)." Kendra stated that she had "not used any form of technology to teach science." Many of the prospective teachers did not answer the question about the use of computers and science. Science instruction was not a major use for the computers.

Assertion 1: Technology as computers would not be used as a major component of the prospective teachers' science curriculum planning and instruction, due to their lack of knowledge and use of computers and science.

In order for technology to be considered a major component of curricular planning and instruction, it must be used. The survey revealed a bimodal curve for the use of technology as computers. The preservice teachers either used the computers or did not. One prospective teacher used the computer more than three times daily, and two prospective teachers used the computers two to three times daily. Five prospective teachers used the computers daily, and another used it two to three times weekly. At the other end of the curve, three prospective teachers used the computer once a week, and two prospective teachers never used the computers.

Over half the prospective teachers said that they used the laptop computers. But, how would the prospective teachers use the computers -- for instructional and learning purposes or for personal purposes? The responses to the survey indicated that the laptop computers were used for personal and instructional development, and for communication.

The communication focused around personal and informational items. "Do you have pattern blocks at school (professor to student)?" "Sorry to hear about your dad - hope all goes well (professor to prospective teacher)." "Do you plan to inspect the lesson plans as part of the seminar (prospective teacher to professor)?" The use of e-mail mentioned instruction, but the instruction was not focused around science. "I corrected math papers this evening and I think I need to re-assess my expectations of students (prospective teacher to professor)." "I'd like you to think about areas of your proposal and present practice that appear to be strengths and weaknesses (professor to prospective teacher)."

The instructional use of the computers focused around unit development, lesson plan development, letters to parents, creating tests, and averaging grades. Glenda was "not really sure how to use technology to teach different subjects." The computers were used as a tool for instruction in science in only a few instances. For example; prepackaged lessons (e.g., Windows on Math, Geosafari, and Kid Pix Slide Show) were used, but no description of how they were used or fit into the lesson was mentioned. Andrea, a fourth grade teacher with extensive knowledge in science, stated "the number one use of computers is to integrate them into other subjects...being able to use it in a science class." Technology in general was not used to teach science, because it was not known how to integrate or use computers in science.

Those that did not use the computer were not sold on the idea that it could be an effective tool in science teaching. Julia stated her reservations that technology "would never replace the human element." Maria concurred with Julia's feelings; "technology would not be on the top of the list for facilitating instruction." Part of the reason for not being comfortable with the use of technology is that there was little support in their field experiences by their cooperating teachers. Diane stated that the "classroom teachers lack knowledge to support student teachers' use of technology." Support not only lacked at the school level, but also at the university level. Jennifer wrote that there was a "lack of university personnel to help solve problems." Technology was suppose to be used as a tool for teaching and instruction, but instead became a tedious bother for some and a teaching tool for others.

Assertion 2: Computer use would not necessarily aid all the participants in developing a greater understanding of teaching and learning science.

The computers were not used greatly for science instruction. Primarily, scientific applications for the computers were CD ROM programs. These programs were used to disseminate material rather than as an interactive tool. Susan used Groliers Encyclopedia on CD ROM to study the solar system and the oceans. Andrea used CD ROM programs from National Geographic.

Many prospective teachers did not link computers and science. The prospective teachers gave more examples of using the computer in other subjects than in science. The science examples were few and only involved CD ROMs for information dissemination. We believe this may be evidence that the teachers did not have enough science content knowledge to facilitate the use of the computers. Sandra "published writing workshop work on the computer, and printed it out." Sandra also used the "Groliers encyclopedia on

CD ROM-studying the solar system and oceans." Cindi commented that her "instruction has been more on the use of the laptop as a personal tool, not for teaching." This would indicate that she needed science instruction with computers to be modeled. When asked if the ATE students were prepared to use technology, Andrea stated: "yeah, but I don't think that's their major focus. I think they're most comfortable with reflecting in it...not necessarily doing the science lesson around the computer."

Many of the prospective teachers used the computer for other subjects, but science was relegated to pictures and images on CD ROMs. Susan used the "CD ROM program to let the children hear sounds such as waterfalls, whales, wolves, and oceans." None of the e-mail correspondences that were analyzed mentioned science. A professor responded to a student who was having difficulty with her lesson plans, "It might help if you and I could agree on the common understanding of the differences between objectives and goals." The computer became a personal tool for communication and organization rather than a tool for science teaching and learning.

Implications for Science Teacher Education

The implications for teacher education programs involve an understanding of co-reform, and how co-reform can help develop a preservice program. The survey we administered at the end of the student teaching experience highlighted many aspects related to the assertions of the researchers, and provide direction for future programs. Susan believed that the program needed to "teach students how to use the laptops and computers before they receive them." The computers were given to them, and they were expected to use them with little or no instruction. Glenda wanted to be shown "how/examples to use technology in the class." Since many prospective teachers had already used computers before, they were more interested in the instructional aspects of the computers. Cindi stated that there should be "more emphasis on technology for instruction than as personal tool." Beth wanted "sample lesson plans using technology in each subject area."

The role of technology eventually meant the use of computers, but students still had difficulties understanding the imposed mandate. Steph wanted the professors to "provide a 'bigger picture' with regard to the role of technology" in the ATE program. Sam wanted to "start with technology earlier in the program." Sam was one student with little background in computer usage. She also suggested that the program "require more undergraduate work in technology." This way the students would be more prepared to use computers and apply them to instruction. Dana suggested that the "technology sessions should focus on topics that can be used for instructional purposes." The application of computers should include "more emphasis on CD ROM technology and software (Diane)." but learning how to use the computer is not enough. There must be a support method so that what is learned at the university in methods classes can be applied in the schools. Beth believed that the professors needed to "tie technology more closely to what is going on in the schools." One way to do this is to "match teacher placements so that students are with teachers who have an interest in and use technology (Steph)."

The following is list of the implications for science teacher education:

1. A background understanding of computers is necessary before entrance into a prospective teacher education program;
2. Instruction in each subject methods class should show examples of the use of computers in that subject;
3. The role of technology in a program would be embraced more easily if all participants' voices were heard;
4. The role of technology in a prospective teacher education course should focus on instructional methods;
5. The use of computers should include interactive software programs which are modeled;
6. The professors and public school teachers should support the theme of technology by knowing how to use computers.

The integration of technology as computers into preservice teacher education programs can be improved with the suggestions in this paper. Teachers would teach science more effectively if they had a better background in science, the use of computers, and professors who modeled computers' use for instructional purposes in science. The findings suggest two significant implications: (a) all participants' voices need to be considered if a change of a program theme is to occur quickly; (b) the initiation of technology for instructional purposes needs to occur early in a program.

Finally, the findings in this study raise some intriguing questions for future research. When should technology be introduced into a teacher education program, or should it be required for entry into the program? How can prospective teachers effectively learn to use computers in the class when the professors and cooperating teachers don't use computers?

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Appendix A

Questionnaire Protocol

1) What image or picture comes to mind when I say the word technology?

2) What is technology?

3) What does it mean to be technologically literate?

4) How should technology be used in the elementary schools?

5) How have you seen technology used in the elementary schools?

6) How is technology being used to teach science?

7) Describe or tell a personal story about an experience you have had with technology. What is the moral of your story or something you learned from the experience?

8) Is there a metaphor that represents or describes your thoughts and beliefs about technology?

9) What should the role of technology be in the ATE Program?

10) How does the emphasis on technology in the ATE Program fit or not fit with the constructivist tenets that have been emphasized in the program?

11) How does the emphasis on technology fit or not fit with the tenants of multiculturalism in the program?

12) How much training have you had in the use of technology?

13) In what ways have you used technology to teach science?

14) What has facilitated or constrained your use of technology?

15) In what ways do other teachers and administrators support or constrain the use of technology in your school?

USING E-MAIL PARTNERS IN THE ELEMENTARY SCIENCE METHODS COURSE: A WORK IN PROGRESS

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Overview of Study

This paper explores the use of e-mail partners between the students of two elementary science education professors in two vastly different parts of the country. Professors of elementary science education in Long Island, New York and in Boise, Idaho paired students from their classes as part of a semester long exchange of ideas in the spring of 1995. Students who participated in this pilot project were engaged in fulfilling specific requirements of the methods course through their e-mail communications.

E-mail partners were arranged through the two professors and assigned to students. The assignments were made randomly at first. Each student in the respective classes was assigned a "buddy" with whom they were expected to communicate through the Internet at least twice a week for a period of 10 weeks. Students were asked to introduce themselves to their e-mail partners and begin to engage in electronic conversation about the following topics:

(1) What do they conceptualize as being a "constructivist" approach to elementary science education?

(2) In what ways do they believe that children learn science best?

(3) What do they believe are gender equity considerations for teaching science? In what ways, if any, do girls and boys behave differently in science in their field experiences?

(4) What local connections are fostered in their home states between classroom science and the local environment? What are some examples of locally relevant science topics and units that they have developed in their own locales?

As part of the elementary science methods course requirements, students were asked to print their communications and journal about them.This required the students to keep a reflective journal in which they recorded their reactions to their electronic communications as well as copies of the communications. They were asked to think about the ways in which this experience impacts their beliefs about doing science with children. Do their e-mail partners hold views about teaching and learning science that are consonant with their own views and with what they are learning in their methods course?

It should be noted that the plan to engage preservice teachers in an e-mail experience with their peers from another locality in the nation was constructed as a result of the professors' participation in the Teacher Education Equity project, a National Science Foundation funded intervention project that prepared teacher educators to integrate issues of gender equity in their science, mathematics or technology methods courses. The larger goal is to prepare their future teachers to be effective with their female students and encourage the participation of girls and young women in mathematics, science and technology. Because of this initial agenda, it was important to the professors that the preservice teachers engage in electronic communication about the issue of gender in teaching science.

At this writing, the data is still being analyzed, however, the following is clear:

(1) the students' e-mail stories informed class discussion and excited them as the semester progressed.

(2) Many students had never communicated through the internet and were required to get university server accounts for the first time.

(3) Several students remained in contact with their partners after the semester ended. One student reported plans to establish e-mail communication with the students of her partner and her students when they begin student teaching.

(4) Many students were surprised that, despite different geographic locations and local interests, science teaching philosophies were remarkably similar.

This paper is informed by student stories and experiences while being "on-line" and has the potential to inspire other teacher educators to attempt a similar level of electronic communication. In this semester's Long Island undergraduate elementary science methods course students are e-mailing with partners in Wichita, Kansas at Wichita State University.

The following sections illustrate some of the e-mail dialogues of student pairs, as transcribed from print-outs, as well as individual students' reflections on these communications as set forth in their journals. These data are from the perspectives of the Long Island students.

On Doing Science with Children

Rachel G.'s Journal

In communicating with my partner Cindy, I found out that we share many ideas about teaching science. Cindy stressed that science should be "hands-on" and fun. I challenged her about the "fun" part and said I didn't think that teachers should get so carried away with "fun" that they lose their main purpose along the way. The students should be active in situations which require some type of thinking; they must be given an activity that makes them think and problem solve in an open and fun way!

We disagreed about textbooks. Cindy felt that they should be used all the time, as resources. I think as long as they aren't used on a chapter to chapter basis, then it is O.K. I would take activities from the book for ideas; you could just change the activities to make them more open.

We both agreed on the value of tying the material in the classroom to one's life. This makes everything you do more useful and valuable to the children (4/95).

Jennifer's Journal

Jen: What kind of learning environment do you think children learn science best in? I feel that hands-on along with minds-on is the best. It just takes a lot more work on our parts as teachers.

Iris: As far as children learning science, I agree with you. Hands on and minds on. If students don't experience things for themselves, they are not going to remember or even understand the idea. Secondly, they will not know how to apply it to their lives and past experiences.(3/95)

Maria's Journal

My e-mail partner, Bobbi, said, "using the Boise, Idaho curriculum guide as a reference, science knowledge should be a vehicle to teach problem solving and process skills. These skills include observing and describing the natural world, and gives a basis for language development. I believe communication is the basis for all learning. This week, in our methods class, we talked about the importance of children asking questions in order for them to learn more in science. With the data we saw, it seemed that the more they were interested in what they were doing, the more they asked content related questions and the more they got out of the class. I know I never asked questions about science when I was in elementary school. It was my least favorite subject."

I wrote her that another way kids learn is probably pretty obvious now to both of us. They need to have hands-on learning and be involved with what they are doing. I don't ever remember doing hands-on science in my elementary school; I only remember textbooks, so I didn't have any interest in it [science] (4/95).

On the Local Environment

Maxine's Journal

I got my second e-mail today from Carol. She talked about how she attends elementary science workshops in her free time. I want to be able to attend workshops as well. I asked her about some of her local science or environmental issues in Boise and I told her about our polluted waters, abundance of garbage, and the breast cancer problem on Long Island. I wonder what sorts of things go on out there.

There are lots of science issues going on in Idaho right now. First of all, we are fighting against receiving shipments of nuclear waste. There is also an issue of wolves right now because the US Fish and Wildlife [Service] transplanted some wolves to Idaho and ranchers hate it because they are afraid their stock is going to be attacked by the wolves.

The biggest issue for the past few years had been endangered species. The salmon and the bruno snail are high on the list and the government regulations protecting these have caused a lot of lost jobs and upset farmers and ranchers. I just finished a thematics unit that was 75 pages long. It was on Native Americans and it had a science theme for endangered species.

It's so neat hearing about issues near you. They are so different from issues here. Pollution is quite a topic here. People just don't care about their beaches anymore. We have had such a problem in the last few years with [the dumping of] medical waste into the water. It's such a shame. I live 1/2 mile from the beach and I can honestly say it looks beautiful, but I haven't swam in the water for years (5/95).

On Gender Equity

Irene's Journal

Rachel M: We have spent a lot of time focusing on gender equity. I am sorry to hear that you are seeing that sexism is alive and well in your class. I did not have the opportunity to observe the teacher teach the class, because we were just there to teach science lessons, not to observe. You have a lot more diversity than we do here. I worry about equity in other areas because teachers and student teachers have such limited exposure to diversity (4/95).

Ann Marie's Journal

The e-mail experience was well worth it. I found out that Tammy felt the same way about children learning science as I do- she agreed that the best way they learn is through hands-on activities. I explained to her how scientists are stereotyped and telling her how we have to show students that females are scientists and that scientists are not just white males; and encourage them that they can and will be able to become scientists and that they are! I spoke about encouraging girls and all students to locate their scientific selves...LIKE I DID (5/95).

On E-mailing

Rachel G.

What I learned most about this e-mailing experience was that teachers and future teachers seem to all have the same types of concerns, questions and fears. I think that having an open line of communication such as we did e-mailing, makes it so much easier. To be able to share ideas and concerns makes us all connected in a way We can help each other out and share our thoughts for input.

Maria

I have to say that I had a great time e-mailing with my buddy in Boise. For the first time I felt like I made a professional connection with one of my own peers. *(author's note: Maria is a returning student and so was her buddy).* Bobbi has great ideas about teaching and we are keeping in touch with each other so we can continue to pool our ideas. Next semester we will have our students become pen pals. We are going to try to plan a long distance dual lesson of some sort .

Jan

I really enjoyed the e-mailing experience. Not only do we get to know what other future teachers are thinking who are very fay away, but it also allows us to experiment and become more familiar and more comfortable with the computer. Computers are everywhere and as teachers we need to be able to feel comfortable enough to share them with our students.

Jen

I couldn't believe how easy it was to use e-mail. I was always so intimidated by it. Today, while choosing the *Science Times* article I wanted to discuss for class, I noticed that you can e-mail the *Science Times* with any questions you may have. I e-mailed a question about the ozone layer. . .I can't wait for an answer.

Concluding Comments

This experience raised the level at which discourse occurred in the classroom. I noticed that the content of their e-mail communication provided them with a professional self-image as they began talking about science teaching across the country. It is enhancing for students to have regular contact with peers with whom they are required to "talk science teaching." For the professor, the e-mail communications can serve as an assessment of how the students make meaning of the underlying philosophies of their science methods course.

The additional benefit is the accessibility the students have to the professor through their e-mail accounts. I found that I gained a deeper knowledge of my students through our e-mail communications and I was able to facilitate some of their science teaching experiences in the field in between our class meetings.

Finally, it is interesting that there has been much research about childrens' discourse as they construct meaning for themselves during science experiences (Gallas, 1995). We give significant attention to the students' dialogues and questions as a way to gain more insight into the complex processes that inform science learning and meaning construction. A similar opportunity presents itself as we study the transcribed communications between future teachers as they explore their own ideas about doing science with children.

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AN INTER-UNIVERSITY INTERNET EXCHANGE PROJECT TO NETWORK PRE-SERVICE SCIENCE TEACHERS

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Introduction

Exchanging information and ideas on the Internet is now a common practice with numerous list servers, gopher servers, and web servers. The virtual classroom established by this telecommunication technology would seem to have tremendous potential for improving how teachers teach and students learn. Telecommunications technology can help meet the needs for pre-service science education as the future of information exchange and information power quickly dissolves the walls of the classroom. The use of distance education technology and practice is expanding rapidly at all levels of education (Hirth, 19993). Telecommunication networks offer expanding access to resources such as data bases, libraries, and curriculum materials as well as a wide-range of opportunities for information exchange with colleagues, scientists, and teachers. Hunter (1992) comments:

> Just as the grand challenges in scientific research require computer-communications network support for collaboration among geographically disparate institutions, disciplines, and individuals, so the grand challenges in educational reform require new kinds of collaborations across previously separate institutional boundaries and among individual whose work was previously isolated from one another. The national and international computer communications infrastructure is being engineered and deployed at the same time as new structures are sought for education. (p. 23)

Recently, there have been several attempts to use telecommunications for teaching and learning in various education contexts with varying degrees of success (Honey and Henriquez, 1993). National Geographic Kids Network, AT&T Long Distance Learning Network, Lab Net, Students' Environmental Alliance, and World Class are just a few of the current K-12 projects in the U. S. that are linking students with students, teachers with teachers, and students with teachers (Coverdale, 1991).

Other projects attempt to establish partnerships between higher education and K-12 schools for both students and teachers. The INSTEP project investigated ways for using computer networking to deliver materials and resources to K-12 science classrooms from university resource centers (Aust, 1991). Project INSITE is an ongoing attempt to use telecommunication technology to facilitate the acquisition and exchange of information between science teachers and university communications (Buchanan, Rush, and Krockover, 1993). Lavoie (1994) utilized compressed video and e-mail to link science teachers, university content professors, university science educators, and secondary-level students together for the purpose of improving scientific knowledge and problem solving skills. The National Science Teachers Network (NSTN) project utilizes an e-mail medium to allow secondary-level science teachers around the nation the opportunity to take science content/education courses for graduate credit during the school year (Lavoie, 1995). Lastly, the Boulder Valley Internet Project (Black, Klingenstein, & Songer, 1995) has brought together teachers, students, experts, and researchers to explore issues related to the utilization of networks in K-12 education.

Generally, the teaching of electronic courses is increasing at most major educational institutions (Klink, 1994). However, exchanging information and ideas on the Internet between universities as part of coursework is largely a novel and innovative idea for elementary and secondary pre-service science teachers. Recent review of the literature through the ERIC database revealed very few studies describing e-mail collaboration between pre-service teachers at different universities. This is consonant with the recent Office of Technology Assessment Report (1995), which states:

- Increased communications is one of the biggest changes technologies offer teachers.
- Most teachers have not had adequate training to prepare them to use technology effectively.
- Despite the importance of technology in teacher-preparation experience it is not central to the teacher-preparation experience in most colleges of education in the U.S. today.

Thus, there is a need to identify potential models, strategies, and problems associated with using the e-mail medium to improve pre-service science-teacher preparation.

Objectives

The objective of this study is to identify factors affecting Internet discourse between preservice students of different universities to enhance their understanding of science and science teaching. Specific questions which the project addressed include:

1. How effectively can e-mail be used to enhance science methods courses by engaging preservice teachers at different institutions in collaborative learning and discussion?
2. What are the advantages and disadvantages of using inter-university collaboration for instruction of science methods courses compared with traditional intra-university classroom instruction.
3. What are useful guidelines for introducing and applying e-mail with preservice teachers?

Methods

Subjects

The subjects participating in this study were twenty-two students from DePaul University (DPU) and seven students from the University of Northern Iowa (UNI) as well as the instructor/researchers conducting this study. The DPU students were graduate elementary education majors who had changed their careers. Many students had full time day jobs with families. The networking was conducted during their science methods class which is a ten week course. Students were required to complete ten hours of field experience. The course content is divided between understanding the nature of science, how children learn science, and pedagogy for student-centered learning.

The UNI students were full-time undergraduate secondary science-teaching majors who had completed most science content courses, a few science methods, and preliminary field experiences. These students engaged in e-mail collaboration to fulfill their requirements for an 8 week course, running concurrently with the DPU course. The UNI course focused on development and instruction of curriculum in junior-high middle-level science. Students were required to complete five hours of field experience. Most of the students had already taken a technology in science teaching course and were familiar with using e-mail.

Project Logistics

This Internet collaboration study involved seven cohorts, each composed of three to four students from DPU and one student from UNI. Students at both Universities were assigned e-mail accounts and, when necessary, were provided with instructions on how to use university computers and the Internet. To facilitate intra-cohort communication each student was required to set up a distribution list for those members of their cohort which included the course instructor/researcher. This ensured that any message sent by one member would be automatically routed to all other members of the cohort and the instructor. The first assignment required the students to use e-mail contact to introduce themselves to the members of their cohort and carry on a brief discussion of their science backgrounds and how they shaped their attitudes toward science. The second assignment required students to discuss an article posted to the NARST listserver by Lemke (1995) which centered on issues of constructivism. It was the intent of the instructor/researchers to engage students on a regular basis through interactive e-mail discussion that focused on science teaching and science-content issues.

Data collected from a pilot project a previous semester was used to modify the project for greater effectiveness and more-in-depth study during a following semester. The instructor/researchers corresponded via e-mail to create surveys, assignments, and to discuss project issues and logistics.

Data Collection and Analysis

To determine changes in pre-service students' perceptions concerning the electronic mail collaboration, short answer response surveys were developed and administered at the beginning, in process, and at the end of the e-mail collaboration project (Table 1). These surveys addressed a variety of dimensions including attitudes toward the use of e-mail, participant-participant interactions, participant-instructor interactions, and actual and future application of the electronic collaboration for preservice instruction as well as K-12 instruction. The e-mail correspondence within cohorts, between the instructor/researchers and the students, and between the instructor/researchers provided additional data. All e-mail correspondence was saved electronically.

Responses to each survey question were summarized and categorized by frequency of the response. The e-mail correspondence was also summarized and categorized by frequency. The instructor/researcher interactions are not included in this paper.

Results

Three major data components were analyzed to understand student thinking about using e-mail for science teaching and learning: pre and post e-mail networking survey, in-process survey, and copies of the actual messages sent among cohort members.

The results of the pre and post surveys are represented in Tables 2-4. The initial question appearing on both the pre and post surveys asked students to list what they knew about e-mail. On the pre-survey, sixty percent said they never used e-mail prior to their networking experience while thirty eight percent identified knowledge about basic e-mail commands such as sending, retrieving, replying, printing, and deleting. One student had an advanced knowledge of using e-mail. The post survey revealed that eighty nine percent listed a working knowledge of basic commands in addition to more advanced commands useful for conferencing, creating folders, and creating distribution lists.

Table 3 represents data collected from a question that asked students to list how they would use e-mail for science teaching in their future classrooms. Table 4 represents data collected from a question that asked students to list how they would use e-mail for learning science in their future classrooms. Categories of similar responses were identified based on the dynamics of the communication. These included interactions between "teacher and expert," "teacher to teacher," "teacher to student," and "student to student." Since the number of responses varied, Tables 3 and 4 represent the percentage of responses within a given category. Some students did not address the questions directly and simply replied that they would either not use e-mail, not sure about using e-mail, or felt the system would change making it difficult to use. These responses

Table 1
Short Answer Response Surveys on E-mail Networking

Preliminary Survey

List out several things you know about using electronic mail (E-mail)?

Are you aware of any schools using E-mail? If so what are they using it for?

Do you feel you need some formal training to begin using E-mail in this class? Why? Why not?

Do you think it would be valuable to use E-mail to help you learn in this class? Why? Why not?

List the kinds of ways you might use E-mail in your future science classroom for learning.

List the kinds of ways you might use E-mail in your future science classroom for teaching.

If you were allowed to collaborate over E-mail with other pre-service teachers list things you might do? Be as specific as possible.

How often do you use E-mail?

What have you used E-mail for?

How often do you use the World Wide Web?

What have you used the World Wide Web for?

In-Process Survey on E-mail Networking

How many times have you corresponded with students from the other university?

If none, please explain.

List the topics you have discussed.

What is the nature of feedback have you received from individuals at the other university (short messages, long messages, substance, etc.).

Post Course Survey on E-mail Networking

List what you learned about using electronic mail (E-mail) by doing this project?

List ways you might use E-mail in your future classroom to enhance your students learning science.

List the kinds of ways you might use E-mail in your future classroom related to your own professional growth.

In the future, if you were to collaborate over E-mail with other pre-service teachers as part of a class similar to this one, list out specific things (activities; assignments, etc.) that would enhance your learning?

Table 2
Pre And Post Survey Percentage Results For Student's Knowledge Of Using E-Mail

	Pre-Survey (n=34) %	Post Survey (n=16) %
Confident knowledge of e-mail	3	11
Never used e-mail before	60	0
Basic knowledge of e-mail	37	89

Table 3
Pre And Post Survey Percentage Results For Student's Knowledge Of How They Would Use E-Mail In Their Future Classrooms For Learning Science

	Pre-Survey (n=34) %	Post Survey (n=16) %
Teacher to experts	0	25
Teacher to teacher	44	38
Teacher to student	6	6
Student to student	38	31
Not sure	6	0
Irrelevant, system will change	3	0
Will not use	3	0

Table 4
Pre And Post Survey Percentage Results For Student's Knowledge Of How They Would Use E-Mail In Their Future Classrooms For Teaching Science

	Pre-Survey (n=34) %	Post Survey (n=16) %
Teacher to experts	0	13
Teacher to teacher	45	48
Teacher to student	10	0
Student to student	42	39
Will not use	3	0

only appeared on the pre-survey and not the post survey. The "teacher to expert" category represented a response such as "wanting to ask experts at universities, NASA, and museums for answers to science questions." Another response was a desire to "talk to science educators". The "teacher to teacher" category included responses reflecting the desire to discuss science lessons and goals, receive feedback about successful teaching experiences, and find ideas and resources for teaching science. The "teacher to student" category represented responses such as using e-mail to give feedback and assess children's learning. The "student to student" category contained a wide range of responses such as having pen pals, sharing data, discussing science topics, and doing projects together.

The percentages in Tables 3 and 4 indicate that similar responses appeared on both the pre and post surveys. In other words, e-mail correspondences experiences within cohorts did not add other dimensions (i.e., category responses) to students' thinking about the use of e-mail to enhance teaching and learning science. The only added dimension was the "teacher to expert" category which just appeared on the post survey. Overall, the responses given on the post survey were more specific than on the pre-survey. For example, students would say on the pre-survey that they wanted to discuss topics, gather ideas, or have students share data but did not provide any examples. On the post survey students gave specific examples such as "discuss the moon phases," "children could share data about the terrain and weather of their particular locations," or "students could do the same project such as examine the same outdoor plants and compare climate differences."

Table 5 represents student responses to a question about their recommendation for using e-mail networking in future science methods classes. Their recommendations are listed with percentages of the number of times they appeared in both the pre and post surveys. Share lesson plans represented 18% of the responses on the pre survey but was not mentioned on the post survey. Sharing hands-on activities represented 29% of the responses on the post survey but only 8% on the pre-survey. Wanting to obtain more resources for teaching science was a response that showed an increase on the post survey. Classroom management tips and a desire to discuss field experiences showed a decline compared to the other responses.

Approximately half way into the e-mail networking experience, students completed the in-process survey to identify their perceptions about the number of times they sent and received messages plus the quality and type of messages. At this point, the majority of student considered their messages to be short (two to three lines) and replies to each other as limited (Table 6). Only five students out of 29 perceived the messages to be in-depth. Three students said their cohort members did not respond and four said they only received introductory messages. Thus, most students did not engage in productive in-depth e-mail exchanges. However, a few individual attempts were well conceived, provocative, and demonstrated reflective thought.

Table 5
Pre And Post Survey Percentage Results Showing Student's Recommendations For Using E-Mail Collaboration In Science Methods Classes.

	Pre-Survey (n=39) %	Post Survey (n=24) %
Developing lesson plans	18	0
Teaching strategies/styles	8	8
Resources	8	13
Hands-on activities	8	29
Classroom management	12	4
Share class projects	8	17
Portfolio development	0	4
Conduct research	2	8
Discuss field experiences	20	13
Don't know	8	4
Miscellaneous	8	0

Table 6 indicates that all DPU students sent between 2-3 messages. However, according to the copies of the messages, 23% of the students had actually sent 9-12 messages. The discrepancy is due to the fact that the actual messages were analyzed a few days after the in-process survey was analyzed. During this time, the DPU students sent additional messages not only to the other university students but also to their own peers within their cohorts. They were apparently motivated by the in-process survey. However, 29% of the UNI students said they sent 4-7 messages which could not be confirmed by the actual messages. There was a range of responses to the perceived quality of the messages. Student comments ranged from excellent, long messages and interesting discussions to one sentence replies. A few students never responded and claimed they received message too late or that the technology wasn't working.

To cross-check for accuracy, the results of the in-process survey were compared with the actual student e-mail correspondence for both university groups (Table 7). Table 8 compares the topics that students said they discussed via e-mail with the actual exchanged messages. Messages from individual students within cohorts were analyzed to identify topics. The first four topics listed in Table 8 were given as assignments. The first assignment was to introduce themselves to each other. A discrepancy appeared between the in-process survey (17%) and the actual messages (8%) for DPU for this particular assignment. The second assignment asked students to discuss issues about teaching science that appeared in the e-mail message from Lemke (1995). Students were asked to discuss the article within their cohorts. Again, a discrepancy appeared for DPU

Table 6
Results Of The In-Process Survey Comparing Student Perceptions Of E-Mail Interactions.

	DePaul (n=22)	UNI (n=7)
Perceptions		
Excellent/long messages	4	1
Never responded	3	0
Good article discussions	2	2
Short message	3	1
Good feedback	1	1
Introductory message only	2	2
Talked about teaching	1	1
Received messages too late	1	1

between the survey (30%) and the actual (8%) messages. The final assignment contained three components: constructivism in the science classroom, examples from field experiences that corroborated constructivism, and barriers to implementing constructivist teaching. While Tables 7 and 8 display discrepancies between the survey and the actual messages, they only reflect what students remembered to put on the survey. Also some messages were completed after the survey. Besides discussing assigned topics, students also shared their frustrations (DPU: 12% and UNI: 17%) and benefits (DPU: 10%) of using e-mail. DPU students discussed non-assigned class topics with each other within their cohorts.

In some cases, UNI students offered feedback to the DPU students on science content questions and issues. In turn, the DPU students offered insights to the UNI students regarding pedagogical issues of the upper elementary and junior high science teaching. The latter helped the UNI students develop more appropriate lessons for their field teaching experience which required them to teach 3 days in the field to junior-high level students.

Table 7
Results of the in-process survey comparing actual vs. surveyed cohort correspondence.

	DePaul (n = 22)		UNI (n = 7)	
Number Category	Survey %	Actual %	Survey %	Actual %
9-12	--	23	--	--
4-7	--	17	29	--
0-3	100	60	71	100

Table 8
Results Of The In-Process Survey Comparing Of Actual Vs. Survey Of Discussion Topics

Topics	DePaul (n=32) Survey %	DePaul (n=40) Actual %	UNI (n=13) Survey %	UNI (n=11) Actual %
Greetings/introd.	17	8	38	27
E-mail article	30	8	31	45
Constructivism	10	10	23	10
Field experience	20	12	8	0
Various class topics	7	10	0	0
Teaching experiences	13	0	0	0
Hands-on learning	3	12	0	0
Constructivism barriers	0	10	0	0
Own learning exper.	0	8	0	0
Technology problems	0	12	0	17
Benefits of e-mail	0	10	0	0

Additional student perceptions obtained from the survey data are summarized in Table 9. The students at both universities perceived similar problems such as dealing with the lag time between sending a message and receiving a response, technical problems of using the system, and general communication problems. Students typically checked once a week for messages. Students from both institutions did not receive immediate responses. Students would often say they sent the message but had not heard from their cohort members. DPU students had more success communicating with each other than with those students from UNI. This success was apparently due to established bonds within given DPU cohorts. Students at both institutions had to be continually reminded to communicate with each other and much of class time was spent discussing computer and networking problems. The instructor/researchers developed additional assignments with deadlines to have a specific discussion completed.

All students saw the need to have easy access to a computer system that works, a relevant topic about which to interact, and to have collaborative e-mail networking integrated within the methods course assignments and activities. The students recognized several advantages of using e-mail such as overcoming the time constraint of the class period, exchanging ideas and experiences, and increasing the resource and collaboration base for completing important projects in science teaching.

Table 9
Summary Of Survey Results

Typical problems:

- not sure who was in cohort
- students absent when cohorts were assigned
- having incorrect addresses
- computers or system down
- differences in class size
- differences in class schedule
- excessive class time was spent discussing networking problems

Barriers to Collaboration:

- technical problems
- communicating with a faceless person
- time constraints

Recommendations:

- Students need training
- Easy access to a computer
- Stable computer software
- Relevancy for students must be established
- Networking must be completely integrated into course

Benefits:

- Opportunity for students to discuss topics in depth when class time is limited and student are not on campus.
- Exposes students to problems and benefits of having children communicating with each other.
- Increases access to ideas and resources. Enables the collaborative development of teaching and learning materials.

Conclusion

This study examined some of the dynamics involved with attempting to use e-mail collaboration between students at different universities to enhance learning in science methods courses. The data suggests that the majority of elementary as well as secondary science majors who participated in this study gained confidence in using e-mail as a tool for learning about teaching science and developed positive attitudes toward the technology. E-mail collaboration became a useful tool for reflection which is critically important in science teacher preparation (Baird, et al. 1991; Russel, 1993). For those students who engaged each other long well thought out messages, it was clear that this kind of electronic discourse is a way for pre-service teachers to make sense out of issues and experiences related to science teaching. Many would agree that this kind of cooperative learning discourse is advantageous (Sharan and Sharan, 1992; Slavin, 1990; Sharon, 1990; Vygotsky, 1986).

Further, previous studies have shown that learning is enhanced through small group collaboration over Internet for K-12 students (Goals 2000 Satellite Town Meeting, 1994). Other studies have identified many benefits of electronic collaboration at the K-12 level which correspond with those identified in this study at the university level. Such benefits include access to information and resources, being freed from time constraints of the classroom, and cooperative learning and sharing (Eisenberg, 1992).

However, some students did not change their attitudes toward using e-mail as an instructional tool and their experiences created negative attitudes. For these students, the medium did not lead to much conceptual learning, constructing, or reflecting relative to science education issues. This was largely due to technology problems that prevented these students from developing systematic and in-depth correspondence with their cohort members. These problems included delays in receiving and sending messages, lack of technical knowledge, not having ready access to computers, and simply not having the time to interact. Application knowledge and technological accessibility are common problems as a recent survey of science teachers in New York revealed that 60% had no access to telecommunications and almost all were unfamiliar with common techniques used on the Internet (Murfin, 1995).

Another factor affecting the results of this study was that all communication involved a "face-less" person. This undoubtedly depersonalized the communication and gave the e-mail correspondence lower priority than other class assignments.

Based on the results of this study the following guidelines were developed to assist other science educators interested in using inter-university e-mail collaboration in their methods classes.

- Provide adequate time for orientation. During this time students must establish links between all members of a collaboration cohort and the instructor and develop a cohort distribution list. This will probably take at least a week as some students will not be as familiar with technology as others and will need training.
- Establish discussion guidelines. For example, this might involve setting a date by which all members of a cohort must have read the messages of the cohort and replied at least twice. This will force students to establish a regular time-line for getting on the system and interacting, which should be at least once a day.

- Establish assessment criteria for quantity and quality of interaction. This will not only motivate the students to interact but will provide the instructors with feedback that can be used to modify the student activities.
- Provide a relevant context for collaboration. The topics recommended by students for future e-mail correspondence supports the fact that relevancy is an important factor to consider. Students would probably have chosen such topics as lesson plans, classroom management techniques, and hands-on activities and resources over discussing constructivism in science education.
- Maintain flexibility and remember that "Murphy's law" applies to technology, perhaps more so than it should.
- Provide some class time for on-line discussions rather than trying to do it only as an after class assignment.
- Develop similar goals, objectives, assignment guidelines, and assessment criteria at each participating university. Every attempt should be made to work concurrently between universities.

Future studies are needed to extend and refine the findings of this study. Other models of e-mail collaboration using relevant and constructivist-orientated contexts will need to be established and tested. For instance, students might use e-mail collaboration to work cooperatively to develop and modify lesson plans for field teaching. During or following the teaching experience, e-mail collaboration could provide an important source of reflection and feedback which would allow the pre-service teachers to make important changes in their teaching knowledge, process, and materials. Clearly, the user must value the e-mail medium and have some intrinsic motivation for using it (Stuhlmann, 1994). Future research must also develop and test assessment strategies that work effectively with e-mail collaboration. For example, students inquiries and responses might be graded on various factors such as originality, motivation, frequency of response, punctuality of response, concept development, concept connections, and Bloom's taxonomy. A mechanism for monitoring students successes and failures might involve forwarding all correspondence received as well as sent out to the course instructor. While this would require greater orchestration on the part of the instructor who would have to remind reticent students to interact, etc., it should lead to more productive discussions.

Additional studies will need to investigate ways that communication with e-mail can be enhanced. For example, to reduce the depersonalizing nature of the medium students could ftp pictures of themselves as "gif" or "jpeg" files. If the universities are relatively close an initial field trip meeting could be very useful. Further, teleconferencing tools such as "Cu-SeeMe" (Cornell University, in Ithaca, New York, USA) could be useful at the beginning and during the experience.

In sum, this study has shown there are many issues to consider and numerous problems to be overcome when integrating e-mail collaboration within science methods courses. Many of the problems encountered in this study resulted from lack of student knowledge, access to technology, and commitment to using the technology. The authors feel that many of these problems can be overcome with better planning, orientation, training, technological availability, inter-university integration, and assessment.

Our nation seems to be moving toward a mixture of the "haves" and the "have nots" based on those who have control over the technology and those who do not. It follows, the power of technology is determining the "haves" and the "have nots" of the science teaching profession. The future uses of telecommunication technology offer exciting possibilities for improving science-teacher preparation and creating a collaborative community of reflective practitioners. It is the responsibility of science educators to catch the rapidly expanding wave of technology and ride it toward new horizons for the benefit of not only our students but for our students' students. As educators of teachers we must pay careful attention to Goal #4 - Teacher Education and Professional Development of the National Education Goals Report - Building a Nation of Learners (1995) which states:

> By the year 2000, the nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century... All teachers will have continuing opportunities to acquire additional knowledge and skills needed to teach challenging subject matter and to use emerging new methods, forms of assessment, and technologies.

Although interactive collaboration is a powerful tool it will require the combined efforts of teachers, students, and perhaps even media/technology staff experts before it can become a viable addition in science methods classes. We are open to working with our colleagues in the future on such e-mail collaboration projects and welcome your feedback on this paper.

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RESTRUCTURING SCIENCE TEACHER EDUCATION THROUGH PROFESSIONAL DEVELOPMENT SCHOOLS: THE SEAMLESS FIELD EXPERIENCE MODEL FOR SECONDARY SCIENCE TEACHER PREPARATION

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Introduction

Science teacher preparation includes the acquisition of both knowledge and skills. Effective science teachers must be knowledgeable not only about the science content that is to be taught, but also about schools and schooling, children, and pedagogy. They must also be skillful in the many components of teaching science. Rosario and Ison (1991) maintain that central to any teacher education program should be its field-based component where students have the opportunity to observe good teaching in progress, assist in teaching under the guidance of a master teacher, and conduct their student teaching experiences. These field-based experiences are the link between theory and practice.

One way to maximize this field component, is for these on-site experiences to be conducted in K-12 schools where classroom teachers are directly involved in the planning for the preparation of the new teachers. In schools such as these, where pre-service teachers are mentored by teachers who have direct input into the teacher preparation program, student teaching is the culmination of a series of coordinated activities which smoothly advances the pre-service teacher from classroom observation through the full-time teaching practicum. In order to assure a seamless series of on-site experiences, an instructional team composed of university faculty and classroom teachers must coordinate on-site activities and K-12 expectations with the university teacher-preparation curriculum. Professional development schools have been found to be ideally suited to this type of collaboration.

Pre-service teachers in many traditional university programs take university courses in foundations and methodology and then "do student teaching" in K-12 schools away from the university and with little contact with their university professors. In spite of the nearly unanimous conclusion that student teaching is the most important component of teacher preparation programs (Yager, 1990) supervising teachers often know little of the teacher preparation program, and may also be unfamiliar with particular strategies or modes of teaching promoted by university professors. Goodlad (1994) noted that when pre-service teachers arrive at the schools for their student teaching, their connection to the university campus and their former professors dropped off quickly. Success in the student teaching practicum may then require student teachers to adapt the teaching methodologies of their supervising teachers even when those methods contradict theories or practices promoted in university courses. Professors complain that students forget everything learned in methods classes and that supervising teachers stifle the creativity of student teachers; supervising teachers protest that professors know little of the real world of teaching.

The use of the Seamless Field Experience Model for Secondary Science Teacher Preparation can provide a smooth transition from the university classroom to classroom teaching through field experiences and student teaching conducted at professional development schools (PDSs) or professional development centers (PDCs). These schools provide an improved environment for both the education of children and the professional preparation of future teachers. Winitzky, Stoddart, and O'Keefe (1992) describe PDSs as showing great promise because they link universities with public schools. The Holmes Group suggested (1986) that these schools and university departments of education can be as close to each other as hospitals are to medical schools.

A PDS is an elementary, middle, or high school in which teacher education occurs along with the education of the school children. Schools in which only a portion of the school's teachers are directly involved with teacher preparation are often called professional development centers (PDCs). In a middle or high school PDC, teachers from selected departments such as science, or just a few teachers from each department, may elect to work with a university in the teacher preparation program.

Historical Perspective

One of the first organized means of providing prospective teachers with on-site experiences was through campus or laboratory schools which were run by universities or teacher training colleges. The Horace Mann School, established in 1887 by Teachers College at Columbia University, and the Laboratory School established by John Dewey at the University of Chicago were two of the first. They provided the model for hundreds of other laboratory schools which were established in the first half of the twentieth century.

Dewey (1896) argued that teacher educators needed a teaching laboratory in the same way that scientists needed research laboratories. His still extant Laboratory School at the University of Chicago was dually centered around educational research, which he considered very important, and field experiences for pre-service teachers.

> The conception underlying the school is that of a laboratory. It bears the same relation to the work in pedagogy that a laboratory bears to biology, physics, or chemistry. Like any such laboratory it has two main purposes: (1) to exhibit, test, verify, and criticise [sic] theoretical statements and principles; (2) to add to the sum of facts and principles in its special line. (Dewey, 1896, p. 417)

Laboratory schools were usually not connected to local school systems but were run by a college of education on the university campus. They were envisioned as places where the best teaching would occur and therefore were superb places for student teaching to occur. However, being directly connected to higher education, they were also convenient places where research could be conducted and new teaching methods could be tried. The Chicago and the Horace Mann school's emphasis on research was the stimulus for the formation of scores of other such college-related schools across the country.

The popularity of lab schools reached its height in 1964 when there were 212 of them (Kelley, 1964). However many researchers believed that lab schools did not represent a cross section of American schools and that authentic research should therefore be conducted in "real" public schools. As a result, lab schools became locations where good teaching, but less research was being done. By the 1950s they became more of a centralized location for the initial teaching experiences of undergraduate students than the locale for a thorough study of pedagogy. Stallings and Kowalski (1990) maintained that by the mid 1980s, based upon the a study of the origin of articles published in research journals, the contribution of laboratory school-based research to the development of theories of pedagogy was very small. With less research being done, there appeared to be less reason for universities to administer them. Laboratory schools were seen by some as sites which did not reflect the "real world" and were therefore unsuitable for student teaching experiences. Indiana University at Bloomington was one of many schools to close its middle and high laboratory school in the 1970s although it still operates an elementary lab school. By 1988 there were fewer than 100 left. (Stallings and Kowalski, 1990)

A Nation At Risk (1983) and other calls for reform in the 1980s spurred the rethinking of the places where teachers should receive their on-site experiences. In *Tomorrow's Teachers* , (1986) the Holmes Group recommended the establishment of professional development schools (PDSs) and made the comparison of PDSs with teaching hospitals used by schools of medicine. Darling-Hammond (1994) proposes that the analogy of teaching hospital can be extended, because the PDS aims to redesign university teacher preparation programs as they change the teaching profession. The Holmes Group report suggested establishing partnerships between universities and public school districts to operate these schools where classroom teachers, school administration, and university faculty would work together to educate school children as well as to prepare new teachers.

Specifically these schools would be based on:

1. Reciprocity or mutual exchange and benefit between research and practice;
2. Experimentation or willingness to try new forms of practice and structure;
3. Systematic inquiry or the requirement that new ideas be subject to careful study and validation; and
4. Student diversity, or commitment to the development of teaching strategies for a broad range of children with different backgrounds, abilities, and learning styles. (The Holmes Group, 1986, p. 67)

Where educational research was a major component in the original conception of laboratory schools and in the Holmes Group's report (1986), its role has been downplayed in other proposals for professional development schools. Schlechty, Ingwerson, and Brooks (1988) proposed a two-fold mission for professional development schools:

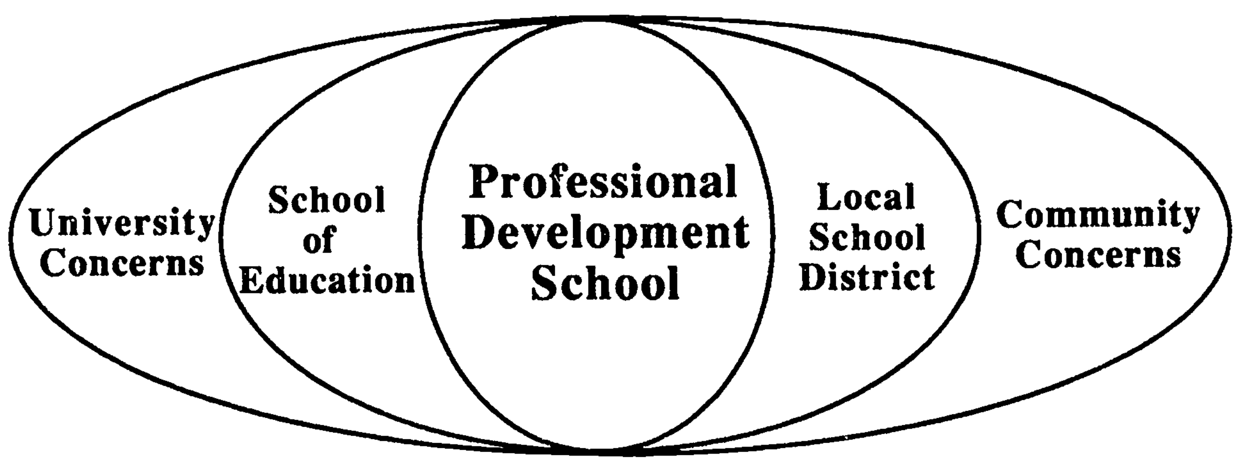
1. To provide exemplary programs for students, while,
2. Providing for the systematic induction of new teachers and administrators into the school system.

However, in *Tomorrow's Schools* (1990), the Holmes Group, proposed that, over time, the established means of introducing new ideas about teaching into all schools should be through these professional development schools.

Collaboration in Professional Development Schools

As a PDS serves both the university student and the classroom student, both school district and university have a stake in its success and input from both is vital in its planning. Figure 1 shows the overlapping spheres of interest of school districts and their communities with universities and schools of education.

Figure 1
Collaboration Model for Professional Development Schools



Shroyer, Ramey-Gassert, and Wright (1995) argue that teacher preparation and school reform are the joint responsibility of institutions of higher education and school systems. They note that professional development schools established by Kansas State University are intended as sites where classroom teachers, students and university faculty create new knowledge about teaching while testing, evaluating and revising new teaching practices.

The collaborative nature of PDSs allows for the modeling of exemplary teaching based upon sound scientific and educational research. As such, they reflect the 1992 National Science Teachers Association Standards for Science Teacher Preparation. Planning meetings between PDS cooperating teachers and university faculty can lead to a confluence of curricula whereby the experiences planned for the pre-service teacher are coordinated with experiences planned for K-12 students.

The major component which results in improved science teacher preparation at a PDS is the collaborative planning and support provided by science education instructional teams. If a bridge is truly to be built between theory and practice, and if what is taught in the university classroom can actually be observed and practiced in the K-12 classroom, then university professors and classroom teachers must form a team to plan and coordinate the program. These instructional teams must collectively review best practices in teaching and assessment, plan field experiences which will be available or required at the PDS, meet with the pre-service teachers to plan and review progress, and reflect upon the curriculum and revise as necessary.

The use of instructional teams is a route to school reform in that instructional team meetings can provide a forum where new ideas can be introduced and where recent documents such as *Benchmarks for Science Literacy: Project 2061*, NSTA's *Scope, Sequence and Coordination,* and the National Research Council's *National Science Education Standards* can be discussed and incorporated into the curriculum.

Grimmett and Ratzlaff (1986) argued that student teaching "promises more than it can deliver." They felt that the role of the cooperating teacher was not well defined and that cooperating teachers are often unprepared for the role of supervisor of student teaching experiences. Young and Copenhaver (1993) found that assigning field requirements was a component of teacher preparation in need of revision. They also noted that cooperating teachers feel that they need to be included in the planning for on-site experiences. The use of teams where university professor and classroom teacher work together to plan and deliver the teacher preparation program can make promises that will be delivered.

At the onset of discussions, instructional teams must determine the scope of their collaboration. For instance, in some collaborations the professor's course syllabus is part of the discussion, in others (such as that at Indiana State University) only the field experience portion of the course is discussed, the syllabus is considered the professor's domain (Sandoval, 1995). An agreement in advance on the scope of the team's domain is essential to preventing feelings of uncooperativeness later.

The Urban Teacher Education Program

The Urban Teacher Education Program (UTEP) in northwest Indiana is a collaborative of Indiana University Northwest (IUN) and the three urban school districts of Gary, Hammond, and East Chicago, Indiana. IUN, located in Gary, is a commuter campus and most of its graduates remain in the northwest Indiana area after graduation. The program was designed in 1988 as a local, urban response to the many national calls in the 1980s for curriculum reform in teacher education and the Holmes Group's call for the development of professional development schools. Most of the funds to plan and operate the program have come from grants from the Lilly Endowment, Inc.

Although the program was specifically designed for urban schools, it has great applicability beyond the urban area. Teitel (1992) argues that PDS-inspired procedures, to be at all long-lasting, must be institutionalized. That is the case with UTEP as many lessons learned from the program are currently being incorporated by Indiana University Northwest to apply to all students.

Since its inception, UTEP field experiences have been housed in professional development centers. Three public schools, one elementary, one middle, and one high school are used as part of this school-university partnership. At the secondary level, the program has parallel programs in

English, foreign language, social studies, mathematics, and science. Each of the participating districts has one school designated as a PDC.

Each of the three UTEP PDCs has a full-time coordinator similar to the teacher facilitator described by Winitzky, Stoddart and O'Keefe (1992). The UTEP coordinator creates observation and seminar schedules for university students, acts as the school district liaison with the university, advises university students and observes them as they teach, assists with student recruitment, participates in program planning activities, and handles the day-to-day operations of the UTEP PDC office. For the length of the Lilly Endowment grants, each of the coordinators were assisted by a half-time PDC secretary and a Parent Liaison. The UTEP coordinators were chosen from the teaching staffs of the respective school districts.

Instructional teams, composed of classroom teachers, the PDC coordinator, and university professors, are the key to successful collaboration at the PDCs. These teams review the course syllabi and design the field work for the potential teachers. The teachers bring to the table recent classroom experience and a knowledge of what has worked in the past; the professors bring their experiences in teacher preparation, syllabi of previous years' courses, and suggestions for improvements. Together they design the "seamless" field component of the program which parallels the science methods courses taught by the professors. The UTEP collaboration has resulted in a cadre of teachers who are very committed to teacher preparation. Because the teachers are directly involved in the creation of the field program, they understand the value of each component and arrange their classroom activities and their time so that the pre-service science teachers can observe, assist with, and teach a variety of science lessons.

Students in the UTEP program are not placed in isolated classrooms; rather their school experiences are within a community of educators. Several Teacher/Instructors work with each student during the year-long practicum; they open their classrooms to the students and present seminars to the pre-service teachers. Seminar topics have included parent conference skills, grading techniques, union contracts and teacher rights, and social services available in the community. Periodically, the PDC coordinators audit university courses so that they may effectively arrange experiences for the university students. They also are able to help the student integrate information from earlier methods classes. Each UTEP student has a support team composed of the supervising teacher, university professor, the PDC principal, and the PDC coordinator. Sandoval (1995) noted that both professors and classroom teachers in the Urban Teacher Education Program indicated that they learned from one another and believed that the integration of theory and practice was advanced.

Table 1
First Semester Field Experience Requirements for Secondary Science Students

1. Observe a science lesson and identify the Indiana Proficiencies which occur in the lesson.
2. Observe students taking part in a science lesson and describe the aspects of the lesson which would appeal to cognitive, affective, and psychomotor learners.
3. Perform duties related to teaching such as taking attendance or preparing bulletin boards.
4. Examine the science curriculum in terms of goals, objectives, resources, classroom facilities/equipment, teacher interests, instructional practices, and student evaluation.
5. Reflect on the design of several different teaching methods with your teacher/instructor.
6. Review safety rules with your teacher. Observe a classroom while students are engaged in a laboratory activity, identifying what safety precautions students take to avoid accidents.
7. Evaluate a lab activity in terms of objectives and efficiency. Prepare and deliver a lab exercise.
8. Create, administer, and grade a quiz or other form of student assessment.
9. Design and teach two lessons Videotape, if possible.
10. Reflect with your teacher/instructor on the effectiveness of the above activities.

As a result of the belief that PDSs are better places for pre-service students, the IUN Division of Education is currently moving towards a PDS model for all its pre-service teachers incorporating many components of the UTEP program.

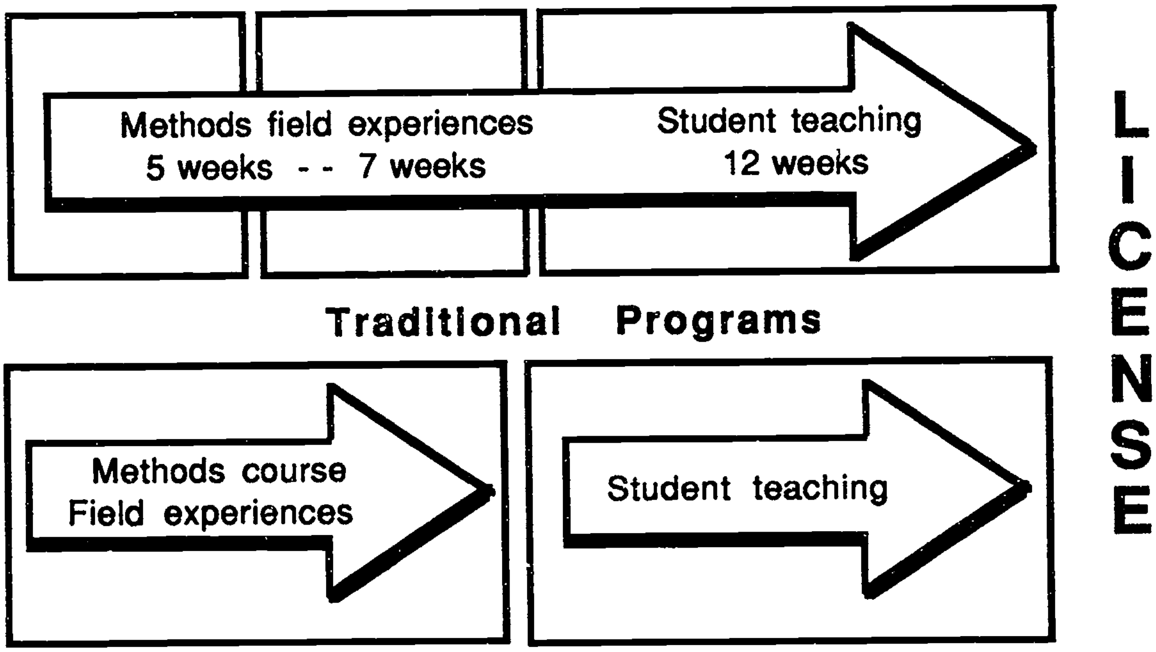
The Seamless Field Experience Model for Secondary Science Teacher Preparation

An innovative model of secondary science teacher preparation has grown out of deliberations at instructional team meetings of this collaboration. The foundation for this model is the instructional team itself composed of the cooperating teachers, the university professor, and the PDC coordinator. Yager (1990) asserts that the philosophy, style, and actions of cooperating teachers may be more important than any other component of teacher preparation programs. In many programs the cooperating teacher is relatively unknown to the university. In some cases the cooperating teacher is at a school hundreds of miles away from the university campus. The use of instructional teams in this model ensures that the cooperating teacher and the university supervisor know each other and are in agreement on program expectations.

Yager (1990) argues that student teaching should be a continuation of a coordinated program. In the Seamless Model, pre-service secondary (middle and high school) teachers spend two semesters during their professional (senior) year conducting field experiences at the PDCs. During the fall semester, students spend one day a week for twelve weeks at the school observing classes, assisting the cooperating teachers, and teaching various science lessons. Beginning in January, student teaching is conducted in the same PDC classroom with the same students. The support team for the student teacher remains the same as well with the methods professor serves as university supervisor for the student teaching experience. Unlike traditional student teaching experiences, these pre-service teachers begin student teaching known by their students and knowledgeable about the school and its curriculum.

This model helps eliminate some problems often associated with student teaching. For instance, Richardson-Koehler (1988) noted that university supervisors, who are unknown to student teachers at the beginning of the student teaching experience, are often unable to spend enough time with them to build trusting relationships. She also noted that university supervisors often rushed into and out of schools and so had no time to acquaint themselves with the schools or the classrooms where their student teachers were assigned. In the Seamless Model, the methods professors confer with the cooperating teachers in developing field assignments and also serve as university supervisors during the student teaching practicum, so they become well known to both the student and cooperating teachers.

Figure 2
The Seamless Field Experience Model for Science Teacher Preparation



Zeichner (1992) laments that much literature on reflection ignores the advantages of teachers reflecting together. Feiman-Nemser and Buchmann (1987) similarly maintain that one of the jobs of cooperating teachers is to talk with their student teachers about what they themselves do and why they do it. They and Richardson-Koehler (1988) noted that cooperating teachers often were unable or at least unwilling to engage in post-class reflection. The Seamless Model draws upon the practice advanced by the Urban Teacher Education Program that reflection is a social process whereby the cooperating teacher and student discuss the day's events often in the company of the PDC coordinator. Reflection as a process of reviewing teaching practices is stressed at PDC meetings and workshops. After visits to the classroom by the university supervisor the student teacher and entire team sit and reflect upon the just-finished lesson and upon student teacher progress in general.

State of Indiana secondary licenses allow one to teach at both the middle and high school level. Therefore pre-service science teachers at Indiana University Northwest divide their time during the fall semester between the middle and high school PDCs. In the spring, if students elect to do their student teaching at the high school, they begin by spending 5 weeks at the middle school PDC, then spend 7 weeks at the high school PDC. At the high school, they work with the same teacher that they will work with during student teaching. Students who elect middle school student teaching follow a similar program but begin their work at the high school level. The Seamless Model in graphic form is shown below in Figure 2.

Yager and Penick (1990) note that in exemplary centers of teacher preparation, students are required to spend more time in K-12 classrooms than traditional programs require and that these field experiences, which are spaced throughout the program, include teaching at a variety of grade levels. At IUN, all secondary education students take general methods and reading methods courses during their junior year and science methods and student teaching during their professional or senior year. Field experiences in nearby schools are required for all three of these sequential methods courses preceding student teaching.

Science methods field experiences, both elementary and secondary, must be more than simply observing teaching in progress. For UTEP students, they include a variety of activities which lead the pre-service teacher to the planning and delivery of science lessons. Each day in the field includes a period of reflection with the Teacher/Instructor. Setting aside this time for reflection is an important part of the teacher preparation process. The university students are encouraged to suggest other ways in which the day's lesson could have been delivered and how that change might have affected the classroom students' understanding. Prior to the beginning of each school year, the science instructional teams meet to establish the specific activities which will be required of students. A field check-list is then devised by the team to guide the student through the methods semester.

The required field experiences are drawn up with the student teaching experience and certification in mind. The semester moves smoothly from observation, to assisting with teaching, to planning and teaching science lessons. Activities which will prepare students for teaching are planned for the beginning of the methods semester while teaching strategies are discussed at the university. Students who follow this model usually begin teaching during their first week of the student teaching semester.

Creating and Using Professional Development Schools

A true collaboration of K-12 schools and universities is not an easy creation. From the onset, the establishment of a new PDS must involve school and university administration as well as classroom teachers and university professors (Winitzky, Stoddart, & O'Keefe, 1992). A PDS can best prosper if all those involved claim some ownership of the program. Rosario and Ison (1991) argue that for successful PDSs to form, there must be the creation of a true collaborative environment.

Communications in many school/university collaborations have been uneasy or strained (Goodlad, 1990; Levine, 1992). Sandoval (1995) credits disconnection to an imbalance of power among partners. She notes that feelings of inferiority may enter into the collaboration. Teachers may feel inferior as they do not have a terminal degree while at the same time feel morally superior because they feel that they know more about teaching practice than do university professors. University professors, who have a higher status than classroom teachers, may act in an arrogant manner. Successful collaboration, however, requires that professors and teachers demonstrate mutual respect. The expertise of both is critical.

The UTEP program has benefitted because its teacher representation included both classroom teachers who were likely work with the university students and teacher union representatives. Teacher organizations, such as the American Federation of Teachers, have expressed strong support for programs which improve teacher preparation (Levine, 1992). Their input and support is vital as the traditional role of teacher changes with the influx of university students into a school. Other aspects of the school to consider are the size of the school, its leadership, climate, and population. Haberman (1987) and Zeichner (1992) maintain that field experiences should be in schools with economically and culturally diverse student populations. Otherwise student teachers may graduate having no experience or desire to teach students unlike themselves. The Holmes Group (1986) also recommended schools with multicultural staff and students. The best schools to employ as PDSs are those which are already involved in school improvement.

The site coordinator, who should be a school-based person--preferably a teacher--needs to be appointed to coordinate student placement and be the PDS liaison with the university. This position may be full or part time depending upon the local situation. This program used full-time coordinators who primarily worked at the PDC but also attended meetings at the university. Other considerations include secretarial support, equipment use, and space designated for the PDS coordinator, for instructional team meetings, student counseling, and administrative duties.

Finally, instructional teams in each subject area (or science only if a science PDC is being established) need to begin meeting to establish goals and objectives of the field experience component of teacher preparation. PDS programs for science need to be compared with current teacher-preparation guidelines such as the Standards for Science Teacher Preparation published by NSTA in 1992 .

PDS collaboration is time intensive. Traditionally teachers are given no more than one class period for planning, and as planning periods usually are not concurrent with each other, teachers can discuss programmatic matters only before or after school or during lunch periods. Both classroom teachers and university professors have noted that sufficient time to plan and reflect is a commodity in short supply (Sandoval, 1995; Winitzky, Stoddart, & O'Keefe, 1992). Sandholtz and Merseth (1992) argue that PDS programs must provide means to compensate teachers for the demands on their time.

Summary

Pre-service science teachers have for many years been required to complete pre-student teaching field experiences along with their university coursework. However, in the past these experiences were usually conducted with willing teachers in nearby schools who had little if any contact with university faculty and certainly had no ownership of the science teacher preparation program. Student teaching was then done in schools often distant from the university campus and with little coordination with the methods semester. Often neither the methods field experience cooperating teacher nor the critic teacher for student teaching had any contact with each other or with the university.

Professional development schools, described by Stoddart (1993) as a "brave new vision," are an outgrowth of the common interest that universities and K-12 schools have in both the improved education of school children and the improved preparation of classroom teachers. Universities hope for better prepared students while school systems want better prepared teachers. The professional development school can work towards both goals. The use of PDSs can help build a bridge between theory and practice. The Urban Teacher Education Program in northwest Indiana has, for five years, prepared both elementary and secondary teachers in professional development schools located in Gary, Hammond, and East Chicago, Indiana.

The Seamless Field Experience Model for Secondary Science Teacher Preparation is based upon a professional development school collaboration of university personnel, classroom teachers, and school-system administration. In this model, students spend two semesters during their professional (senior) year conducting field experiences at the PDCs. A field experience course which parallels a science methods course is held in the fall and student teaching in the same classroom is conducted in the spring. Instructional teams, composed of the university professor, the cooperating teachers and the PDC coordinator plan, deliver, and assess the field experience components including methods course experiences and student teaching. The same cooperating teacher and university supervisor work with the student during both semesters.

The establishment of a new PDS must involve school and university administration, classroom teachers, and university professors. A successful collaboration requires that professors and teachers demonstrate mutual respect. The expertise of both is needed. Field experiences should be in schools with economically and culturally diverse student populations. Other components to consider are the size of the school, its leadership and climate, and space requirements. The best schools to employ as PDSs are those which are already involved in school improvement. Programs must provide means to compensate teachers for the demands on their time.

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Initial Development and Validation of a Scale to Self-Evaluate the Implementation of the Learning Cycle

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The learning cycle has been shown to be an effective instructional model that has widespread applicability to a variety of grade levels and course materials (Purser and Renner, 1983; Saunders and Shepardson, 1987; Barman, 1990; Barman and Shedd, 1992; Allard and Barman, 1994). Originating in an elementary science program called Science Curriculum Improvement Study (SCIS), the learning cycle is an activity-oriented approach consisting of three distinct phases: (1) exploration, (2) concept introduction, and (3) concept application. During the exploration phase, students engage in a motivating activity as the basis for developing a specific concept and related vocabulary. The exploration activity also allows teachers to explore with students their existing ideas about the concept and identify any inaccuracies in their views of the natural world.

The second phase, concept introduction, takes place after the students have had ample time to complete the exploration activity. As the students discuss the results of the exploration activity, the teacher uses this information to introduce the main concept of the lesson as well as relevant vocabulary.

The final phase, concept application, gives the students the opportunity to use the information they have acquired in the exploration and concept introduction to one or more new situations. Ideally, the application activities will have a direct relationship to the students' everyday experiences.

To successfully implement the learning cycle, teachers must possess a variety of effective teaching skills. For example, they must be able to use effective strategies to assess students' prior knowledge, they must be able to use good questioning techniques, and they must be able to engage students in hands-on/minds-on activities. The purpose of this project was to develop a valid and reliable instrument to assess preservice and inservice teachers' ability to use the requisite skills necessary to effectively implement the learning cycle.

Bandura (1986) theorizes that individuals perceive proficiency by organizing the cognitive, social, and behavioral skills needed to perform a specific task into integrated courses of action. In other words, for individuals to gain the proficiency or to perform a task, they must develop the requisite skills to successfully complete the task and they must possess the cofidence that they can effectively use these skills. To apply Bandura's theory to the effective implementation of the learning cycle, a person would require the appropriate skills to facilitate all three phases of this teaching model and would also have confidence in his/her abilty to perfom this task.

Analysis Techniques Used

The instrument (see appendix) was admimistered to 96 preservice teachers. Item response theory (IRT) was used to build and evaluate this instrument. Advantages of using this model are that the possible non-linearity of rating scales can be corrected and standard errors of measurement are calculated for each respondent and survey item. Also fit statistics based upon Guttman patterns can be used to identify items that are causing idiosyncratic responses on the part of individuals. Rasch (1969), Andersen (1977), and Wright and Masters (1982) can be consulted for an explanation of item response theory.

Results

Idiosyncratic Item and Person Behavior

The use of so-called fit statistics to evaluate the way in which items do and do not work together to define a scale provides a robust way of evaluating the functioning of a scale. In general, fit statistics suggest that the majority of the items used in the survey seemed to work well with the students. This meant that a student's answer to an item could predict their answer to other items presented in this survey. In addition to investigating idiosyncratic behavior of items, person fit statistics were used to investigate whether or not particular individuals (or groups of individuals) behaved in a strange manner with regard to this set of items. Evaluation of person fit statistics suggested that only two of the 96 students sampled behaved in a somewhat unpredictable manner with regard to this scale. A person separation reliability was calculated to be .89, while an item separation reliability was calculated to be .87.

Selection of Response Categories

Of the 1,533 single response selections, 15% were strongly agree category, 42% were the agree category, 32% were the somewhat agree category, 9% were the somewhat disagree category, 2% were the disagree category, and less than 1% were the strongly disagree category. This suggests that with this population of respondents, the disagree and strongly disagree categories provide almost no information regarding respondents, while the three agree categories appear to be critical.

Patterns and Non-Patterns in Responses

For this section, Figure 1 is used to show all of the items in one single plot, while figures 2-4 are used to show the survey items as a function of learning cycle phase. In general, the survey items fell into three major groupings: Group 1 (Item 9); Group 2 (Items 1-8, 10, and 12-16); Group 3 (Items 6 and 11). Item 9 (I consistently use students' observations from the exploration phase to begin a discussion) was rated very positively by students. This meant that this item stood the greatest chance of being given an "agree" rating. Item 11 (I consistently ask students to use new vocabulary to explain the lesson's concepts) was the item that was most difficult for the students to agree with. Item 6 (I consistently use techniques that encourage students to question their views) was also difficult for the students to "agree" with. The remainder of items fell in a large group between the supportive rating given to item 9 and the not as supportive rating given to items 6 and 11.

FIGURE 1

On Average More Likely to Be Answered as Agree

1

Q

Q9-CI-I consistently use students' observations from the exploration phase to begin a discussion.

S

Q8-CI-I consistently use both open and closed questions. Q14-CA-I consistently have students demonstrate they can apply the lesson's main concept(s).

Q13-CA-I consistently use both open and closed questions. Q16-CA-I consistently ask questions that require students to use the main concept(s) of the lesson to generate new ideas.

Q3-EP-I consistently use both open and closed questions.
Q15-CA-I consistently use appropriate techniques to assess students' understanding of the lesson's main concept(s).
Q1-EP-I consistently assess students' prior knowledge of the subject.

M 0 Q10-CI-I consistently use students' ideas from the exploration phase to develop the main concept(s) of the lesson.
Q5-EP-I'm consistently able to engage students in a hands-on/minds-on activity.
Q12-CA-I consistently use adequate wait-time (3 seconds or longer) between questions.

Q4-EP-I consistently help students collect data by suggesting ways to obtain information.
Q7-CI-I consistently use adequate wait-time (3 seconds or longer) between questions.
Q2-EP-I consistently use adequate wait-time (3 seconds or longer) between questions.

S

Q6-EP-I consistently use techniques that encourage students to question their views.

Q

Q11-CI-I consistently ask students to use new vocabulary to explain the lesson's concept(s).

-1

On Average More Likely to Be Answered as Agree Somewhat

The ordering and spacing of survey items resulting from an analysis based upon a probabilistic model. Those items at the top of the page represent those items which (from a probabilistic standpoint) are most likely to be answered with the selection of the Agree response. Those items at the base of the page are those that are most likely to be answered with the selection of the Agree Somewhat response. The standard error of all calibrated survey items is roughly that displayed for item Q6. EP is used to indicate an item involving the exploration phase; CI is used to indicate an item involving the concept application phase.

In general, it appears that regardless of learning cycle phase, the students feel it is easier to use both open ended and closed questions than it is to have adequate wait time between questions. In addition, if one compares the distribution of spacing of survey items for the exploration phase (Figure 2) to that of the concept introduction phase (Figure 3) and the concept application phase (Figure 4), it seems that the average responses of the students to the items of the concept introduction phase are spread over a much greater range of "attitude" than is the case for the exploration and concept application phases.

FIGURE 2
Exploration Phase Items

On Average More Likely to Be Answered as Agree

1

Q

S

Q3-EP-I consistently use both open and closed questions.

Q1-EP-I consistently assess students' prior knowledge of the subject.

M 0

Q5-EP-I'm consistently able to engage students in a hands-on/minds-on activity.

Q4-EP-I consistently help students collect data by suggesting ways to obtain information.

Q2-EP-I consistently use adequate wait-time (3 seconds or longer) between questions.

S

Q6-EP-I consistently use techniques that encourage students to question their views.

Q

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-1

On Average More Likely to Be Answered as Agree Somewhat

The ordering and spacing of survey exploration phase items resulting from an analysis based upon a probabilistic model using all the survey items. Those items at the top of the page represent those items which (from a probabilistic standpoint) are most likely to be answered with the selection of the Agree response. Those items at the base of the page are those that are most likely to be answered with the selection of the Agree Somewhat response. The standard error of all calibrated survey items is roughly that displayed for item Q6.

FIGURE 3
Concept Introduction Phase Items

On Average More Likely to Be Answered as Agree

1

Q — Q9-CI-I consistently use students' observations from the exploration phase to begin a discussion.

S — Q8-CI-I consistently use both open and closed questions.

M 0 — Q10-CI-I consistently use students' ideas from the exploration phase to develop the main concept(s) of the lesson.

Q7-CI-I consistently use adequate wait-time (3 seconds or longer) between questions.

S

Q

Q11-CI-I consistently ask students to use new vocabulary to explain the lesson's concept(s).

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-1

On Average More Likely to Be Answered as Agree Somewhat

The ordering and spacing of concept introduction phase survey items resulting from an analysis based upon a probabilistic model using all 11 survey items. Those items at the top of the page represent those items which (from a probabilistic standpoint) are most likely to be answered with the selection of the Agree response. Those items at the base of the page are those that are most likely to be answered with the selection of the Agree Somewhat response. The standard error of all calibrated survey items is roughly that displayed for item Q7.

FIGURE 4
Concept Application Phase Items

On Average More Likely to Be Answered as Agree

1

Q

S — Q14-CA-I consistently have students demonstrate they can apply the lesson's main concept(s).

Q13-CA-I consistently use both open and closed questions.

Q16-CA-I consistently ask questions that require students to use the main concept(s) of the lesson to generate new ideas.

Q15-CA-I consistently use appropriate techniques to assess students' understanding of the lesson's main concept(s).

M 0

Q12-CA-I consistently use adequate wait-time (3 seconds or longer) between questions.

S

Q

-1

On Average More Likely to Be Answered as Agree Somewhat

The ordering and spacing of concept application phase survey items resulting from an analysis based upon a probabilistic model using all survey items. Those items at the top of the page represent those items which (from a probabilistic standpoint) are most likely to be answered with the selection of the Agree response. Those items at the base of the page are those that are most likely to be answered with the selection of the Agree Somewhat response. The standard error of all calibrated survey items is roughly that displayed for item Q14.

Discussion

The scale described in this paper appears to provide a measure of students' (self-evaluated) ability to use the learning cycle. This is suggested by the analysis techniques which indicate a lack of misfitting persons and scale items. Therefore, this initial scale appears to be a useful tool for those students (preservice and insrvice) interested in implementing the learning cycle. It provides feedback regarding specific requisite skills needed to effectively use this teaching model.

This scale could be used by students who are performing practicum or student teaching experiences and by inservice teachers that are trying to incorporate the learning cycle into their classroom instruction. The instrument could provide useful formative and summative feedback regarding their use of the learning cycle.

In addition, this scale could be used in conjunction with on-site observation. A student teaching supervisor or a teaching mentor could record their analysis of the student's use of the learning cycle. Using the results of this scale, the students could compare their perceptions of how well they presented the learning cycle lessons with those of the supervisor. This would provide an excellent basis for discussion and critique of each student's ability to implement this teaching model.

Although one use of this scale is to provide feedback to a preservice teacher or inservice teacher using the learning cycle, another by-product of this device construction is the consideration of whether there is a latent-trait for the learning cycle or whether there is a latent-trait for each component of the learning cycle. When new attitudinal measures are computed from sets of items, an assumption is made that a latent-trait exists.

Conclusions

This initial scale seems to be a useful tool in helping students assess their ability to use the learning cycle. However, several issues still need to be addressed regarding the scale's use and effectiveness. These issues include the following:

• What are the pros and cons of considering the set of items together (pooling the three different phases together)?

• Will the items maintain the same ordering and spacing when more data is collected?

• If there is an interest in differentiating students' attitudes (as opposed to looking at the ordering of items based upon a pooling of data) then some items from the scale might be dropped. For example, the items involving wait time were all answered in a similiar manner by respondents. Since this was the case, as much information about respondents could have been gathered by the administering of one of these items, as opposed to three of them.

• The low end of the rating scale was hardly used by students at all! Most of the information gathered from respondents was the result of their using the strongly agree, agree, and somewhat agree rating categories. In future versions of this scale, added categories might be added to the agree portion of the scale.

• How might the latent-trait that is conceptualized for the instrument (and hopefully verfied by the data) be used to help improve students' use of the learning cycle and guidance provided during science methods classes.

• We recognize that any self-assessment may not accurately describe the true performance of an individual to implement components of the learning cycle as detailed in this instrument.

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Appendix

Learning Cycle Self-Assessment Scale

Please indicate the degree to which you feel confident about using the learning cycle by circling the appropriate letters to the right of each item. SA = Strongly Agree; A = Agree; AS = Agree Somewhat; DS = Disagree Somewhat; D= Disagree; SD = Strongly Disagree

During the Exploration Phase:

1. I consistently assess students' prior knowledge of the subject.	SA A AS DS D SD
2. I consistently use adequate wait-time (3 seconds or longer) between questions.	SA A AS DS D SD
3. I consistently use both open and closed questions.	SA A AS DS D SD
4. I consistently help students collect data by suggesting ways to obtain information.	SA A AS DS D SD
5. I'm consistently able to engage students in a "hands-on/minds-on" activity.	SA A AS DS D SD
6. I consistently use techniques that encourage students to question their views.	SA A AS DS D SD

During the Concept Introduction Phase:

7. I consistently use adequate wait-time (3 seconds or longer) between questions.	SA A AS DS D SD
8. I consistently use both open and closed questions.	SA A AS DS D SD
9. I consistently use students' observations from the exploration phase to begin a discussion.	SA A AS DS D SD
10. I consistently use students' ideas from the exploration phase to develop the main concept(s) of the lesson.	SA A AS DS D SD
11. I consistently ask students to use new vocabulary to explain the lesson's concept(s).	SA A AS DS D SD

During the Concept Application Phase:

12. I consistently use adequate wait-time (3 seconds or longer) between questions.	SA A AS DS D SD
13. I consistently use both open and closed questions.	SA A AS DS D SD
14. I consistently have students demonstrate they can apply the lesson's main concept(s).	SA A AS DS D SD
15. I consistently use appropriate techniques to assess students' understanding of the lesson's main concept(s).	SA A AS DS D SD
16. I consistently ask questions that require students to use the main concept(s) of the lesson to generate new ideas.	SA A AS DS D SD

INTEGRATION AND UTILIZATION OF TECHNOLOGY BY SECONDARY PRE-SERVICE SCIENCE TEACHERS

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The pace of technological change is quickening. Some critics of American schools charge that our secondary schools have taken too little action to assure that graduates have the technical skills needed to function in our increasingly technologically oriented society (Barlow, 1992). Secondary schools today are under pressure to make students more personally familiar with emerging technologies which in turn influences teacher education programs to appropriately train pre-service teachers.

There is a general belief that students graduating from the secondary schools must have levels of expertise beyond a simple ability to use current technology. What is needed is technological competence (Armstrong & Savage, 1994). This implies a sophisticated cognizance of technologies that includes an ability to see novel applications and to expand the nature of the technologies themselves.

Procedure

Three universities in the southeastern United States participated in this longitudinal, multicase study. A series of questions was developed and is being utilized. This is an ongoing study with new case studies to be developed with each senior class of science education students. The data for this study were generated by pre-service secondary science teachers who were followed with the same set of questions over a year. The questions were asked at the beginning, middle and end of the methods course and then at the middle and end of the student teaching experience. The questions asked were:

- Define technology in your own words.
- During your entire school experience, how did you see technology used?
- What do you perceive is the role of technology in teaching in your content area?
- How do you think you will use technology in your classroom?
- Diagram the use of technology as it relates to your teaching area

After the second data collection, the authors decided to discard the last question. Students at all three schools were diagraming either the classroom there were doing their practicum in or one of the laboratories where they were taking classes.

The Setting and the Students

This study is being conducted at three universities in the southeastern United States. These universities are: College and University of Charleston, South Carolina; Jacksonville State University, Alabama; and Radford University, Virginia. Each category described by the pre-service teachers has data from each of the three universities. The samples chosen are typical of the data collected.

Data Analysis

Data were compared and analyzed at each collection point by the three investigators. Sequences of events or constructs about perceptions of technology and pedagogy were described. Subsequently, pattern analysis began and the results, to date, are described in this paper.

The data were collected using the questions as stated, with the hope that the open-ended format for answers would obtain data that was unbiased by research format or the investigators' prior conceptions.

The Interviews

Interviews were conducted after the pre-service teachers answered the questions listed above. The interviews were open-ended in nature so that the perceptions of the teachers could be elucidated in accordance with the from the inside perspective. Questions such as, "What does the line connecting computers to the nature of science mean?" and " You keep saying that there is a connection between science and technology, can you explain what you mean?"

Findings

The pre-service teachers initial conceptions of "What is technology?" were minimal. Most of the definitions from the first data collected were very simple minded, but described advance/complex equipment such as the space shuttle or the Hubbell telescope. The words used to define technology were either absent or stated, "tools to help us learn." Such words are in direct contrast to the items they listed as technology. Across the first semester of data collection, the definition expanded to mean, "tools to help us learn and that are created by people." Secondly, most students mentioned that technology, "made life easier," or "improved the human condition." Thirdly, students began moving beyond electronics and sophisticated equipment items and began including anything that, "...made the world easier or more fun" and "...anything that allows people to manipulate their environment."

Initially, students defined technology as separate, unattached, or unrelated to science. They defined technology by listing items. By the end of their methods class, some students had moved from seeing technology as a thing to seeing it as a process for discovery (e.g., from a "satellite" to "its the how to, to knowing").

Responses about using technology to teach science varied from no response to computers at the first data collection. By the end of their methods class, most students indicated the belief that teachers need to be very creative and "invent" technologies for the classroom since they are not likely to be many pieces of "expensive" equipment in the classroom. Most students found little technology in the science classrooms of their field experience prior to student teaching. Most felt they must either make or devise technology to run activities in their assigned classrooms.

In the classroom, most students noted that the schools they perceived as "richer" had more technology. They had microscopes, video disc players, computers and software, and other lab equipment. In fact, they had these supplies, they were in good condition, and there were plenty for the class. The students who were placed in schools they perceived as "poorer" found the opposite. They found old, broker, or no equipment to complete even the most rudimentary activities. These teachers began using any item or designing any item that would make the activity work. The efficiency of technology in teaching was emphasized by several student teachers. Many also began to view technology as anything that enhanced efficiency and allowed them to teach more material more quickly. Also apparent at this stage was and increasing awareness of the negative side effects of various technologies. Several students were concerned about the effects on the environment and the quality of human life. None of the participants mentioned the social benefits that could accrue via technologies nor expressed interest in the science behind the technologies.

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UTILIZING TECHNOLOGY IN ENHANCEMENT OF THE TEACHING OF SCIENCE

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The use of technology in the classroom can take place in a variety of ways and through the use of a variety of technologies. It is not the scope of this presentation to discuss the various technologies, but rather to look at one form of technology, the electronic computer and some quite basic applications in the science classroom.

Problems with Computer Usage

Several factors tend to impede the use of computers in the classroom, but perhaps some of the most compelling are a) insufficient teacher basic knowledge in the use of computers, b) teacher lack of training in application of solid teaching principles, c) lack of sufficient hardware, and lack of adequate software. The teacher in the classroom has the most control over the status of items a and b.

It seems safe to say that individual teachers of science have at best only one computer in his/her classroom or laboratory. The situation makes it rather easy for the teacher to dismiss the dilemma as unsolvable without further funding and administrative support. As a result the available single computer is used for record-keeping, word processing, and perhaps occasionally for data acquisition through an interface device.

Imagination can help turn a single computer into a useful and powerful tool for assisting students in facilitating their learning as well as upgrading their computer usage skills. Such imagination need not be glitzy, requiring the very latest in hardware and software. An integrated software such as ClarisWorks can offer the features of a word processor, a draw program, a paint program, a spreadsheet with associated charts, a data base, computer slide shows, clip art, templates, and a communication component. The power of the integrated program is in equipping the teacher or the students for incorporation of a number of the features into one cohesive document or presentation. For example, charts can readily be incorporated into a spreadsheet which in turn can be incorporated into a word processing document.

Upgraded ClarisWorks 4.0 can really add to computer activities, but for a good share of the work that one can do, ClarisWorks 2.0 is just fine. Such software gives one the capability of utilizing a word processor, a draw program, a paint program, and makes available several neat prepared graphics. One can prepare spreadsheets, data bases, and unique colored (or black and white) slide presentations. For more sophisticated slide presentations, a person might prefer to employ programs such as Aldus Persuasion which offers a fairly wide range of bells and whistles.

The Group Presentation

A unique device which can be used with the aid of a word processor is a group presentation with an LCD panel on an overhead projector. The teacher prepares a stimulating sentence or paragraph which identifies some science-related social issue or personal problem indigenous to the local area. The students in the class are invited to each in turn come up to the computer and enter a sentence or two which leads to the completion of a narrative and which is of interest to the students. Of course it can be done without the aid of a projection panel with students sitting in groups around the computer and taking turns at keyboarding. Such an exercise is great for introducing the new school year, semester, or a unit.

Data Bases

Data bases can be powerful teaching tools. They, of course, offer the features of setting up easily retrievable categories and offer the luxury of sorting, which takes the tedium out of finding desired data. The label option is useful in labeling specimens, categories, etc. The power of the data base as a learning tool is in establishing the fields of the data base. The students can brainstorm the needed and desired fields, which produces considerable learning prior to data entry.

Spreadsheets

Spreadsheets can be used in the data collection processes as well as in making observations. Again, the setting up of column and row headings can lead to increased learning and the development of computer skills. Spreadsheets are basically numerical devices. Therefore the student needs to be advised that functions cannot be manipulated unless the data are in numerical form. A common mistake is to place script in a spreadsheet cell and later attempt to conduct numerical calculations with that cell. Spreadsheets have the powerful feature of automatically graphing the entered data to conceptually observe relationships. Various types of graphs can enhance conceptualizations and show interrelationships of data.

Draw and Paint Function

The draw and paint functions can provide students with the ability to show the functions of various phenomena such as the strata of certain sections of the earth, cross sections of volcanos, trees, etc. A draw function can be used to sketch atomic models which can be enhanced through more non-discrete orbitals and the addition of color. Utilization of the "copy" feature aids considerably in the production of electrons of the same size and shape. Again such an exercise can aid the student in the development of computer skills.

Mini-Book

Students can also be involved in the production of a "mini-book" telling the story of some science phenomena or a phenomenon. The research of some facet of nature and the development of a story line can increase learning and serve as a motivation of student interest.

Newsletters

A newsletter about a unit science activity can be compiled by the students using a word processor. The draw function can add to the appeal of the newsletter. Graphics can be developed using the paint functions. Of course a color printer can enhance such a production to a great degree. The gathering of information for the newsletter can aid enormously in student learning and motivation. Such student activities can provide a wonderful link between the school, the home, and the community. A newsletter can effectively provide information to the parents or guardians as to the academic activities of their child. An activity such as this is a good promotional mechanism for the teacher as well.

The Internet

Use of the Internet, especially the World Wide Web, can greatly enhance the ability of students in data and information acquisition and the sharing of such around the world. However, a number of schools do not have the Internet available, but the number adding it is increasing.

Summary

Several examples have been cited for making use of a single computer in the classroom in infusing technology into the teaching of science. Activities such as these can be orchestrated around one computer by making various group assignments required for the completion of a product. Planning should take into consideration that all cannot use the computer at the same time. Data organizational planning, researching data, data gathering, data entry, and data analysis necessarily must take place at different times. Various groups of students can be involved with such activities and take their turns at the computer.

From the preceding discussion, one can see where it is rather easy to involve students with rudimentary activities with the computer leading to increased student benefits. As more and more technology becomes available to the teacher, the situation will improve. The one thing the teacher needs to have the most of is imagination. Imagination can turn even minimum facilities into learning and motivational enhancement.

PROJECT PRISM: TEACHERS, SCIENTISTS, AND SCIENCE EDUCATORS DEVELOPING CONCEPTUAL COMMON GROUND IN 1-9 SCIENCE EDUCATION

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Introduction

PRISM (Project to Improve Science Models) is a collaborative effort to redesign the University of Wisconsin-Eau Claire preservice elementary education sequence to reflect constructivist perspectives about science and science learning. Faculty from Arts and Sciences, the School of Education, and 43 elementary and middle school mentor teachers are constructing a two and a half year professional education sequence. Preservice teachers complete three science courses in biology, geology, and physics, a science methods course that builds directly on the science courses, and a concurrent set of two field experiences in PRISM mentor teachers' classrooms. Students completing the PRISM sequence thus experience seamless science education that connects the study of science to current methods of science teaching grounded in the realities of existing classrooms.

Core Science Courses

Through a variety of collaborative mechanisms, PRISM staff are developing and revising core courses in geology/earth science, biology, and physics. Each course is grounded in constructivist principles. Course content is informed, though not dictated, by current K-12 curricular reforms embodied in Benchmarks for Scientific Literacy and the National Science Education Standards. The courses are connected by important curricular themes (such as scale.

constancy and change, systems, and model building), by explicit attention to helping students take charge of their own learning, and by emphasizing the importance of understanding scientists' habits of thought, communication, and practice (Duschl, 1990).

The teaching strategies modeled in the core courses reflect contemporary arguments about successful conceptual change and collaborative learning strategies (AAAS, 1996; Hewson & Hewson, 1987; Lee & Anderson, 1993; Osborne & Freyberg, 1985). Students engage in collaborative model-building using historical and field data, engage in reflective and persuasive writing, pose problems, develop inquiry strategies for investigating them, and defend their results to peers and experts. Questions and demonstrations are designed to promote cognitive conflict by posing discrepant events, engaging students in comparing and judging the merits of competing models, and contrasting individual conceptions with scientifically appropriate conceptions. Presentations include extensive use of metaphor, analogy, and story-telling. Instructors encourage reflective attitudes in ways that are sensitive to the anxieties that often emerge when students are asked to engage in debates about events that don't initially appear sensible to them.

Students also begin the study of science teaching by selecting topics from their science courses and visiting PRISM mentor teachers' classrooms to better understand how the science is transformed to make it accessible to younger learners. Though the focus is on the actual subject matter, university students also work directly with elementary and middle school learners and participate in the teaching strategies used by the mentor teacher.

The mentor teachers and the science methods instructor work with the core science course faculty to design activities, observe classes and laboratories, and help instructors connect the course activities to elementary/middle school contexts. The mentor teachers meet for three weeks during the summer to help university faculty enhance integration and incorporate examples.

project is the development and teaching of a 7 - 10 day sequence of lessons as part of their field experience in PRISM teachers classrooms.

Guided Practice with Experienced Mentor Teachers

A primary role of the PRISM elementary and middle school teachers is to serve as mentors for students during their pre-student teaching and student teaching experiences. Students gain practical experience designing curriculum, planning and carrying out instruction based on the models experienced in the science courses and methods course. In particular, students sharpen reflective skills needed to assess the success of classroom practices and make appropriate modifications to improve their work. Because the PRISM teachers work with University faculty to design the science and methods courses, they share ownership of course goals and teaching strategies. Preservice teachers placed with PRISM mentors thus enter classroom environments where they receive clear, focused support for their efforts to plan and teach within a constructivist framework.

Evidence That the Program Works

PRISM differs from many other teacher education reform projects in several respects. First, we have not attempted to impact a select group of students such as the science-oriented individuals. Instead, our goal is to impact all students completing the program regardless of their academic expertise. Second, we are committed to a true collaborative effort rather than enlisting the aid of classroom teachers to help us "do it our way." Clearly, there are trade-offs in this approach. Making significant impact on a broad spectrum of students is far more difficult than shaping the thinking of students who are already inclined to enjoy (and thus teach) science. Thus, success, in our view is measured by the changes in the belief systems of students who begin the program as "science-shy" but emerge as beginning teachers with appropriate planning and teaching skills who believe they can successfully teach science. Adherence to a collaborative model results in a different blend of theory and pragmatism than either the teachers or university educators might have preferred. At the same time, though, opportunities to provide program experiences that are more directly attuned to the here and now needs of students are enhanced.

Evaluation data. We are monitoring students' thinking about science and science learning using a modified version of the Ideas of Science survey (IOS) developed by Strike and Posner (1992), the Test of Science-Related Attitudes survey (TOSRA) as used in the SALISH consortium, and through course-specific exit surveys completed on the last day of each science class. Our analyses are ongoing, as students from the PRISM science courses are just now entering the professional education sequence. Students complete the IOS at the beginning of the first PRISM science course, at the beginning of the methods course, and as an exit survey at the end of the certification program. The TOSRA is completed by students at the start of their second science course, at the start of the methods course, and as an exit survey at the end of the certification program.

Our feedback at this point is primarily formative yet is highly encouraging. Data for some science courses includes students who enrolled in PRISM courses to complete general education requirements, but who do not anticipate electing majors in elementary education. Data reported for students entering the methods course include students who completed at least one of the initial PRISM courses, but who in many cases have not completed all three, or who completed the science courses during their first offering.

Changing views of science and scientific knowledge. Students in the core science courses judge the collaborative inquiry as different from past experiences, intellectually challenging, and generating much thought about the nature of science. Pretest data indicate that over 80 per cent of students taking their first PRISM science course view science as mostly facts and information. Data from students who have completed at least one PRISM course show that less than 40 per cent of the respondents describe science as mostly facts and information (data for students completing all three courses is not yet available). In contrast, 60 per cent of students entering the methods course after completing traditional science courses but without benefit of the PRISM core science courses describe science as mostly a set of facts and information and that scientific theories are derived from data but are not the products of human thought. These data, while far from complete, suggest that the science courses are impacting students' beliefs and attitudes about science. Our analyses to date suggest the following trends:

1. increased emphasis on the interrelatedness of scientific ideas and their relevance to personal and career activities;
2. consistent shift away from a view of scientific knowledge as primarily facts and information;
3. shift towards a view of scientific knowledge as tentative and subject to modification, but primarily through the addition of new knowledge.

Changes in attitudes toward science and science teaching. Data describing students' willingness to teach science show similar changes. Our analyses to date show that

1. 95% of respondents to exit questionnaires in the geology and biology courses reported sustained or more positive attitude towards the science courses;
2. 75% viewed the subject matter as relevant to their teaching interests;
3. 55% judged the activities and teaching strategies as good ideas (with modifications) for elementary teaching.

As students spend more time in classroom settings, and find more and more connections between the activities of their science courses and the activities used by the PRISM mentor teachers, we anticipate increased success in helping them become aware that the methods used in their courses are those that can work in their own classrooms.

We are also using the Teacher Pedagogical Philosophy interview associated with the SALISH Consortium for Research on Teacher Education with a small sample (n=9) of students to track their thinking as they complete the program. Additional interviews explore students' thinking about different course and program experiences such as the methods courses, foundations courses, school contexts, and the influence of cooperating teacher attitudes. While small samples cannot be judged representative of the population of students completing the program, the insights gleaned from in-depth interviews sharpen issues that can then be developed into large group focus questions.

Evaluation by PRISM mentors. Feedback from the mentor teachers about the PRISM perspective is uniformly enthusiastic. Detailed descriptions of two teachers' analyses of the PRISM perspective are provided later in this paper. Evaluation surveys completed by the PRISM teachers at the end of the summer workshops show unanimous support for the central program components. Some representative comments from mentor teachers include:

> With the new innovations that PRISM can provide and with the willingness of University instructors to try new ideas I believe the teachers coming out of UWEC will be much better prepared to meet the challenges of the classroom!
>
> I feel strongly that teacher preparation in science is definitely going to improve!
>
> The people involved in this area of teacher education are headed in the right direction in science instruction. I'm excited about it!!

The PRISM approach has shown me even more of how poor some of the science courses were when I attended [UWEC]!

It's nice to feel that our perspectives as teachers are respected and acted on. I can already see that changes we suggested last year are being put into effect this year

I didn't graduate from UWEC or graduate recently so I do not have a base of comparison. I do know that UWEC provides a much more in-depth experience than I have seen at many places

Summary

Our initial results are encouraging, yet they point our the difficulty of effecting changes in deeply held patterns of belief about science and science learning. Our emphasis on helping students construct scientific knowledge by engaging them in good quality science activity and modeling sound teaching practices hasn't yet produced large changes in thinking about science and science learning, but has been consistently shifting students thinking in ways we view as appropriate to teaching. As we refine our courses and build stronger connections to professional education settings, we expect to produce greater changes in students' thinking about science and learning. We have clearly made significant positive impact on students' attitudes towards science and their enthusiasm about teaching it. Thus, we've achieved one major PRISM goal. It remains a challenge to further foster and solidify these emerging positive attitudes and blend them with sound teaching knowledge and skills during the professional education series.

In the following sections, we present views of the impact of PRISM from the perspective of an elementary teacher, a middle school teacher, a University Arts and Sciences faculty member, and a science educator. From these perspectives, we then explore the emerging "conceptual common ground" that is shared by PRISM participants. We believe that identification of such common ground is a key element in developing enduring programs that actually impact deep-seated beliefs about science and science teaching.

The perspectives presented below were developed independently. Our goal was to first articulate the key issues, successes, and dilemmas from our individual perspective, then use the writing as a context for making explicit our sense of the conceptual common ground embedded in PRISM. Following individual writing and revising, we met as a group of four to find similarities and differences in our interpretations.

An Elementary Teacher's Perspective

I became a part of the project called PRISM in the summer of 1994. Quite frankly, I saw it as an opportunity to earn three free graduate credits, receive a monetary stipend for my time and have an opportunity to share my interest in science instruction with colleagues of a similar interest and background. Little did I imagine then how profoundly my involvement, along with approximately 40 other elementary teachers, would affect current college instruction of pre-service teachers, or my own personal and professional growth.

Through PRISM, I have had the opportunity to become acquainted with eight hard-working university instructors dedicated to changing the current geology, biology and physics classes as well as the science methods courses, to more appropriately instruct pre- service teachers at UWEC. They have an honest and sincere desire to discuss and learn about science instruction from my perspective as a second-grade teacher and use that dialogue as the impetus for shaping their lessons and methods of teaching at the university level.

Our experience together began with an overview of PRISM and then just as quickly became a mini crash course in their university classes as the instructors shared their course outlines, modeled their lessons for us and took us on field trips intended for their university students. At every opportunity, the university instructors listened respectfully and whole-heartedly to our thoughts, suggestions and feelings. Buzz words common in our elementary classrooms such as cooperative groups, stations, hands-on activities, active learning, full participation, critical thinking and integration, to name a few, were being used at the college level as well. Our methods of instruction were being incorporated into university instruction and we realized that we were directly affecting the future course work of pre-service teachers. I am quite certain that no other program has ever given primary teachers, in particular, this kind of respect or consideration for their thoughts and suggestions. It certainly created a bond of mutual respect between university faculty and elementary teachers that I have not previously experienced.

It would be dishonest, however, to imply that all of the discussions were always positive, constructive and respectful. Finding consensus, or even a common ground, among more than 40 teachers was at times difficult, if not impossible. There were occasional 'bird walks' and some discussions were monopolized by a few of the more outspoken participants. I recall, in particular, one discussion concerning the need for more science content instruction and additional course work requirements being necessary for middle school and high school teachers as opposed to elementary teachers. Obvious biases became evident as well as opposing philosophies regarding current science instruction. It was a difficult day for most participants. However, it led to a restructuring of discussion groups into multigrade level as well as grade-level sessions and a clarification of discussion rules that carried over into all of our future work. One might say that the 'air was cleared' and our mutual respect was strengthened.

When the 1994-95 school year began, evidence of our summer's work became clear. Students in PRISM science classes were being taught with good hands-on learning methods, class sizes were smaller, field trips were included and lab and lecture had been restructured.

Early exposure to real-life science classrooms and students was one issue that PRISM mentor teachers had strongly recommended. We felt that it would help future teachers identify their career goals sooner and make their subsequent course work more meaningful and relevant It was in February of that school year that a group of four UWEC students visited my classroom on three separate occasions to observe my second graders studying electricity. The children were at first attempting to light a bulb with wires and batteries. Later, they were experimenting with series and parallel circuits. The adult students observed, interacted with the children and assisted in questioning and leading the children in their discoveries. The adult students were amazed to see what second graders were able to do and shared with me, as well, that they were doing exactly the same kinds of experiments in their physics class. Feedback from the visiting students was overwhelmingly positive and reinforced our belief that this had been a valuable addition to their studies. What a powerful learning experience for them! How relevant their own course work must have been following these visits!

A common criticism often heard among elementary teachers is that university professors in their 'ivory tower' have lost touch with our schools and the dramatic changes that have taken place in them. In PRISM, both students and instructors were given time to observe our classrooms. Having the university instructors take the time to visit me 'in the trenches' further solidified the bond that had been created and gave me an opportunity to discuss all of the situations that we face in our classrooms daily. Since this was such a powerful experience, it certainly would be appropriate for elementary teachers to also be given the opportunity to visit the college classrooms and interact with students in their unique situations.

Another extremely positive experience for me has been my participation in the internship program which was made possible through PRISM funding. Interns are students who have shown exceptional quality and ability in their undergraduate studies and methods classes and are interested in a full semester of teaching with a PRISM mentor teacher. I am currently team-teaching with one exceptional intern and have another coming this spring semester. I feel confident that these students will be well prepared for teaching, particularly science, as they enter the work force. I would hope that the university would continue to place its student teachers and interns with PRISM participants.

At this time, unfortunately, it is still too early to see clearly the impact and real value of PRISM on the education of the majority of our future teachers since those students participating in the restructured science and methods classes will not be out in the classrooms for block and student teaching experiences until the 1996-97 school year. However, I am confident that the efforts of everyone involved in PRISM will impact positively on future teachers as there have been many positive outcomes for the participating PRISM teachers, despite the fact that our gain was not the intent or focus of this project. Through the sharing and modeling of university course lessons, we were able to add to our own repertoire of lessons, with appropriate adaptations, of course. We were also introduced to and schooled in the current technology that is available to college students, but not necessarily available at the elementary level. As a result, we are all now connected through Internet.

In closing, PRISM has been an outstanding experience for me. I would like to see even more teachers embraced by this project, however I am concerned about how larger numbers would impact on PRISM's effectiveness and continued success. I would like to see high school science teachers, as well, involved in a program similar to PRISM. I would like to see the strengths of this project expanded to include additional university instructors and their classes. And I am concerned about the continuation of this project when the current funding is no longer available. Despite my wishes and concerns, however, I am pleased and proud to say that I am involved in this worthwhile project called PRISM.

A Middle School Teacher's Perspective

I am happy to say that I have been involved with PRISM since it was a proposal involving educators (at all levels) and administrators. At that time the goal was to improve the science competency of new elementary teachers. Many students were leaving college poorly prepared to teach science. The goal was to provide not just more science classes but those that would model effective teaching methods, enhance content, and provide a comfort zone for new teachers. At the same time experienced teachers would be selected to help develop curriculum and to serve as mentors for the college students. With a lot of hard work and effort, an NSF grant was secured to put these ideas into practice. PRISM is in its third year, and I judge it to be highly successful.

PRISM now involves eight university instructors. four sections of students, and over forty elementary teachers. Students complete 12 credits classes in geology, biology, and physics before taking their science methods course. This has been an effective rotation that generated many positive experiences for both students and teachers. Students are now receiving earlier classroom experiences. As part of each science class, they are required to visit one or more of the teacher participants two or more times. Students are exposed to good methods, solid teachers, and elementary students. They are able to see the application of college classroom activities to the elementary classroom. College students can also work with the elementary students. This gives the college students early opportunities (during the first two years of college) to feel what teaching is like.

Preservice students are being instructed in their PRISM courses with the same hands on methods that are being expected of them when they become teachers. If I had to summarize the one thing that makes PRISM special is the increase in hands on activities with less emphasis on lecture. This is what the elementary classroom has to be like in order for science to be meaningful. There is coordination between the instructors of the geology, biology, physics, and science methods courses. Students experience more than just lecture, lab, and discussion techniques. They are being asked to use problem solving/critical thinking skills. Laboratory exercises are designed more towards the format that would be used for elementary students.

Students are in smaller classes. This allows them to receive more individual instruction. Smaller class size also allows for students to go on more field trips during their content classes which makes learning more meaningful for them. These field trips allow for direct application of classroom content to everyday life such as the geology of the Chippewa Valley related to rock formations and understanding the geological history of the region. At the same time, the trips place students in a context where they develop the interpretative skills used by geologists working in field settings.

The PRISM mentor teachers recommended that students need practicality before theory. We felt that exposing pre-service teachers to practical classroom situations before receiving instruction about different teaching theories would be most beneficial. Views on this vary with college instructors but the design of PRISM has university students following this program. Students are introduced to different learning styles and theories of science education and required to use them in their science classes rather than waiting until they take methods courses (often two or more years later). It allows for more working with different methods/aspects of good teaching. Students work with constructivist theory, concept maps, questioning methods, and conceptual change strategies. Integration becomes a regular part of assignments for curriculum and instruction courses. I am sure that these activities happen in the normal education courses but the PRISM difference is that teachers have input. They give assistance and suggestions to both instructors and students. PRISM students can see the effect of content and methods in the classroom for immediate feed back.

For middle school teachers PRISM has also been a positive association. Sometimes teachers feel that a chasm exists between K-12 teachers and university educators. PRISM has broken down these barriers. Teachers are asked for input into the organization of the content courses, methods courses, and field experience design. University campuses in Wisconsin face tremendous pressure for students to achieve their bachelor's degree in four years. At the same time, teacher education programs are being restructured to be consistent with new baccalaureate degree requirements and to better meet the needs of preservice teachers. Here again elementary teachers have been asked to provide input for this difficult task. This has taken away the feeling of separation and negative attitude that can exist.

Teachers have also felt the support of the School of Education for the changes suggested by the PRISM format. University administrators and other staff members directly support and participate in the project. During the summer when teachers gather, input sessions have been held which allow for dialogue between university administrators/instructors and elementary teachers. They have explained what is done in various methods classes not involved with PRISM and asked us for input. At the same time they have listened to our concerns and tried to understand them and respond. The opportunity for discussion has helped all parties better understand the opportunities and constraints that must be considered in developing more coherent programs.

Teachers have been asked to become more involved in designing the university field experience sequence. This is especially true in the area of giving students more elementary classroom experiences before BLOCK or student teaching. Teachers have worked on ways to make the BLOCK experience more effective by changing its sequencing. Teachers are invited to visit the university classroom during the school year. Some PRISM teachers function as consultants who regularly observe university classes and provide feedback about teaching strategies, help develop connections to K-12 classrooms, and serve as resources for students. In this manner, we can better see what is happening with PRISM students and how it relates back to our classrooms. Correspondingly, PRISM instructors are now starting to visit the classrooms of the elementary teachers. This allows them to see what is happening in the trenches and help their own students when they return to the university. Furthermore, now all teachers and staff are connected through Internet. This greatly increases the sharing that occurs between all participants and staff members.

Since I have been involved with teacher education/professional development because of prior responsibilities, I feel very positive about PRISM. I see it as a means to improve teacher education and professional development. Yet I still have concerns that I feel the staff of PRISM is aware and trying to solve. First, I believe that the University chemistry department should be involved with teacher education. It is important for students to experience chemistry in the same ways they experience biology, earth science, and physics. Second, it would be greatly helpful if more instructors at the university would follow methods used in PRISM or show greater support for it. In some cases there is still too much lecture. Some PRISM courses are general education course completed by education and non-education majors. In these classes, larger enrollments result in less flexibility between lecture and laboratory. Instructors then must lecture rather than use hands-on activities. This prevents all students from having the same experiences.

While small numbers in classes is highly desired, it does prevent others from being involved. Instructors need release time to visit the elementary classrooms. Such activities promote high quality communication that is an important link in the program. However, small classes and release time cost more money. If PRISM courses (or courses designed around PRISM principles) were opened to more students, the benefits would increase but so would the cost. What happens when the grant runs out?

As graduation requirements are being revised, the future of the PRISM sequence becomes less certain. What does this mean to the overall program? Each subject area/department is territorial. What will this give and take look like especially since teachers are recommending that chemistry be added to the program? Can harmony be achieved and if not who will make the final decisions?

Program changes involve money, the support of many, the respect of views, and working together. Can this be achieved at the university level with the suggestions made by PRISM participants? There has to be viable working relationship with all parties at the university. Now that more PRISM students are approaching student teaching will the university make every effort to assign them to participant teachers? This is sometimes a problem for the people in charge of student teacher placement. A mentor relationship with student teacher/coordinating teacher must exist if this final stage for PRISM students is to be successful.

Finally as the number of PRISM participant teachers grows bigger each year, can the views of all be addressed? It is sometimes very different at the present number of approximately 40 to do this. Everyone has valuable contributions to make, but a new vehicle must be found in order to bring about this input for the improvement of PRISM.

I hope it does not seem that I am negative about PRISM. Quite the contrary. I strongly believe in it. I was involved when it was just an idea. I am proud to be associated. I truly believe that it is making a difference in the Eau Claire area and other regions in Wisconsin will want to be involved in similar plans.

A Geologist's Perspective

Most scientists are traditionally under-concerned about the science education of teachers. The reward systems at most universities value research including the search for extramural funding as of paramount importance and rank teaching as a secondary concern. Even in institutions where teaching is valued, most emphasis is placed on teaching science majors and teaching towards the recruitment of additional science majors. From the perspective of scientists, teaching has been effective if we have created individuals who think just as we do (a phenomena I refer to as cloning). The present value system (research and cloning) has been ingrained in scientists since their earliest days in graduate school and is difficult to overcome. Promotions, tenure, and salary increases are all tied to performance in the areas of research and cloning, but rarely emphasize quality science instruction that results in meaningful learning. Individuals who are successful in the science have learned early to play the game and for the most part serve to perpetuate the cycle.

Considerable inertia is present when you consider that scientists teaching in today's universities were successful learning science in very traditional settings. The traditional science course includes lectures where important topics are introduced and discussed followed by laboratories that reinforced the important lecture material. Quite possibly a scientist s most compelling learning experience occurred in such a lecture dominated instructional system. Most scientists enjoy a good lecture and don t understand individuals who may not learn well in this style. Among scientists, there is a tendency to label individuals who don t learn science well in the lecture format as being science phobic and quite possibly beyond our help. The science community has embraced the concept of hands on science yet interpret that phrase as additional laboratory or field experience in support of lectures.

Several years ago, there was a general alarm sounded within the science community that we were not producing enough scientists/engineers and the expected shortfall became a national concern. For the first time in many years, science teaching gained the spotlight. There came a realization that the pipeline of scientists was being affected by events in the precollege curriculum and therefore, the production of precollege teachers committed to improving science instruction became a priority. The first inclination of scientists was to simply provide more of the same type of science instruction and make precollege teachers more like ourselves. The reasoning, which appeared valid based on our own experiences, was that if teachers were better at science they would be better science teachers. Most local scientists agreed a two pronged approach was needed: inservice teachers would need workshops to increase their knowledge base and preservice teachers would need more science training. Considerable thought was given to the content knowledge expected of these individuals but little effort was devoted to discussions of pedagogy. Even during the early years of science reform, scientists of my acquaintance often discussed the differences between the way we did science and the way we taught science realizing the absurdity of the situation. We most often taught science as a body of knowledge but did our research using a different paradigm. The inconsistency was acknowledged but few local scientists had any plans to implement changes in a "comfortable" system.

At this point, university scientists started to develop a different approach to science education at UWEC and from this effort, project PRISM was born. According to practicing teachers, education faculty and even the scientists, the old science requirements did not meet the needs of our students. With the development of new courses we started to investigate new possibilities for science instruction. Coordinators from the School of Education called a meeting of science educators and scientists who had been active working with teachers during inservice workshops. The assigned task was to develop better science courses for the preservice teachers. As a first step, the model involved improved communication and coordination between university faculty. Next, the group examined the science curriculum (scope and sequence) for the local school district, the Wisconsin State science standards and verified a suspicion that our preservice science curriculum didn't address the needs of the local community. The most glaring defect was the total omission of any Earth or planetary science component in the preservice preparation; components prominent in the local elementary curriculum. The next most apparent defect in the offerings was a content based curriculum lacking real science experiences. During these meetings between scientists and science educators the scientists were introduced to the concept of constructivist teaching strategies and alternative pedagogical methods. At the same time, several critical barriers to improving science education were identified:

1. Faculty and administrative resistance to adding credits to an already bloated education program, especially when there was considerable pressure to reduce time to graduation and limit the number of credits required for a degree;
2. Faculty resistance to change. Even with recognition of significant deficits in existing courses there was significant resistance among Arts and Sciences faculty to changes which required new courses and course materials;
3. Limited faculty resources for staffing new instructional models in existing courses, and for supporting a new course in an area never before covered;

4. Lack of a reward system to recognize education as important;

5. The need to shift resources between science departments dues to changes in credit distribution.

The science faculty were adamant about increasing the amount of time education students spend in the science building yet the education faculty were not willing to give up experience elsewhere without reassurances that the additional time in the sciences would be well spent. The sciences agreed to a laboratory based instructional style where the bulk of the additional experiences would be outside the lecture setting and a careful coordination of the science and science methods experience to eliminate duplication and maximize effective use of time. The education faculty were impressed that the scientists were willing to meet and discuss teaching philosophies and granted the additional credits to the sciences. The overall change was from 9 to 12 semester credits of science with all of the increased credits committed to laboratory experience.

Administrators were willing and eager to discuss changes in reward structures to allow time for science faculty to pursue changes in pedagogy and allocated additional personnel resources to the PRISM project. What college administrators found most compelling was the possibility that extramural funds could be leveraged to help pay program costs. Reassignments of faculty positions were undertaken slowly so that no department felt threatened during changes in the curriculum.

Most importantly, the administration carefully used faculty retirements within the sciences to hire new faculty members with exceptional scientific backgrounds, an interest in science education, but limited science teaching experience to develop the new science courses. The importance of this step can not be underestimated. Hiring new faculty was vital because even existing faculty who were committed to the change had vested so much time in the previous courses that changing would have been difficult and the rate of change slower. By hiring new staff who had not yet developed course materials the new courses could be developed from scratch increasing the rate of change. In addition, new faculty were eager for direction and willing to try entirely new methods of instruction. Indeed, the new faculty typically found working in a collaborative environment with faculty from across the institution to be an excellent motivational experience.

With new faculty and a model for change approved by all of the interested parties the scene for significant reform was set. Scientists demanded the following ground rules for developing new courses and revising existing courses:

1. Courses would be taught by scientists who were respected within their disciplines for their contributions as scientists. The new faculty would have time for both teaching and scholarship.
2. The science courses developed would be rigorous (not dumbed down) but still clearly focused to meet the needs of the preservice teachers.
3. The courses would be offered through science departments and carry science department designations rather than education or non-science prefixes.
4. Faculty teaching the science courses would receive credit for working on the course development as a professional activity and would be evaluated on both teaching and scholarship.
5. Faculty time would be allocated to working with inservice teachers from the local community.

6. Resources would be available to keep faculty current within the sciences for the dura·i ·n of the project by supporting attendance at professional science meetings, providing funds for student research assistants and defraying other professional development costs.

Three new science faculty were hired to develop new courses in Earth, Biological and Physical sciences which were to be coordinated with each other and the science methods experience. Teachers from the local community volunteered to help design both the science courses and the science education experience. For the first time all of the important players in science education -- science faculty, science educators, and inservice teachers -- were working together to promote a better science education experience. This group of individuals working together developed the current plan that makes up Project Prism. The project received funding from the National Science Foundation which made the university administration happy and allowed for the implementation of the changes in a timely manner.

Impact after two years. The science faculty have found working with both the science educators and the inservice teachers to be very rewarding. It has been many years since most science faculty have spent a substantial amount of time in the precollege classroom and none had ever observed science teaching from the perspective of a scientist. Many valuable ideas have come from the mentor teachers classrooms regarding how to best teach subjects in our college courses. Teachers have freely offered both advice and activities appropriate for the instruction of preservice teachers. The quality of classroom instruction varied, but the university faculty gained much respect and admiration for the precollege teachers during these visits and during summer workshops. Building relationships with the inservice teachers has allowed for the development of early practical field experiences for the students in the university science courses (described here or elsewhere) and has significantly improved the college science courses.

PRJSM has also affected had some courses for the majors and minors within the sciences. Partially as a result of the program the Department of Geology has revised their introductory sequence of courses to add more practical experiences. Biology is currently restructuring their introductory course sequence to address fewer themes in more depth. Such changes are slow, and will require consistent effort and support if lasting effects are to be realized.

Science faculty found working with education faculty just as rewarding. The scientists in our work group have very little formal training in education and were astounded at the knowledge base available in educational research. The concept of constructivism and the preconceptions and misconceptions of college students allowed for careful design of lesson plans. Faculty for the first time started to question the content driven nature of most science courses. As courses were developed and revised, there was a considerable shift away from covering a lot of content towards a coherent focus in a few key themes in each course. The goal has become one of developing meaningful understanding rather than transmitting the substance of a densely packed syllabus.

Probably the most important barrier we overcame as a group was the realization that scientists did not need to cover (and couldn't cover) every subject a teacher would eventually have to teach. Leaving the security of content coverage is difficult for scientists, individuals who typically pride themselves in the number of details they can remember. The forsaking of content was one area where group therapy of the PRISM staff really helped. In a group of mixed scientists and educators it was easier for the scientists to see that an educated person need not know every detail about the science. The details became less important than the processes and we were able to concentrate more clearly on a thematic approach. For example, if details of the Krebs Cycle were not covered but students understood basic energy flow in organisms then we were satisfied as a group that real progress in science education occurred. Not surprisingly, the scientists feel better about the courses they developed with extensive review from outside critics that they would have without the outside support. Each subject taught can ideally be justified based on a content argument and its contribution to a bigger program.

Barriers to progress. There have been barriers to continued progress in Project PRISM that are specific to the sciences:

1. New faculty hired to develop new courses are somewhat isolated from the rest of the department. Some department members don t know what s happening within the new courses and some just don't care to know.
2. Time spent on course development and working with the mentor teachers has limited progress on research. There is only so much free time for new faculty. While this has not been a negative in terms of reappointment or salary considerations it is a personal consideration of new faculty.
3. Not all members of the science departments understand the changes and give credit to the new faculty for time spent on pedagogical improvements.
4. Administrative awareness and support for the project varies. Three levels of organizational change are occurring in the University community at the same time as PRISM. The project has lived through three different Deans of Arts and Sciences (and two Deans in the School of Education).
5. PRISM science courses are labor intensive. The Biological and Earth Science courses both require four hours of lab and only two hours of lecture each week. Thus, each

faculty member serves 75-80 students per semester compared to 200 - 300 students per semester in non-PRISM courses Faculty have less time to offer upper-division science courses specific to their sub-disciplines..

Despite the problems the science faculty feel that the courses do successfully meet the needs of UWEC preservice teachers. PRISM has developed a cadre of scientists in the participating departments that will ensure continuation of the core science courses. Extending the change model beyond the current courses will require developing ways to involve additional faculty in the program.

A Science Educator s Perspective

PRISM is successful in part because of the commitment to real reform on the part of all project staff. As a science educator, I believe it is important to find ways to share new insights drawn from research, curriculum changes, new technologies, and professional issues such as the emerging national science education standards with the teachers who work directly with our students. PRISM provides a context to share and consider the implications of new ideas and changing standards. The mixture of university staff, elementary teachers, and middle school teachers guarantees a lively debate that helps each group learn about the others and how new ideas impact the teaching of science. Such debates are crucial to the emergence of clearer goals for science teacher preparation. Thus, PRISM serves as one model for collaboration among faculty with diverse expertise. Equally important are the bridges being built among university-based staff and school-based staff. In order for real improvements in teacher education to occur, all participants in the education of prospective teachers must find ways to work together, to recognize the power of a shared community of expertise in shaping underlying beliefs about teaching and learning.

Too often, preservice programs rely on a technical-rational format (Schon, 1983, 1987) that provides students with many ideas too far in advance of opportunities to understand them or make them workable in teaching settings. As a result of PRISM, students have opportunities to learn in a community of experienced teachers who model teaching practices that are emphasized throughout the program. Early school experiences provide opportunities for students to clarify their own career choices; many individuals enroll in PRISM science courses before they've solidified a decision to enter teaching. Students have opportunities to try out hands-on activities, work on questioning strategies, and develop management skills in learning environments that exemplify the fun and excitement of good science teaching.

Students learn early on that PRISM staff are committed to helping them learn to be good science teachers and are available and willing to help them learn to teach specific topics. They also learn that PRISM staff at the university share ideas and strategies with K-12 teachers. Thus, students tend to seek help from a variety of sources rather than relying solely on methods instructors and cooperating teachers. Such shared support is successful because of the high level of communication and collaborative goal-setting that characterizes PRISM.

Another key element is the influence of program activities on the university course instructors. For two years, the university-based staff have held regular meetings (weekly or biweekly) to discuss progress, brainstorm solutions to classroom dilemmas, and sharing successes. PRISM created an intellectual and organizational space that supported the sustained engagement and the hard work required to rethink fundamental ideas about teaching and learning and to transform ideas into workable classroom strategies. As a result, the university science instructors have developed much greater awareness of education issues and perceive themselves as empowered to address those issues. Discussions in meetings and in local presentations emphasize the reflective nature of the endeavor; a major point university instructors make in presentations to other Arts and Sciences groups is the way they've come to question their own choices in teaching courses in their respective majors. At the same time, opportunities for me to work in a highly science-specific setting are refreshing and challenging. I've learned and relearned a lot of science in the past two years; questions from accomplished scientists challenge me to keep rethinking the connections among science, learning, and teaching, and in particular the constraints that must be removed in order to implement quality practices in traditional university settings.

PRISM has kindled much discussion about the nature of exemplary teaching of science. Through modeling of science instruction, discussions during summer sessions, and during interactions with students, the entire PRISM group has been able to participate in highly reflective discussions that transform many implicit notions about excellence into explicit forms. As a result, we all have enriched our thinking about good science teaching and are better able to guide students as they learn to teach.

More importantly, teaching practices at the university and in the schools are changing; issues raised during summer sessions are put into practice. Courses now place increased emphasis on meaningful understanding of scientific knowledge and ways that scientists engage in inquiry and less emphasis on covering content. The role of students' scientific thinking has played an increasing role in course design; facilitating understanding is judged more important than "covering" topics. Course foci have narrowed to provide time for greater depth of exploration of school-oriented topics. University students not only study topics typically taught in elementary and middle grades settings but also observe ways that the subject matter studied is transformed to be appropriate for younger learners. Thus, the task of learning to teach science explicitly begins as the students are learning the subject matter. By the time student enter the professional education program, they have already developed significant awareness of ways that elementary students think about science, and about the demands that those students make on their teachers.

Perhaps the most important impact of PRISM is that discussed below: the emergence of conceptual common ground that ties together the students learning experiences. Common teacher education goals have emerged which are grounded in shared commitment. Students get fewer mixed messages about the nature of good science teaching without being subjected to a rigid, prescriptive doctrine. Because the emerging goals are situated in both the university and K-12 settings, it is easier to help students draw upon science experiences as well as anticipate classroom possibilities. Thus, we have a developing base of shared experience for reflecting on deeply-held beliefs about science and science teaching.

Finding The Conceptual Common Ground

The notion of conceptual common ground has roots in the premise that reform in teacher education must account for the gains in our theoretical knowledge about how students learn, about how teachers learn to teach. At the same time, reform must be contextualized in the realities of changing school practices and reforms engineered by K-12 educators.

A key element of PRISM is the collective effort to draw on both domains to identify the key common elements that all participants agree are central to the development of prospective teachers. These elements, which are emerging over the course of the project, form the basis for preservice teachers experiences as they learn to teach science. While not all elements are of equal significance (e.g., some are more essential to the development of middle school teachers than to the development of elementary school teachers; some may hold greater status for university staff than for school staff), identifying key themes and making them explicit for all participants is a PRISM goal that underscores the collaborative premises of the project.

We have defined conceptual common ground as the set of knowledge, beliefs, and practices that the PRISM staff agree are most essential for the beginning teacher. In seeking the conceptual common ground, we began with the task of writing about PRISM from our own perspectives then using the writing as a basis for identifying common themes we each saw in the project. Through discussion of common points in our interpretations, the following elements have emerged as the current common ground:

1. Science courses must be designed around a few key themes rather than attempting to cover all the bases. Interdisciplinary connections should be developed when possible.
2. Science should be studied from the standpoint of what children are asked, and are ready, to learn as well as from the perspective of the science disciplines.
3. Preservice teachers need a clearly articulated balance between theory and practice. In particular. theories and general principles about teaching must be understood in the context of practice in order to be useful.
4. Preservice teachers need clear models that help them understand how children learn science.
5. Teaching for meaningful understanding must be emphasized as the goal of science instruction.
6. Preservice teachers need early and consistent direct experiences with science as taught in context of schools.
7. Science courses, education courses, and field experiences should more clearly articulate the classroom management and organizational skills needed for successful science instruction.

Conclusion

Each of the above perspectives illustrates the significance of a professional community that includes university educators and classroom teachers as equal partners contributing to the preparation of beginning teachers. Within that community, shared experiences in each other's teaching environments are key to the development of mutual understanding and respect for the differing demands placed on science teachers. Though we have consensus that the overall PRISM approach is both appropriate and successful, clear differences in emphasis exist between elementary and middle school mentors. The role of traditional subject matter preparation, balance between practical experiences and theoretical knowledge, and the efficacy of different instructional models are only three of the dimensions that generate lively debate each time the mentor teachers gather to review and refine the PRISM model. Over the first two years of the project, though, some themes have emerged which have high status. We believe that identification of the core ideas is essential to the longevity of our efforts to develop a seamless science education experience. The conceptual common ground will evolve as the project move forward. An essential goal is to maintain the collaborative commitment both to the goals as well as to the goal identification process. Many of the key components are consistent with teacher education reforms proposed by other groups; their significance in the context of PRISM is that a high level of shared commitment to them exists. Thus, they are apt to be implemented and sustained.

Our experience suggests that it is not only possible, but crucial, that the perspectives of classroom teachers inform the design of all elements of the preservice program rather than just the "professional education" components. The professional community created through PRISM provides a significant opportunity for experienced teachers to further their own development as well as contribute to the growth of others. Sustaining such an environment and nurturing its growth as a vehicle for professional devel pment will require personal, professional, and policy commitments.

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PREPARING SECONDARY-SCHOOL SCIENCE TEACHERS TO USE COMPLEX INSTRUCTION

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Many research studies have demonstrated the advantages from teachers using cooperative learning strategies in small groups within classrooms. Among the varous recommended strategies for organizing small groups, Complex Instruction is stressed in our program for preparing secondary-school science teachers because it is well supported by research findings. It is designed to provide access to the curriculum for all students in heterogenous classrooms of untracked schools, the common situation in our local schools. The principles of Complex Instruction are based on 17 years of research and development at Stanford University, and are described by Elizabeth Cohen (1994) in her book *Designing Groupwork: Strategies for the Heterogeneous Classroom.* Participants in this workshop will receive copies of several research articles on this subject.

Some of the principles of Complex Instruction are the following:

1. Differentiated and non-routine assignments organize multiple groups and materials to provide different products from open-ended, discovery tasks that fill all available time. The students have varied opportunities to understand central concepts, e.g., by listening to presentations from other groups that include the use multiple abilities, e.g., singing, writing poems, analyzing data, performing skits, etc.

2. The delegation of authority makes students responsible for individual products. Teachers assess performances of each student. Groups are responsible for helping individuals. The teacher promotes group interaction, and avoids "hovering," i.e.,

controlling the actions of the group.

3. Students are controlled by norms and roles. Cooperative norms are internalized, e.g., "You have the right to ask anyone at your learning center for help." "You have the duty to assist anyone who asks for help." "Help others without doing things for them." A task role is assigned by the teacher to every student, e.g., facilitator, reporter, etc. Roles rotate according to the teacher's assignments to include everyone in significant responsibilities.

4. Status treatments are the raising expectations for competence. The first step is to assign tasks that include many different intelligences. Through this multiple ability treatment, some students will be encouraged to display skills that were previously unrecognized. Assigning competence to low-status students is the recognition of the performance of various intelligences by students who previously may have had poor achievements in the usual school assignments, i.e., skills in reading, writing and calculating.

To design lessons in Complex Instruction, the teacher should include all of the following features:

A. Open-ended problem solving that requires higher level thinking. Teachers must avoid recipes in instructions to the task.

B. A series of tasks that are thematically linked and develop an understanding

C. The tasks that involve a variety of intelligences.

D. Classroom organization where the teacher assigns students into heterogenous groups; each student is assigned a task role within the group. Learning occurs especially through talking and working together.

E. The teacher does performance assessment of each student.

The principles of Complex Instruction have been incorporated into many of the activities developed at the same Stanford University in the Human Biology Middle Grades Life Science Project (Hum Bio), funded by the National Science Foundation. The fundamental goal of this project is the creation of an academically sound, yet practical science curriculum for the adolescent. Biology provides the core of the curriculum because it offers the knowledge needed to combat the array of high risk behaviors confronting today's youth. Biology's natural link to health concerns provides a legitimate bridge to critical judgment issues while avoiding the dangers of alienating students by making them defensive. The "Hum Bio" curriculum builds a core curriculum of the life sciences that integrates biology with the behavioral and health sciences.

Participants in the workshop will review several activities of the Hum Bio Curriculum. The selected activities will consider aspects of human sexuality, i.e., topics that are often considered appropriate for students in the senior high schools. Because these activities include the principles of Complex Instruction, the participants will be invited to do tasks that require various intelligences, e.g., by creating a skit, a debate, etc., and will evaluate the activities in terms of their appropriateness for use at different grade levels.

Activities of Hum Bio are currently in use at test site schools throughout the United States. The curriculum under development includes units on the following topics: 1. The Changing Body, 2. Reproduction. 3. Sexuality, 4. Becoming an Adult, 5. Your Family, 6. Your Community, Your School, Your Self, 7. Your Place in the History of Life - Evolution, 8. Your Place in the Biological World, - Ecology, 9. A Concept of Culture, 10. The Transmission of Biological Information - Genetics, 11. The Relationship Between Biology and Culture, 12. Your Body, An Overview, 13. The Nervous System, 14. The Effects of Drugs, 15. The Lives of Cells, 16. Control of Cell Activities by Chemical Messengers - The Endocrine System, 17. From Cells to Organisms, 18. Circulatory System, 19. Breathing, 20. Digestion and Nutrition, 21. Salt, Water, and Nitrogen Balance, and 22. Body Defences.

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PROMOTING PRIMARY SCIENCE

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Introduction

This paper discusses how four first grade teachers improved their own science teaching. It is not unusual for elementary teachers to be less than enthusiastic about teaching science. Riggs and Enochs (1990) showed that science is a lower priority subject in elementary schools. In elementary schools where teachers focus on developing their students' literacy, there is an average of 90 minutes spent on reading as compared to 17 minutes per day spent on science (Enochs & Riggs, 1990). Science is seen as not helping elementary students move toward developing literacy. Developing literacy is seen as requiring a focus on language arts skills, meaning there is not a place for a subject that is not seen as advancing students' literacy development. Three of us fell into the category of being reluctant to teach science because we felt inadequately prepared, and that we didn't know enough science. Atwater, Gardener and Kight (1991) reported the same response that even though teachers agree that science should be taught in a "hands-on" fashion, teachers are unsure of their abilities to do so. Our science curriculum was text-based, and not set up for hands-on interaction. Bybee (1991) stated that even when using a curriculum designed to make teaching hands-on science more "teacher-friendly," elementary teachers still often feel inadequately prepared. We knew we should spend time teaching science to our students, but given the demands of the primary curriculum, science would be shuffled aside. This has been a perennial problem in elementary classrooms (Cox & Carpenter, 1989; Enochs, 1982).

Valarie, first author of the paper, was very enthusiastic about teaching science, and taught science on a daily basis. Her principal has jokingly asked her whether she ever taught anything besides science, to which she replied, " I teach everything else through science." Her classroom was nearly always noisy, though she said it was productive noise. Though it may have looked disorganized from the outside, the students always knew teacher expectations and procedures, and Valarie said she knows they learned very much. She holds a B.A. in Psychology and Ed.M. in Elementary Education. Much of her master's work was in science education. She has taught four years in the primary grades, two at first grade.

The other three of us fell into the category of elementary teachers who did not feel confident or prepared to teach science. Kathy earned her B.A. degree in Elementary Education with an emphasis in reading, and her Ed.M. in Literacy and Language Arts. She has taught for six years. She was reluctant to give much validity to teaching science in the primary grades. She didn't like teaching science, particularly physical science. Kathy is a very organized teacher. Her classroom, while not quiet, was much more organized than Valarie's. She was looked at much more favorably by the custodians. Her room was very neat, and lots of learning took place. Elaine has over 20 years of experience teaching first grade. She has a B.A. in Social Studies and an M.A. in Education as a Curriculum Specialist. She taught science weekly, but was always looking for a reason to cancel because the lessons in the adopted textbook were so boring. She has compiled a wealth of teaching ideas and units during her time as a first grade teacher. She was looked to for direction by the newer teachers because of her successful experience as a first grade teacher. She had lots of well-organized resources and was willing to share with the other teachers. Her classroom was very neat and organized, and children were always happily buzzing away and learning much on lots of interesting projects. Judy has taught for 17 years, mostly first grade. She has a Masters of Education in Language Arts Curriculum and Instruction. From the outside her classroom sometimes looked disorganized. She always had her students involved in lots of interesting projects, at different states of completion. It was always amazing to the other first grade teachers how Judy was always able to find anything in what sometimes seemed to be a room in disarray. Her students were also always learning. In general, however, no matter how many projects our students were involved with, the three of us taught science as little as possible. We used our science textbook at most two or three times a week, for about fifteen minutes each session. We had the students read the chapter, and tried to hold discussions as the teacher's guide suggested, but the discussions were always flat. The topics covered were usually repeats of Kindergarten and at such a low level students already knew the material. But the reading level was too difficult. The topics did not build on what the students already knew. As assessment of "understanding," the students would fill out worksheets, as well as take paper and pencil tests that went along with the chapters. There was no discussion of the nature of science within the textbooks, just facts. Students did not look forward to science each day, and we were easily lulled into thinking "Who cares? They already know the science covered anyway." We three did not like teaching science--it was as boring for us as it was for the students.

One winter day we had a grade level meeting in Valarie's room because she had popcorn and we could snack as we worked. She had charts of her students' explorations with electricity hanging around her room. Elaine wondered why she would be teaching electricity to first graders. It didn't seem like a very wise thing to do. How could first graders learn anything about electricity? Valarie's students had requested to learn about electricity. They wanted to know about it, and she was fortunate enough to be able to respond to their wishes with a unit she borrowed from a professor at a local university. Valarie had not taught first grade before, and didn't know first graders "should not" be able to learn about electricity. Elaine later told her that "ignorance is bliss." Valarie decided to forge ahead, because it is what the students wanted to learn.

We continued to hold our grade level meetings in Valarie's room because she continued to provide popcorn. These meetings became weekly. We continued to watch what she did with her unit on electricity. Judy was concerned that though students seemed to be learning, Valarie must know lots about electricity in order to be able to teach it. However, Valarie stated she didn't know everything there was to know about electricity, that she was curious about it herself, and she had studied about it so she knew enough to teach it. She also said she was willing to investigate along with her students to help them learn. She seemed to be confident and enthusiastic in teaching and learning about electricity. We realized that lack of confidence and enthusiasm for science would not inspire children, nor help them to understand science content or processes. From watching one of our peers we knew first graders could learn more than we had previously anticipated. Elaine thought it looked like Valarie was having lots of fun teaching science. Judy was concerned that Valarie must know a lot of science and that's why she taught it so much. Kathy thought Valarie simply spent too much time on science to the detriment of other subjects. However, we all knew if we wanted to provide the kind of instruction we wanted for our students we would need to make some changes that would fit with our teaching styles.

Though we were not aware of it at the time, the developments we were making in our teaching fell in to line with national reforms. For instance, our goals for teaching matched those of AAAS' *Benchmarks* (1993). We wanted students to know about the nature of science rather than just scientific "facts." We wanted students to develop their own understandings, through our facilitation, and be able to ask their own questions and devise ways to answer them. We wanted students to enjoy science, and know science as one way of understanding their world. We endeavored to find ways to create in-depth understandings of concepts rather than "covering" lots of material as presented in our textbook. It was obvious to us students were not coming up with understandings we wanted them to gain.

However, with the exception of Valarie, we were not confident in our abilities to invoke these changes in our teaching. We did not see ourselves as scientists, nor as science teachers. Science, as we were used to teaching it, did not seem to help us toward our goals of developing literacy in our first graders. It was obvious to us we needed to become more confident in ourselves as science teachers before we could influence students.

Gaining Confidence to Teach Science

Three goals seemed of most importance in helping us become more confident in teaching science. First, we knew we needed support in developing our science teaching, and this led to the formation of a supportive group. We were already meeting as a grade level to talk about education, so decided this would be a good place to talk about science teaching issues. Secondly, we knew we needed to understand science pedagogy emphasized in science education reforms, and realized an increase in content knowledge must parallel improved pedagogy. With a change in teaching we would need to develop new assessment strategies, and so this was our third emphasis in our development.

Development of a Cohesive, Supportive Group

In order to develop our teaching strategies we knew we would need to be able to discuss our successes as well as our failures, to share ideas with others, and to use the strengths we could all bring to the group. In the midst of a busy teaching schedule and committee work we all faced, we still felt it was important to set aside time to discuss ideas and support new efforts. We have met for about one-and-a-half to two hours each week, without fail, for two school years.

In those sessions we discussed several things that we believed would help us improve our science teaching. We shared our current teaching strategies and provided feedback to one another. We watched science videos, and looked at resources we might want to use. We talked about problems we were having, and shared successes. One issue that was troublesome was the idea that we didn't have enough science knowledge to be effective science teachers. Judy in particular felt because we didn't know enough science, we couldn't teach it well. However, Valarie reminded us how well we knew our students, and about how much we knew about teaching. We realized that we didn't know everything about anything we taught. The way we currently taught science was much different from the way we taught other subjects. When we taught other subjects we used strategies that were child-centered and open-ended. Kathy thought it might be appropriate to teach science a similar fashion--to allow students the opportunities to build their own connections rather than being given information through a textbook. In the absence of knowing everything about a science concept we were teaching, we would familiarize ourselves with the basics of the concept, and then share science explorations and investigations with the students. We decided to learn, experiment, and inquire right along with them. In this way we would be increasing our own knowledge as well as inspiring students in science. Children would learn they didn't necessarily need to know everything either, but that they could use scientific ways of knowing to help them answer their own questions.

In other sessions we discussed our developing knowledge of pedagogy and content, assessment strategies, and created our own child-centered hands-on units that integrated into our language arts program. These will be discussed later in the paper.

We grew more comfortable teaching science, and began trying things without feeling pressured to know everything. This was developed by sharing and supporting each others' ideas, and also questioning each other in our weekly meetings. Through questioning each other of why we thought certain strategies or activities would develop our students science knowledge, we helped each other think through effective, and not so effective, teaching strategies and concepts. Valarie had developed a unit on "Bubbles" that incorporated physical science. She videotaped some of her lessons and shared them with the other teachers. The "Bubbles Unit" was seen as the "turning point" for interest in physical science. Elaine grew interested in teaching physical science. She developed a unit on sound waves. She was excited about how much her students were learning. She shared her unit with the other teachers for feedback and input. Her unit was well-received and used by other teachers. Judy reluctantly decided to try some hands-on physical science teaching. She said, "Okay, if you're sure I don't have to know everything about it, I'll try it." She borrowed videos Valarie made of her science teaching to get ideas. Judy developed a unit on "floating and sinking" that fit her teaching style and her students. It was also well-received by the other teachers. Kathy began by trying some science teaching related to biological science. She still didn't see a real use for physical science. She developed a unit on penguins to connect with the Christmas program the first grade was presenting for parents. Her students read, wrote and engaged in activities around learning about penguins. At each step of each other's development we shared what we were working on with each other and asked for input. We strongly believe that by trying things and reflecting on them together and individually we have become better science teachers.

Increased Content and Pedagogical Knowledge

As we grew to enjoy teaching science, we became aware of opportunities to learn more about it. Our whole group attended science inservices and conferences such as Washington Science Teachers Association Conference and National Science Teachers Association Conference, to gain new ideas about science teaching. Kathy and Valarie took science education courses at a local university with the purpose of gaining knowledge of current science teaching practices. We shared these ideas with Elaine and Judy. We learned about how important it is to take children's current understandings into account when teaching science. We learned strategies such as the learning cycle, to help us develop children's ideas, and to enable them to develop their own scientific understandings. We all believed that to teach reading students actually need to read, and came to understand that to effectively teach science our students needed to actually do science. Students needed to develop and conduct their own investigations to help answer their own questions. We learned how important it was for all people to become scientifically literate, and how to encourage under-represented students in science. Valarie videotaped her use of the teaching practices she was learning, and we all watched and discussed the videos. We agreed the first graders seemed to be learning more than we expected they could, and decided to try the methods and compare results. We shared and discussed these results in our weekly meetings.

Meanwhile, Valarie served as chair of the Science Curriculum Adoption Committee for our school district. Our school district adopted a hands-on science program that included no textbook. We were excited about using it in our classrooms, but found there was little available for first grade. Since there was no single program we deemed most appropriate for our grade, we chose from National Science Resource Center's *Science and Technology for Children* (1991), and Lawrence Hall of Science's *Full Option Science System* (1993) to provide units for our classes. There were still not enough well made science units available for first grade. We applied our knowledge of students and our newly gained knowledge of science teaching and together created a unit on insects. For about four months during our weekly meetings we discussed objectives, wrote a curriculum guide, and searched for and ordered resources. Our district gave us $500 to develop this unit. We included not only science explorations, but also tradebooks that supported our reading program, as well as writing ideas for language arts lessons. Following this we decided to create another unit on recycling. At this time Elaine decided to make science her personal growth area for her district teaching evaluations. At her suggestion we used personal and classroom supply money to create a variety of science kits. We took the information gained in the conferences and coursework and enthusiastically implemented it in our own classrooms. When teaching science or developing a unit we always included a section in our units to find our students' current understandings so we could plan to address any misconceptions in subsequent lessons. This was accomplished in each unit through group discussion, brainstorming, and KWL methods. KWL refers to a language arts method for finding out what students Know, what they Want to know, and what they Learned about the concept under study.

To increase our science content knowledge, we used information from the conferences and workshops. In addition, Valarie elected to take an introductory college physics course at a local university. While less than pleased with the course, she shared physics information with the rest of us, along with some information about how not to teach science for understanding. Valarie discussed physics concepts she was learning with the others almost daily over lunch. The rest of us would commiserate over the difficulty of the course, and Elaine once told her "I don't really want to know any more about that joule stuff." Kathy grew tired of hearing about "How much candy you'd have to eat to get to the top of a mountain." However, they were patient, and being able to talk about the physics course and strategies for solving the problems helped Valarie in learning the content. It also illustrated to us how difficult it could be to learn science content and the importance of using appropriate strategies to help students understand what they are learning.

Elaine, Judy, and Kathy were excited about science topics on *Reading Rainbow*. This was seen as an especially teacher-friendly show because it integrates various concepts, sometimes science, with reading and language arts. Copies of various episodes were included in the units being developed by each teacher. Valarie was excited about *Bill Nye the Science Guy*. She enjoyed it because of the excitement and energy he brought to science. We decided to watch episodes of these children's shows in our group meetings to help us gain science content knowledge. We discussed what we were learning, and how to implement it in our classrooms. We began to use the programs in our first grade classrooms. We used them to explore concepts in different ways than we were doing in class. We saw them as additions to our science curriculum, not replacements.

Development of New Assessment Strategies

We had different points of view on assessment. Judy and Kathy believed that science didn't really need to be assessed in first grade. Elaine thought that all first graders would deserve top grades, because after all, they were first graders without much science knowledge. Valarie thought it was as important to accurately assess science as reading.

Through some discussion during our weekly meetings we agreed to try some different types of assessment to see if we could track development of science knowledge in first graders. It was difficult to assess our more open-ended, child-centered teaching. We were accustomed to using paper and pencil tests in conjunction with our textbook. Valarie decided to create an informal assessment observation checklist. She shared it with the rest of the group, who, while they liked the idea, found it to be a little intimidating and too lengthy to be of much classroom use (see Appendix A). Kathy thought it was a little much to be using to assess first graders and stated she wouldn't use something quite so lengthy, nor would she use something on which she didn't understand all the terminology. In another group meeting we discussed ways to make the checklist easier to use in the classroom, and would provide the information we would need to assess our students (see Appendix B). Elaine, as part of her personal growth project, further refined the checklist and again, it was shared in a group meeting (see Appendix C). With input from the group the current version of the checklist allowed spaces for notes of individual student thinking during inquiries, and of how they were working to solve problems (see Appendix D). Each student was not assessed everyday, rather our goal was to assess five a day using our checklists, as students investigated. We would circulate the room, observing students and making detailed notes of about five students' current understandings. At our weekly meetings we discussed how we were using the checklists. We were used to using checklists to assess reading and writing, so it seemed almost natural to use them for science. Judy helped us refine definitions for terms on our checklist to make sure we were assessing the same things. Since our students did not all fall in the same categories of expertise, the importance of individual assessment of science became apparent. We wanted to assess first grade science abilities to help students become better learners and problem solvers. The assessment also helped us focus our teaching to better meet student needs. By noting the differences among students it became apparent that assessing student understanding would provide more information about each student and would allow us to better plan instruction.

Valarie was extremely interested in student misconceptions. She chose to hold class discussions and listed student responses to questions on butcher paper that was later posted in the classroom. Elaine, Judy and Kathy saw these charts and asked her about them. Valarie did this to enable her to assess the thinking of the class as a whole, and to plan future lessons. Elaine and Kathy decided to do a similar recording of student responses on the chart paper they used for reading and language arts discussions. Judy chose to list the responses on Post-It Notes she stuck to the chart paper that enabled her to move the responses around to different columns. We extended the listing of group responses by having students respond to class discussion questions individually in science journals. This allowed us to capture the thinking of specific students, and enabled us to reply to student comments and questions, to help them redirect their own ideas, and to serve as assessment for future lessons. We were familiar with using daily journals for writing, and students were used to writing in journals, so this was an easy extension for our classrooms. Students used the journals to record ideas and data, and teachers responded to students daily. Valarie decided to videotape individual groups of students as they were working. She asked probing questions of students and videotaped their responses as they were working. This allowed her to review the tape and understand individual ideas, as well as overall group thinking.

We are still developing assessment techniques that will allow us to plan future lessons, and to accurately evaluate student thinking. We know our current methods are more enlightening than our previous multiple choice tests, but are still working toward even better ways of understanding our students.

Making Time for Science

A big problem we found with our new enthusiasm for teaching science was the lack of time in our day. Time is always a consideration in any teaching situation. In our school our language arts and reading program (SUCCESS, 1978) requires two-and-a-half hours daily. Combined with lunches, recess, pull-out subjects such as physical education, and other subjects that need to be taught, it was difficult for us to find time to teach as much science as we wished. We searched for ways to integrate science into our already full curriculum. With the blessing of our principal, we decided to incorporate more science into our language arts time block. During our weekly meetings, we talked about strategies for fitting science into the half-hour writing module of our program. We found we could use that time for students to write observations and reflections in their science journals. We could have a question for them to ponder, such as "what is electricity?, " hold a short whole-group discussion on the topic, listing student responses on the butcher paper, and then have students respond individually in their journals for the remainder of the writing session. In this way we were able to use the language arts skills of speaking and writing to find out student ideas about a topic. This enabled us to note any misconceptions, and to plan future lessons.

Another half-hour block of time was required during our daily research module. During the research module students are generally assigned to look through newspapers, magazines, maps, and other materials, to find information relating to the topic in a teacher's guide. The topic didn't necessarily fit with anything studied in class. We decided we could have our students engage in the searching activity as defined in the language arts book but have it related to the science concept the students were investigating. Instead of having students search through magazines for 'things that begin with the letter e,' for example, we could have students search for 'things that use electricity.' Occasionally we would have students conduct short investigations during the research period, or watch a demonstration, and then search through the written materials for more information.

In addition, we found many science tradebooks that interested children. These books were often read during the half-hour storytime module, after which students completed a project related to the book. We realized that reading science books to students, having them search for information through written materials, and having them write their ideas about science in journals is not actually having students engage in science. However, all this prior work primed students to be prepared for engaging in hands-on activities. They were consciously thinking about science concepts for an hour to an hour and a half longer each day than we previously taught. This was in addition to our regularly scheduled science times (which varied from daily to twice a week) during which students would be involved in hands-on problem-solving activities. These activities provided impetus for their learning, discussions, research module topics, and future journal writings.

Teaching Science in the Primary Grades is Important

Our commitment to improving our science teaching, and in finding time to make it possible, has increased our effectiveness as science teachers. Valarie is now enrolled in a doctoral program in Science Education. Kathy has gradually come to understand and value the importance of good science education in the primary grades. Elaine, who previously searched for reasons to cancel science, now looks forward to teaching science daily and is even working with an enrichment Science Club program for second graders. Judy was excited by observing other primary teachers giving first graders opportunities to explore and experiment with science materials and concepts, so she is involved in developing and using first grade hands-on science kits. We confirm Perkes' (1975) findings that teachers who feel adequately prepared and confident will teach more science in the elementary school. We each now teach a minimum of two hours a week of hands-on science. This is in addition to the journal writing, research, and storytime module science integration. Our students enjoy science now. Students rush into Elaine's class in the mornings asking "Do we have science today?" Valarie reported that her students "know" why science is scheduled at the last of the day--it's because "we all like it the best--we save the best for last." Judy's students love science now, when previously they didn't even know what it was. Kathy's students cheer when she tells them they're going to get to do an experiment. We also like teaching science more. We can see the results in our students. Sometimes it requires much work and our classrooms may look chaotic, but we have come to believe that when students are actively engaged and are thinking about what they are learning, things sometimes may look in disarray from the outside. However, through our new assessment techniques we can know that students are learning more science, and learning more about science than they have before.

We continue to search for better ways to teach and assess our students, and to provide them with quality content, as well as the ability to conduct scientific investigations on their own. We know that through working together and supporting one another, we have all become better science teachers and are influencing our students in very positive ways.

Suggestions to Improve Elementary Science Teaching

Our suggestions for other elementary teachers who wish to develop their science teaching include methods we successfully used. First of all, it was imperative that we supported each other's trials in teaching. This is not to say we always agreed with each other, or continually stated, "You are doing such a great job!," but we also felt free to tell each other when something we were doing did not seem consistent with our goals. We felt free to make suggestions of other strategies to try to help us meet our goals.

Secondly, in order to provide meaningful input to each other's developing teaching strategies, we needed to find out more about good science teaching and science content. This developing knowledge of pedagogy and content helped us be more aware of our own and each other's effective, and not so effective, teaching strategies. We needed to be open to new ideas, and to be able to see that our new strategies were making a difference. This we discovered through the development of assessment strategies that better informed us of the understandings our students were gaining of science.

Thirdly, we needed to make adjustment in our curriculum in order to be able to teach science in the way we felt would better serve our students. We needed to be able to integrate science into other subjects in order to make better use of our time. This interdisciplinary teaching allowed us to have students engaged in thinking, reading, and writing about science during language arts times of the day, and enabled us to allow students time during science to explore concepts in a hands-on inquiry fashion instead of reading from a textbook.

Fourth, the process of change is very developmental and takes time. We still realize we have more progress to make, and have already spent five years in developing our teaching strategies and improving our content knowledge. Any change in teaching will necessarily take time for teachers to try new things, get feedback, and make adaptations. Kathy said with Valarie studying away from the building and no longer prompting a focus on science teaching, it is again becoming easier to neglect it. This would indicate the process not only takes time, but it is also necessary to keep following up on "how things are going" to ensure teachers continue in their efforts.

Fifth, Kathy stated that an important component in the success of our development was the influence of a person who was enthusiastic about science and prompted those who were not so excited about it. She noted that it was important to have someone interested in science who was also a first grade teacher at the same school. Kathy said there would have been much less credibility and that the teachers wouldn't have "listened to someone else," who was either not a first grade teacher or was from outside the school. Even someone with second grade teaching experience wouldn't have been seen to be as valuable as someone with first grade teaching experience. Someone who has common experiences and knowledge of students will have a more successful time influencing the teaching of inservice teachers. Kathy emphasized there would have been resistance to change if these teaching strategies and other ideas had been imposed from the administration. Judy agreed, stating it was "a good thing we didn't know we were doing this (becoming more comfortable and interested in teaching science) or we would never had done it. It was not intimidating the way it happened." Elaine felt the same way, stating "It was fun working together and seeing the changes we were making in ourselves and our students. We wouldn't have done it if it weren't fun."

Lastly, the Finley School District was very supportive of our change process. We received support from our building principal, school board, and superintendent. For the past five years our school district has joined with us in our commitment to improve our science teaching. They have allowed us to spend the district Eisenhower Fund allotment for the past several years on the first grade team. We have used the monies to attend conferences and workshops to improve our science teaching and content knowledge. From our experiences, it is obvious that the money was well-spent and our new expertise in teaching science will make a difference in all our future students' success in science. It is essential that the school district support teachers in their efforts to effect change in their teaching.

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Appendices

Development of Assessment Checklist for Elementary Science

Appendix A

QTR 1st 2nd 3rd 4th Student________________________

Science Process Skills Checklist

Lesson									
Date									
Hypothesizes									
logical prediction backs up prediction									
Controls Variables									
notices missing control can tell why important can tell how to control									
Observing									
uses various senses and tests; uses logic.									
Collects Data									
records data, uses logic uses equipment									
Measurement									
estimates; compares uses numbers uses equipment									
Classifying Data									
logical categories backs up choices									
Inferring									
draws and backs up conclusions; uses data uses observations relates to hypothesis									
Communicating									
during and after experiment written; oral									
Questioning									
wonders "what if" has follow-up questions									
Designing Experiments									
uses logic knows what is needed includes science processes									

Notes________________________

QUARTER 1 2 3 4 STUDENT______

SCIENCE PROCESS SKILLS

	LESSON								
	DATE								
OBSERVING USES VARIOUS SENSES AND TESTS; USES LOGIC									
HYPOTHESIZES LOGICAL PREDICTIONS BACKS UP PREDICTIONS									
RECORDING DATA COLLECTS DATA; USES LOGIC; USES EQUIPMENT									
WORK HABITS									
PARTICIPATION									
ON TASK									

NOTES:

Appendix C

Science Checklist

Quarter 1 2 3 4

Name______________________________

Date						
Participation						
Follows Directions						
Records Observations						
Works Cooperatively						
Participates in Discussions						
Handles Equipment						
Knowledge						
Makes Predictions						
Explains Observations						
Makes Comparisons						
Draws Conclusions						

+ skilled

√ developing

- exploring

Science Checklist

Quarter 1 2 3 4

Name________________________

Lesson Name					
Date					
Participation					
Follows Directions					
Records Observations					
Works Cooperatively					
Participates in Discussions					
Handles Equipment					
Knowledge					
Makes Predictions					
Explains Observations					
Makes Comparisons					
Draws Conclusions					

+ skilled
√ developing
- exploring

INTERDISCIPLINARY MATH AND SCIENCE: A HANDS-ON CONSIDERATION OF INTEGRATED REFORM

Lynne E. Houtz, Nebraska Wesleyan University
Julie A. Thomas, Texas Tech University

Interdisciplinary Math and Science

At the beginning of this workshop presentation, conference attendees introduced themselves and explained their objectives in participating in this one-hour session. Some explained they were considering an integrated approach to methods courses, and they were looking foı models, problems, and solutions. Others were looking for hands-on activities and a few were seeking to familiarize themselves with more of the research.

Participants considered the term "Integrated Learning" according to Fogarty (1992) in the attached paper, "Toward Interdisciplinary math and Science Education: A Literature Review in Science Education Reform." Additional discussion referenced science as a concrete experience in mathematical ideas (McBride & Silverman, 1991) and science as motivation for learning mathematics (Berlin, 1994; McBride & Silverman, 1991). Presenters Houtz and Thomas shared their experience in integrated science and mathematics methods instruction at Nebraska Wesleyan University and the University of Nebraska-Lincoln. Houtz shared examples of the Nebraska state math and science frameworks which link the concept and process skills of math and science.

Active Participation

Following this brief introduction, Houtz and Thomas facilitated three hands-on activities in integrated math and science. The NSES Standards, Project 2061 Benchmarks, and the NCTM Standards were referenced with each activity. In "Giant Hands," participants worked with partners to solve how tall a giant might be, given a handprint. Participant pairs used a variety of strategies including algebra and ratios. For "Marble Dynamics," participants were given simple materials and charged to construct a ramp and travel surface that would permit a marble to roll and stop exactly 80 cm from the end of the ramp. The third activity, "Raisin Counters," focused on forming hypotheses, counting, and graphing both the hypothetical and actual numbers of small boxes of raisins. Throughout the cooperative hands-on/minds-on activities, participants were mindful of the mathematic and science content and process skills including communicating, connecting, hypothesizing, inferring, interpreting data, measuring, modeling, observing, patterning, problem solving, predicting, questioning, reasoning, and researching. The conversation was lively with implications of utilizing this approach in pre-service teacher education.

Research Questions

The session ended with a reference to the attached literature review considering the challenges of integrated teacher education (McKinney, 1992; Stepans, 191), the limited integrated curriculum resources available, and the limited research in integrated math and science teaching (Berlin, 1994). Participants generated possible research questions: Does integrated teaching improve student knowledge and understanding? What are the achievement benefits? Is integrated learning more or less effective for some students than for others (i.e. low socioeconomic or high ability)? How can we measure math/science learning?

Giant Hands

Question

How tall is the giant who made this hand print?

SCIENCE STANDARDS

Every organism requires a set of instructions (genes)for specifying its traits.
Nutritional balance has a direct effect on growth and development.

Project 2061

Tools (tape measures) can give more information about things than can be obtained just by observing things without their help.
Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.
When people give different descriptions of the same thing, it is usually a good idea to take some fresh observations instead of just arguing about who is right.
Raise questions about the world and be willing to seek answers by making careful observations and trying things out.
Describe and compare things in terms of number, shape, texture, size, weight, color, and motion.
Use numerical data in describing and comparing objects and events.
Results of scientific investigations are seldom exactly the same, but if differences are large, it is important to try to figure out why.
Offer reasons for findings and consider reasons suggested by others.

NCTM Standards

Use problem-solving approaches to investigate and understand mathematical content.
Formulate problems from everyday and mathematical situations.
Use patterns and relationships to analyze mathematical situations.
Apply estimation in working with quantities, measurement, computation, and problem solving
Collect, organize, and describe data.
Develop the process of measuring and concepts related to units of measurement.

Materials

large paper hand prints, 2-3 metric tapes for each group, wall-mounted tapes for metric height measurement

Discussion

1. How tall is the giant? How did you figure it out?
3. Did each group get the same answer? Why?
4. What is the average class height? What is the average of the giant's height? Ratio?
5. Could the giant sit in your chair? Work at your desk?
6. How tall (wide, long) would the desk be? Chair? Bed? Dresser?
7. Could you ever be as tall as this giant?

(Adapted from AIMS, "Hands on the Giant")

MARBLE DYNAMICS

Question

Which ramp setup allows the marble to roll farthest? shortest? closest to 40 cm?

SCIENCE STANDARDS (from draft)

The position and motion of objects can be changed by pushing or pulling and the size of the change is related to the strength of the push or pull.
Objects change their motion only when a net force is applied.
Gravity is a universal force that each mass exerts on any other mass.

Project 2061

People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.
Tools (measuring tapes and rulers) often give more information about things than can be obtained by just observing things without their help.
In doing science, it is often helpful to work with a team to share findings with others. All team members should reach their own individual conclusion, however, about what the findings mean.
People can use objects and ways of doing things to solve problems.
Raise questions about the world around them and be willing to seek answers to some of them by making careful observations and trying things out.
Results of scientific investigations are seldom exactly the same, but if the differences are large, it is important to try to figure out why.
Recognize when comparisons might not be fair because some conditions are not kept the same.

NCTM Standards

Use problem-solving approaches to investigate and understand mathematical content.
Develop and apply a variety of strategies to solve problems, with emphasis on multistep and nonroutine problems.
Estimate, make, and use measurements to describe and compare phenomena.
Collect, organize, and describe data.

Materials

paper tubing for ramps, meter tape, objects to adjust height of ramp, 2 marbles per group, metric ruler

Discussion

1. What adjustments did your team make to determine how far the marble would roll?
2. What variables needed to be controlled to accurately compare the adjustments and rolls?
3. Which setup allowed marble to roll farthest? Shortest? exactly 40 cm ?

Raisin Counters

Question

How many raisins are in a box?

Science Standards

The sun is a major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle.

The characteristics of an organism can be described in terms of a combination of traits. S... traits are inherited and others from interaction with the environment.

Project 2061

Everybody can do science and invent things and ideas.

Numbers can be used to count things, place them in order, or name them.

It is possible (and often useful) to estimate quantities without knowing them exactly.

Simple graphs can help to tell about observations.

Describe and compare things in terms of number, shape, texture, size, weight, color, and motion. Mathematical ideas can be represented concretely, graphically, and symbolically.

Use numerical data in describing and comparing objects and events.

NCTM Standards

Use problem-solving approaches to investigate and understand mathematical content.

Formulate problems from everyday and mathematical situations.

Use patterns and relationships to analyze mathematical situations.

Apply estimation in working with quantities, measurement, computation, and problem solving

Collect, organize, and describe data.

Construct, read, and interpret displays of data.

Materials

small boxes of raisins for each group, overhead chart for hypotheses count, group graph for hypotheses count, overhead chart for actual count, group graph for actual count, centi-cubes, markers, calculators for each group

Discussion

1. How does your group hypothesis compare with other groups' hypothesis?
2. What conclusions can you make from the hypothesis chart?
3. How does the hypothesis graph differ from the hypothesis chart? Why?
4. How does your actual data differ from the hypothesis data? Why?
5. How are raisins made? Why aren't the numbers of raisins equal in each box?
6. Who eats dehydrated foods? Why?

(Adapted from AIMS, "Mini-Boxes of Raisin Fun")

Toward Interdisciplinary Math and Science Education: A Literature Review in Science Education Reform

Paper presented at AETS International Conference, Seattle, WA, January 11-13, 1996
Julie Thomas, Texas Tech University

One of the most discussed issues in education today is that of interdisciplinary or integrated curriculum and instruction. Some believe interdisciplinary curricula is the panacea for American education -- that connected thinking will best prepare America's students for the dilemmas of the next century (McKinney, 1993). Others admit that there is a need for connectedness in classrooms, but are more concerned with increasing the knowledge base -- particularly in science and mathematics content. Greenberg (1993, p.1) observes these educators are "ensconced in their areas of specialization."

Currently, national science and math education reform initiatives call for an increase in the integration of science, math, and other content areas. Documents such as *Science for All Americans* (American Association for the Advancement of Science, 1989) and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989) stress the interrelatedness of math and science and the natural implication for curriculum development and instruction.

Interdisciplinary math and science education is not new (Dubins, 1957; Kinney, 1930; Payne, 1957; Rassmussen, 1964). The Central Association of Science and Mathematics teachers organized around the turn of the century to bring a closer correlation between the two disciplines (Breslich, 1936). Now, again, science and mathematics professional organizations are promoting the integration of the two disciplines. A decline in student achievement in math and science has raised a concern for continued national strength in an international business place.

As a result, the National Council of Teachers of Mathematics (1989), the National Science Teachers Association (1983), and the American Association for the Advancement of Science (1989) issued a challenge for reform in science, mathematics, and technology to enable students to solve real-world problems. AAAS *Project 2061* (1991) calls for less curriculum content and more depth -- encouraging teachers to find more connections across the disciplines to facilitate cognitive development. The National Council of Teachers of Mathematics (1989) has set curriculum standards which promote math as a way of thinking -- the language of problem solving. Teachers are encouraged to integrate this new mathematics instruction with other areas of the curriculum.

The Process of Science and Mathematics Integration

Interdisciplinary teaching changes the customary order of thinking and decision making. It challenges teachers to take a different route in their lesson development. Hayes-Jacobs (1989) suggests teachers put aside th 'scipline orientation to consider general themes of interest to students. Teachers then sel· ɔrganizing centers" which are neutral in character and do not depend on any discipline for their essential force but include experiences or events that are universal to each student's background. Organizing centers such as Relationships, Exploration, Interconnections, and Change are then subject to analysis to determine appropriate content material. Teachers next think of questions which will "grab" student interest and select learning materials which will help students discover alternative solutions (and generate their own questions) while they are doing both math and science.

This interdisciplinary planning process is the unfolding of a comprehensive framework. It proves to be an engaging intellectual exercise for teams of teachers as they meet to make crucial, instructional decisions. In the experience of Greenberg (1993), teachers are no longer isolated individuals but members of a bonded team working to improve the education of their shared student population. Interdisciplinary team teachers begin to realize they are all responsible for teaching thinking processes as well as skills knowledge -- and for the formation of well-educated, productive young citizens. Integrated instruction is project oriented; Robert Tinker suggests instead of "teaching students", teachers "empower students to undertake original investigations to do math and science" (in Berlin, 1994, p.35).

Fogarty (1992) lists multiple models for integration that follow along a continuum. These ten models indicate the variety of ways in which a teacher can plan to cross disciplines.

Integrated curriculum can be connected, nested, sequenced, shared, webbed, threaded, integrated, immersed, or networked. This continuum is reminiscent of Bloom's (1956) Hierarchy of Thinking and Learning ranging from the levels of knowledge and comprehension to higher levels of analysis, synthesis, and evaluation. Integration plans can be as simple as relating ideas across disciplines and connecting overlapping concepts or as complex as threading skills through various disciplines. Fogarty (1992) identifies integration terminology and clarifies the fine lines of meaning.

(Insert Table.1)

The Philosophical Underpinnings of Integrated Teaching and Learning

Integrated instructional philosophy has its roots in constructivism. The constructivist paradigm posits that meaningful learning is constructed by the learner as a result of his or her sensory experiences with the world. Learners respond to their sensory experiences by building or constructing in their minds, schema or cognitive structures which constitute the meaning and understanding of their world. "Individuals attempt to make sense of whatever situation or phenomenon they encounter, and a consequence of this sense making process (a process which takes place within the mind of these individuals) is the establishment of structures in the mind" (Saunders, 1992, p. 136).

The implications for constructivist classroom instruction include maximal use of hands-on investigative laboratory activities which provide learners with a high degree of active cognitive involvement. A necessary condition for cognitive restructuring is an opportunity for repeated exploratory, inquiry-oriented behaviors about an event or phenomena in order to realize if an intact schema is still tenable or if it is necessary to revise one's cognitive structure so as to be more consistent with new data, measurements, or observations. In the constructivist learning model (Saunders, 1992), the Natural Universe is necessarily interdisciplinary. Interdisciplinary curricula in science and mathematics, however, would support student investigation as they accommodate their learning. Further, the integration of science and math supports the development of logical reasoning and problem solving -- a goal in both science and math instruction (National Council of Teachers of Mathematics, 1980; National Science Teachers Association, 1983).

Common Problems Regarding Integrated Instruction

Integrated Instruction can pose some dilemmas for classroom teachers.

• In most schools, science and math curricula are organized and taught as separate subjects. There are separate text books and separate instructional time periods. In addition, they are tested separately on standardized tests (McBride and Silverman, 1992).

• Typically, science applications are not considered part of a standard math lesson. More planning time and more instructional time is required to teach mathematics concepts through science activities (McBride and Silverman, 1992).

• Often, integrated lessons require hands-on materials . Many teachers do not have such hands-on mathematics and science materials collected and organized in their classrooms. As a result most science is taught by lectures or question-and-answer techniques based on district selected textbooks (Berlin, 1994; Kyle, 1985).

• When students are involved in investigative exploration, accountability for achievement is a challenge. Teachers are new to systems of individual assessment for group work (Berlin, 1994).

• Students greatly enjoy integrated lessons. Teachers, administrators, and parents worry whether students are really learning or simply playing. A strong public relations program is needed (Berlin, 1994).

• Integrated or interdisciplinary lessons require more than one text book. Few teachers have access or are aware of additional curriculum materials that support the integration of science and mathematics (McBride and Silverman, 1992).

Published Integrated Elementary Math and Science Resources

Models of integrated math and science curricula do exist. Fresno Pacific Math-Science Project at Fresno Pacific College has developed integrated science and mathematics activities called Activities that Integrate Mathematics and Science (AIMS) materials. These materials are activities developed for grades K-9. They are available from the AIMS Educational Foundation, P.O. Box 7766, Fresno, California, 93747, (209) 291-1766.

Great Explorations in Math and Science (GEMS) is a program developed at the University of California at Berkeley. Twenty-four publications integrate math with life, earth, and physical science for students in preschool - high school. Lessons use the guided discovery approach and are written for teachers with limited background in science and mathematics. These are available from the Lawrence Hall of Science, University of California, Berkeley, CA 94720,(415) 642-7771.

Unified Science and Mathematics for Elementary Schools (USMES) materials integrate science and mathematics for students in Kindergarten to eighth grade by presenting students with problems from their school and community. There are no right solutions and students have to develop their own ideas. They are included on Science Helper K-8, a CD-ROM data base available from the University of Florida at Gainesville.

School Science and Mathematics Association (SSMA) publishes a monthly journal which includes activities called SSMILES (School Science and Mathematics Integrated Lessons). SSMA has also produced a collection of readings on the integration of science and mathematics

A Rationale for Mathematics and Science Integration

Science and mathematics are closely related systems of thought and are naturally correlated in the physical world. Science can provide students with concrete examples of abstract mathematical ideas that can improve learning of mathematics concepts (McBride & Silverman, 1991). Children learn best when they discover through their own concrete experiences (Berlin, 1989; 1990). Math can enable students to achieve a deeper understanding of science concepts by providing ways to quantify and explain science relationships. Science activities illustrating mathematics concepts can provide relevancy and motivation for learning mathematics (Berlin, 1994; McBride & Silverman, 1991).

To become a nation of thinkers and problem solvers, teachers must move away from emphasizing "how to" as the goal in mathematics (and education in general) and into the why

(National Research Council, 1989; National Council of Teachers of Mathematics, 1989). "Teaching for understanding means students don't just memorize information but actively seek it, building relationships among data. It means that teachers are facilitators, not just preachers of facts. It means moving away from simply absorbing facts, to constructing knowledge" (McKinney, 1992, p. 7). Arthur Wiebe (1989) of the AIMS Foundation holds,

> . . . science and mathematics should be studied as a unified subject as a means of enriching and giving meaning to both. Separation impoverishes these disciplines, robbing them of the benefits that accrue from integration. Interrelating science and mathematics lets students have meaningful experiences in the classroom that parallel those they will find in the real world providing them with realistic preparation for careers in science and mathematics as informed citizens.

Elementary Pre-service Education and Integrated Instruction

Lonning and DeFranco (1994) suggest, "If integration of mathematics and science is to occur, teacher preparation programs at colleges and universities must provide the leadership in developing and modeling methods of teaching integrated content" (p. 18). Lonning and Defranco have begun to define a course at the University of Connecticut. A few other universities have begun to change their science and mathematics teacher education programs as well. In the Mississippi State experience, Harpole (1991) believes that the majority of teachers at all levels tend to teach as they have been taught. Thus, model teaching by academic faculty is a critical element in educating teachers for elementary classrooms who are prepared in content and practice good teaching strategies. To achieve this end, a series of weekend workshops have been designed for university science and education faculty. The goals are to acquaint the faculty with current pedagogy and to prepare them to serve as model teachers for preservice teachers to emulate as they move into the elementary classroom.

Heikken and McDevitt (1991) have begun a five year project at the University of Northern Colorado in developing and evaluating a model to prepare prospective elementary teachers in mathematics and science. Nine undergraduate content and methods courses are being re-designed or created as part of this comprehensive project. Teaching fellows, recruited from elementary and middle-level teachers through local Colorado districts, participate in a team capacity. The teaching fellows hold half-time assignments on campus and typically focus their efforts on one course. For each course, three to four months of full-time support are offered for the enhancement and revision of the course in line with project objectives.

The Preparation of Elementary Mathematics and Science Teacher (PEMST) Project has developed at the University of Northern Iowa. Ward (1991) explains the goal is to develop improved programs for students majoring in elementary education who wish to minor in mathematics or in science. The project has generated three new intermediate level science courses which consider pedagogical as well as content issues. One methods course has been revised and another new course with a strong field experience component has been developed as the culminating course in the program.

Stepans (1991) at the University of Wyoming is working on a project to develop and field test a program focusing on prospective teachers' understanding of science, their confidence in teaching science, their level of concern and their attitude toward science. This program merges content and pedagogy and encourages reflection on student learning.

Concerns in Teacher Education Regarding Integrated Instruction

Some researchers offer recommendations for integrated program development. Stepans (1991) at the University of Wyoming indicates that building bridges from content to teaching and good learning cycle lessons are not easy to teach or write. In addition, the logistics and administration of a heavy field component with meaningful supervision and evaluation is difficult. Wilkinson (1991) indicates, "In too many cases the effect of pre-service on campus work is quickly eroded by placing student teachers in settings which are not compatible with the methods instruction in campus classes. The transition into the first year of teaching can also erode many of the positive impacts of the preservice program" (p. 177). McDevitt & Lindauer (1991) suggest that pre-service teachers who experience a coherent, internally consistent set of teaching methodologies and conceptual underpinnings for these strategies, will be better able to adopt the strategies themselves in their own teaching. They recommend cooperation between university faculty and elementary teachers.

> ...experienced teachers, brought in as full and equal partners, have the capacity to serve as productive catalysts for change. They can model effective teaching for students, confirm

the value of the course content for students, assist faculty in their attempts to pare down and focus concepts, and otherwise instill teacher preparation with grounding in elementary classroom realities (p. 344).

McDevitt & Lindauer (1991) make it evident that significant changes in course design and program development require substantive commitments of time and collaboration between faculty members across disciplines.

> We urge other institutions contemplating similar programs to build specific mechanisms that solidify connections between and among faculty members and experienced elementary teachers. . . . We believe that innovations in teacher preparation cannot be implemented successfully without such collaboration (p. 346).

The pre-service program must employ cooperative learning strategies, coaching and feedback, student teaching with mentor teachers committed to teaching science and mathematics, and a blended approach to science and math content and teaching methods to expose students to positive attitude-enhancing experiences. Programs are needed to help prospective teachers become aware of their own perceptions, develop knowledge and skill in identifying children's preconceptions, develop skills in creating learning environments to bring about conceptual change in children, and become knowledgeable about research in the area of teaching for conceptual change. Beginning teachers need to be aware of these new programs, understand the pedagogical content, and be able to manage classrooms where active learning is occurring (Bybee, 1991).

> If we expect students to construct mathematical and scientific knowledge for themselves, then it is critical that teachers learn by the same path. Yet this is not happening in most of our universities. In fact, the lecture format often used by the liberal arts faculty to teach mathematics and science courses to education majors will not bring about the improved teaching we want from elementary and secondary teachers (McKinney, 1992, p.11).

We cannot continue to educate teachers in traditional ways while policy makers expect them to teach in non-traditional ways. In the words of Gary Sykes, associate professor from Michigan State University, "We end up expecting children to learn what we don't educate teachers to teach. (McKinney, 1992, p. 10)" College content and methods courses should duplicate or model what we want the teaching of mathematics and science to look like in our classrooms. McKinney suggests that education and liberal arts faculties must begin to work together as a teaching team to develop improved preservice programs for prospective mathematics and science teachers. Cooperating teachers need to become a part of the education team. They must have the opportunity to help shape the content and methods of the "on campus" courses in the pre-service program.

Model programs are needed to support the needs of first year teachers as they develop integrated instructional strategies. These may include mentor / mentee relationships, long distance services such as newsletters, encouragement to attend professional meetings, meeting of graduates within scheduled professional meetings such as state science and mathematics conferences, electronic mail, and telephone support.

More Research is Needed

There is more rhetoric than research regarding the effects of interdisciplinary instruction. In the area of humanities education, teams of teachers in New York City have been immersed in the interdisciplinary model to restructure the humanities departments in their schools. Evaluation has shown that student participants in these programs show greater understanding of content, find it easier to make connections among different disciplines, improve their skills, and achieve better results in assessment protocols. Teachers are revitalized by the experience, enjoy better collegial relations, and gain a more comprehensive understanding of the subject matter as taught across curriculum areas (Greenberg, 1993).

In science education, Friend (1985) investigated the achievement of a seventh grade integrated physics unit -- two classes integrated and two classes non-integrated. The results were mixed. Students who received integrated instruction and who were above grade level significantly out performed 1) a group of students who were above grade level and received non-integrated instruction and 2) a group of students who were on grade level and received non-integrated instruction. No significant difference was found in the performance of students on grade level who received integrated or non-integrated instruction. Similar results were found by Kobala and Bethel (1986). Integrated instruction may facilitate student transition from one cognitive level to another (Renner, 1971) or may cause math concepts to have more meaning (Shann, 1977).

In collecting a bibliography of literature on the integration of science and math education, Berlin (1994) found 99 related to theory and 22 concerned with research. "There is clearly a need for careful conceptualization and additional research on integrated science and math teaching and learning" (p. 33). More empirical research regarding student motivation, understanding, and achievement as they relate to the integration of mathematics and science is needed (McBride & Silverman, 1991).

There are still many questions to be answered. Can student motivation toward learning of selected mathematics concepts be improved by science integrated instruction? Can student knowledge and understanding of selected science and mathematics concepts be improved by integrated instruction? Does integrated instruction increase student perception of relevance between what they are learning and their own lives? Is integrated instruction more or less effective for students of differing characteristics such as socioeconomic status, achievement level, or attitude? Does integrated instruction enhance constructivist theory? What are the integrated science and math professional content skills? How can teachers best be educated to design and support integrated instruction?

The issue of integration needs to move beyond the discussion level. Current national reform initiatives are guided by intuition and theory. Real reform in integrated instruction needs the support of a research-based rationale. Additional research is needed to determine specific data about the ways in which integration affects learning, the particular students it affects, and the professional skills necessary to plan and teach integrated lessons. A continuing collection of empirical data will guide the development of integrated programs and determine whether or not integration will continue to be a focus in science education reform.

Curriculum Integration Models

Model	What It Means	How it Works
Fragmented	traditional, separate and distinct disciplines are fragmented by subject area	occasional, intentional relation of math/science topics within distinct time slots for each area
Connected	attention to deliberate relationships within each discipline	concept connections are identified (i.e. fractions are related to decimals)
Nested	multiple skills are targeted within a subject area (i.e. social skill, thinking skill, content skill etc.)	a unit on photosynthesis targets consensus seeking (social skill), sequencing (thinking skill), and plant life (content skill)
Sequenced	topics or units of study are sequenced to coincide with each other but remain separate subjects	students read a period piece of literature in language arts and study the same historical period in social studies
Shared	overlapping concepts become organizing elements for two disciplines (or two teachers)	data collection (science) and charting and graphing (math) are introduced together (may be team taught)
Webbed	a topical or conceptual theme connects curriculum areas	a topical theme(circus) or conceptual theme (conflict) webs to content areas
Threaded	thinking skills, social skills, technology, and study skills are threaded through various disciplines	prediction is targeted across disciplines -- predict next event in reading, predict next number in a pattern sequence in math, and forecast current events in social studies
Integrated	cross disciplinary approach blending four major disciplines by finding overlapping skills, concepts, and attitudes in all four	reading, writing, literature and speaking skills in a holistic, literature-based program
Immersed	an immersed learner makes constant connections in the world of experience to a particular topic of interest	a highly motivated student, interested in insects, collects them, reads about them, writes about them, and draws them
Networked	learner filters learning through the expert's eyes making internal connections leading to external networks of experts in related fields	a student interested in Native Americans participates in a summer dig project networking interests with geologists, anthropologists, archeologists, and illustrators

Table 1
(Adapted from Fogarty, 1992)

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PROJECT SIMULATE: TECHNOLOGY STAFF DEVELOPMENT FOR INSERVICE AND PRESERVICE TEACHERS

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Overview

Project SIMULATE (Science Integrated with Mathematics Using Language Arts and Technology Education) is an elementary school-university partnership designed to improve science and mathematics instruction through the use of multimedia technology and language arts. The intent is to assist inservice and preservice elementary school teachers to modernize their teaching of science and mathematics content and processes. Through the use of technology-rich instruction with hands-on involvement, these teachers are helping their elementary school students see the relevance of the science and mathematics concepts they are learning.

Rationale

Colleges of education seek to provide students with models for science and mathematics instruction based on the current recommendations of the American Association for the Advancement of Science (1989, 1993) and the National Council of Teachers of Mathematics (1989, 1991) These models incorporate the belief that technology, including multimedia, is a critical tool toward preparing today's students for the problem-solving, decision-making, investigative inquiry, real-world applications, and justifications of solutions necessary for life beyond the year 2000. Unfortunately, preservice teachers are often teamed with mentors who have neither the skill nor the hardware and software to utilize technology instructionally. In such instances, the knowledge developed by students during their course work may atrophy during their preservice training in the classroom. It is therefore incumbent upon universities to supply technological support. Simply placing computers on school campuses, however, is insufficient; effective implementation of technology-rich instruction requires both equipment and staff development (Shaw, Okey, & Waugh, 1984).

To this end, Project SIMULATE has given current and future educators both the knowledge and the equipment necessary to implement instructional practices that prepare students for the 21st Century. A summer institute on ways to use technology to enhance science and mathematics instruction was followed by sustained support during fall implementation. Benefits are accruing to inservice educators, preservice teachers, and elementary school students. The **participating inservice teachers** maintain a high level of concern about their learning, since they have committed themselves to modeling these current practices for the university students they are mentoring and documenting the resultant learning of the children in their classrooms. As an ongoing benefit, these practitioners will also share this knowledge base with other preservice teachers they mentor in the future. The participating **preservice teachers** received both intensive summer training and opportunities to apply this knowledge base in real classroom settings in collaboration with experienced practicing teachers. Because of this involvement, it seems these preservice teachers will be more likely than most to become effective change agents when they enter the education profession and take responsibility for their own classrooms. **Elementary school children**, motivated through technology simulations, are participating in integrative experiences in science, mathematics, and language arts; using higher order thinking skills as encouraged by national standards; and developing transferable problem-solving strategies.

This project is being conducted in an effort to effect systemic change in the way science and mathematics instruction is delivered in elementary school classrooms. To maximize its impact it is being implemented at a single school location where an on-site university program already exists. The participants create their own technological and curricular support system in an educational community with four levels of learners: professors who deliver methodology courses on the campus, teachers who teach K-6 classes on this campus, university undergraduate education majors who attend classes and spend 90 hours per semester in these K-6 classrooms, and 5-13 year old students who learn on this campus daily. This concentration of effort at one location is a vital feature of this project as it provides the critical mass favorable to successful implementation (Office of Technology Assessment, 1995).

The use of multimedia simulations was selected as the focus of thematic planning because the simulation format is motivational, a popular form of entertainment (Schwabach, 1994). If used appropriately this game-style approach can be used to help students internalize science concepts and practice problem-solving processes. "Through the use of simulation and problem-solving software, computers have a tremendous potential for assisting students to develop their higher-order thinking and inquiry skills" (Hunt, 1991, p.212). Multimedia simulations provide students opportunities to conduct investigations not normally possible in a school laboratory (Freidler, Merin, & Tamir, 1992). Such an investigation can be deeply engaging and lead students to meaningful application of a concept. "Students build great ownership of the process, problems, and solutions involved in a concept. They see that concept from the inside because of experiential learning" (Harding, Melling, & Fulton, 1991, p. 44). It is our hope that the multimedia simulations in Project SIMULATE will serve as beginning points for preparing presentations, conducting surveys, and designing community service projects.

Project Description

Goals and Objectives

The goal of Project SIMULATE is to design and implement an exemplary preservice traineeship program that fosters the use of multimedia simulations in science and mathematics instruction, enhancing undergraduate teacher preparation, improving inservice teachers' instructional strategies, and having the potential to influence children in schools across a wide geographic area.

The specific objectives are these:

1. to provide professional development for preservice teachers and their mentor teachers in using multimedia-based technology for science and mathematics;

2. to assist preservice teachers and their mentor teachers in collaborative production of integrative units centered on multimedia-based simulations, thereby linking current technology and pedagogy; and

3. to facilitate preservice and mentor teachers' application of multimedia-based instruction in their classrooms, developing children's skills in inquiry, investigation, and problem-solving.

Staff Development

Preservice education majors and their mentor teachers were paired at a K-6 school where a field-based program for undergraduate education majors is in its fifth year. The university undergraduates were matched with the mentors for their field experiences within the education program in the fall semester. Participation was voluntary and grant stipends were provided for 26 teachers and 13 university students.

Participants received 60 hours of staff development on technology and pedagogy during a summer institute in 1995. The institute was comprised of two workshops, one in June and one in August, provided the teaching teams both basic training in the use of multimedia equipment and a variety of instructional models from which teachers chose those most appropriate to the instructional units they were preparing for fall implementation. The university provided the use of a computer lab on the university campus for the June training and ten multimedia carts which the twenty teaching teams shared during the remainder of the summer, the on-site August workshop, and the school-year implementation. Some basic software was installed on all carts, and a variety of other software packages, with a range of topics and difficulty levels, was made available through the university and the local school district.

The institute content was structured to offer activities that met the project goal and objectives, both technological and pedagogical experiences to enhance student learning in science and mathematics. Coverage was then adjusted to the competency levels of the participants. Surveys prior to the institute and hands-on tests on the opening day were used to determine individual participants' experiential levels in the use of technology and knowledge of current instructional practices in science and mathematics. The intent of the technological training was to help participants gain confidence in operating computers, CD ROMs, laser disks, and software applications. Pedagogical staff development included sessions on simulations, higher order thinking skills, and integrative curriculum.

Participants were given opportunities to explore a variety of multimedia materials selected for their alignment with the district and state essential skills; their potential for prompting students' decision-making and problem-solving; and their capacity to serve as the core of interdisciplinary units. Resources, available through the district and the university, included programs such as *Great Ocean Rescue* (Tom Snyder Productions), *BioSci I & II* (Video Discovery), *Oh, Deer* (MECC), *Zookeeper* (Davidson), and *Designosaurus* (Britannica). During daily sheltered practice time participants self-selected tutoring, personal practice, unit work with their teams, or exploration beyond class coverage. The ratio of coaches to participants during this sheltered time was approximately one to eight. Daily evaluations helped instructional leaders adjust session contents to the needs of participants.

During the workshops the teams were given time to adapt materials to match their own grade levels, themes, topics, and instructional styles. Each team designed a thematic unit containing a simulation surrounded by activities to expand upon it. Units incorporated hands-on activities, research, narrative writing, and presentations using technology such as *Hyperstudio, KidPix Slides*, *Inspiration*, and the *Claris Works Slide Program.* The thematic units the teams developed during the summer institute became part of the university students' field placement experiences in the fall semester and have been incorporated into the local school's curriculum bank. On the last day of the summer institute, the teaching teams presented a workshop for parents and their children. The purpose was tri-fold: to give the participants practice using the programs they had learned or created; to make members of the community aware of these current means of teaching science and mathematics; and to afford the teaching teams the opportunity to gather feedback from children and parents about their ideas before taking them into their classrooms.

Continuing Support for Participants

Since participants are at one site, they communicate daily and assist one another both technically and motivationally. Monthly follow-up meetings during the school year offered a more structured opportunity for participants to share new insights, discuss problems and solutions, ask questions, request assistance and resources, encourage others' efforts, and celebrate successes during this implementation stage. At each session inservice teachers who had opted to complete extended requirements for university graduate credit presented demonstrations of their use of technology in the classroom.

Preservice and inservice teachers are further supported, because experts who delivered the institute remain available for technological and pedagogical coaching. Leaders of the project were specifically chosen for this accessibility beyond the time of the institute. The lead instructor for the institute is on the administrative staff of the school district, and three teaching/technology assistants are employees of the local school. Four of the professors who were an integral part of the summer institute have course assignments in the field-based university program, and were therefore able to support the implementation of the thematic units as they continued to work with both local faculty members and university students.

Classroom observations by the university project personnel have offered three forms of support. First, observers have identified some needs for technological assistance. Second, having demonstrated their individual levels of implementation, the teachers/teams are eager to gain feedback and suggestions for next steps. Finally, they are proud to hear what their students say about their instructional involvement with multimedia. The intent is to create a community of technology users, effecting systemic change within the local school site, across the district, and in the larger professional arena through the preservice teachers who will be hired across a wide geographic area.

Methodology

During the summer institute and the 1995-96 school year implementation, both quantitative and descriptive data are being collected and analyzed to evaluate this exploratory, multi-methodological study. Multiple instruments are being administered to determine participants' levels of competence, confidence, and levels of implementation; and anecdotal information from journals and observations offer insights about the overall effectiveness of the project.

Population

The 39 participants include thirteen preservice and 26 inservice teachers. The 13 preservice teachers are elementary and special education majors at Arizona State University West in Phoenix, Arizona, six student teachers and seven interns. The 26 inservice teachers are faculty members of the Orangewood Elementary School, nine primary (K-2), twelve intermediate (3-6), one teacher of special education, one Title I teacher, one teacher of gifted, one librarian, and one technology assistant.

Orangewood Elementary is a K-6 school with an enrollment in excess of 800 students. The community is experiencing rapidly shifting demographics, with a rising number of minority children and children from low-income households. Approximately 50% of the students are eligible for the federally-funded free/reduced lunch program, and 20% of the total population are Hispanic, African-American, Native American, or Asian.

Data Collection

Data are being collected by means of pre-post interviews with selected participants about their technological and pedagogical competence; written surveys of teachers, university students, parents, and elementary school children about the relevance of the techniques taught in the project; daily critiques and journal entries by the institute participants about ways they expected to use multimedia in their classrooms; logs of personal and classroom usage time by teachers and students to indicate levels of productivity during implementation; classroom observation notes by institute leaders to determine the quality of implementation; and journal entries of participants during the fall describing any changes in student learning.

Analysis of the data at the close of the project is expected to answer the following questions. Did Project SIMULATE participation:

1. increase the technology skills of the participating inservice teachers, pre-service students, and elementary school children?
2. change the instructional/pedagogical approaches of these practitioners?
3. increase the amount of time spent on the use of technology to teach science and mathematics in these elementary classrooms?
4. improve these elementary school children's problem-solving skills?
5. improve these elementary school children's understanding of scientific and mathematical concepts?
6. make science and mathematics instruction more relevant for children?

Evaluation Instruments

Self-Report of Computer Competency

During the opening session of the institute, each participant completed a Self-Report of Computer Competency in basic computer skills, word processing, databases, and spreadsheets. The instrument was provided in two formats, on the computer screen and on paper. Each participant chose the appropriate format, depending upon his/her level of computer proficiency. On the last day of the institute, the same test was administered.

Self-Efficacy Questionnaire

Each participant has been administered a Self-efficacy Questionnaire (Enochs, Riggs, & Ellis, 1993) to assess his/her sense of competence in using technology to teach science and mathematics across the time of the project. This instrument measures two variables: Outcomes Expectancy (OE), the teacher's perception of his/her capacity to improve understanding of science and mathematics concepts through the use of technology; and Personal Efficacy (PE), the teacher's perception of his/her ability to use computers for science and mathematics instruction. This instrument will be administered a total of five times: on day one of the institute, at the end of week one of the institute, at the close of the institute, midway through the implementation stage, and at the end of the project.

Perceptual Questionnaires

On the first day of the institute, participants completed Perceptual Questionnaires with both Likert-type and open-ended items to provide baseline data about their individual perceptions of the role of technology in education. The same instrument will be administered at the close of the project and pre-post analysis will be made.

Student-Parent Workshop Evaluations

At the close of the student-parent workshop, each family filled out an Evaluative Questionnaire with both Likert-type and open-ended items. Data were analyzed to determine participants' perceptions of the experience as to levels of learning and enjoyment.

Personal Journals

During the institute, participants evaluated the effectiveness of the instruction and their individual confidence levels in using the new techniques by writing daily entries in Individual Journals, focusing on the appropriateness of their learning for use with students. Between the June and August sessions, participants made weekly entries, indicating what they tried, what they learned, and how they expected students in their classrooms would benefit. During the school year, they are again writing weekly. Analyses of these descriptive data will indicate the participants' levels of use, the instructional values the multimedia experiences provide for children, and the degrees of comfort both teachers and students experience using technology within the science and mathematics curriculum.

Usage Logs

During the summer break and the fall semester, each participant has maintained a Teacher Usage Log, in which s/he records his/her own use of technology. For each use, s/he indicates the amount of time spent; the type of technology used; the mode, that is, alone, with a tutor, as a tutor, or with a team; and the purpose, that is, for previewing materials, lesson planning, unit planning, grading, writing communications, or keeping class records. During the semester, each teacher-intern team is also keeping a Classroom Usage Log in which they record the amount of time spent on multimedia in the classroom, indicating what software is used and by whom. Data are being quantitatively analyzed.

Levels of Use Interviews

Before the institute, 11 of the 26 inservice teachers participated in Levels of Use Interviews (Loucks, Newlove & Hall, 1975) to determine baseline information about the degree to which each was integrating technology into science and math curricula. The instrument measures both self-perceptions and objective indicators of implementation. At the close of the project, we will interview the same teachers to measure any changes in their use of the innovations presented through the project.

Integrative Units

Each teaching team developed theme-related instructional plans incorporating multimedia and at least one simulation. Student teachers and interns incorporated their simulation-based plans into units for their university course work. Teachers either augmented their existing thematic units or developed additional units using the new multimedia materials they created during the project. Unit components will be analyzed to determine the participants' technological and pedagogical accomplishments. Children's products will be examined for evidence of inquiry, investigation, and problem-solving.

Classroom Observations

Project personnel are conducting Classroom Observations of participants as they implement their multimedia plans. Observational notes include the technology used; the instructional pattern, that is, full class, small group, or individual; the extent to which instruction is connected with ongoing curriculum; and the degree to which higher order thinking is elicited from students. During the visits, the observers dialogue with students to determine their levels of motivation, conceptualization, processing, and problem-solving.

Findings

Data collection and analyses are not yet completed since the project is still in progress. The following findings reflect analysis of the four measures which have been analyzed to date.

Computer Competency Questionnaires

Self-reports of Computer Competency Questionnaires were administered in June and August of 1995. For all three categories of Basic Skills, Word Processing, Database, and Spreadsheets, the group means increased. All pre-post gains were statistically significant (Table 1).

Table 1 Pre and Posttest Self-Report of Computer Competencies

Skill	*Mean*	*S.D.*	*Standard Error*	*N*	*t value*	*Probability*
Basic Skills Pretest	26.3	11.6	2.3	26	t=-5.02	p<0.001
Basic Skills Posttest	36.5	2.3	0.4	26		
Word Processing Pre	29.7	13.7	2.7	26	t=-5.48	p<0.001
Word Processing Post	40.1	5.9	1.2	26		
Database Pretest	5.3	4.9	1.0	26	t=-4.73	p<0.001
Database Posttest	9.7	4.6	0.9	26		
Spreadsheet Pretest	4.2	3.7	0.7	26	t=-5.30	p<0.001
Spreadsheet Posttest	7.1	3.7	0.7	26		

Self-Efficacy for Using Computers to Teach Science and Mathematics

The *Microcomputer Utilization in Teaching Efficacy Beliefs Instrument* (Enochs, Riggs, and Ellis, 1993), contains the variables Outcome Expectancy (OE) and Personal Efficacy (PE). No effects resulted when a repeated measures analysis of variance was conducted for the OE variable. A significant main effect was found when this analysis was conducted for the PE variable ($p<0.001$). A subsequent post hoc analysis using pair-wise comparisons indicated significant differences between PE1 and PE2 ($t=2.61$, $p=0.014$), PE2 and PE3 ($t=3.73$, $p=0.001$), and PE1 and PE3 ($t=5.33$, $p<0.001$). The values for PE increased as training progressed. The means (and standard deviations) for PE1, PE2, and PE3 were 47.6 (8.9), 50.4 (7.5), and 53.5 (7.6) respectively. The group means for the OE and PE are graphically represented in Figure 1.

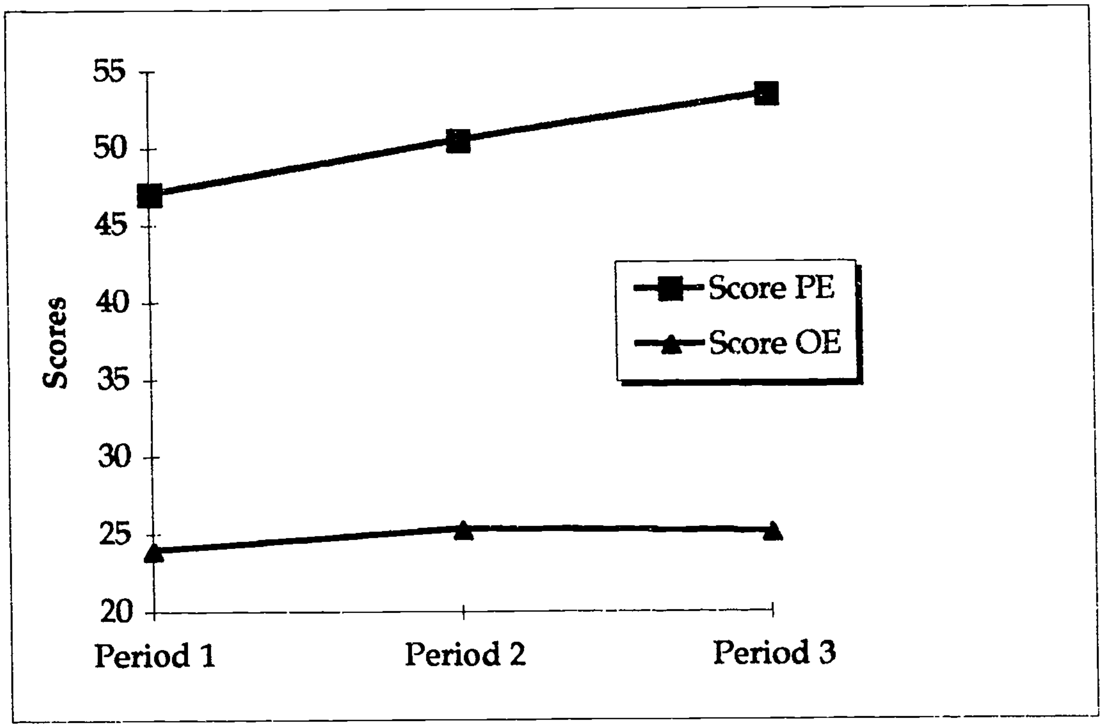

Figure 1. Graph of Outcome Expectancy Means and Personal Efficacy Means Over Duration of Summer Program.

Parent-Student Workshop Evaluations

A Likert survey was administered to student-parent teams following the workshop. Analysis of the data showed that parents agreed or strongly agreed that they enjoyed the program ($M=4.65$, $SD=0.49$) and their children enjoyed the program ($M=4.90$, $SD=0.31$). Seventy-five percent agreed or strongly agreed they had learned a lot from the program ($M=4.05$, $SD=1.15$) and ninety-five percent agreed or strongly agreed their children learned a lot (M=4.35, SD=0.75). Eighty percent of the parents agreed or strongly agreed that the program helped them realize there are a variety of effective ways to teach mathematics and science (M=4.35, SD=0.81). Written answers to an open-ended question asking the benefits of the program showed overwhelmingly favorable response to the technology being offered to students in the coming school year.

Journal Entries

Summer Journals

Two generalizations appear through analysis of the summer journal entries. First, collaboration with colleagues, either teacher-to-teacher or teacher-to-university student interactions, appeared to have a strong positive effect. Those who collaborated experienced a greater sense of accomplishment, more "AHA!" moments, and a wider range of experimentation than those who worked independently.

Second, the individual's focus appeared to be a factor in the amount of energy spent on technology. Those who left the June institute with specific ideas about how they could incorporate technology into their classroom instruction spent considerable time investigating and constructing materials. They previewed software, formatted newsletters, created Hyperstudio stacks, and experimented with KidPix. Those with no specific thoughts about how they would use technology to enhance curriculum spent more time on non-instructional applications. They surfed the internet, made databases, set up spreadsheets, and wrote letters for personal purposes.

School-year Journals

Four generalizations appear to be emerging in journal entries during the school year. First, participants began the semester with great expectations and were discouraged when they were unable to fully utilize the many ideas from the institute. Their greatest source of frustration was time management. With an already over-burdened curriculum, teachers find it difficult maximizing use of technology within the existing schedule. Arranging to have the hardware and software available, providing time for students to learn how to operate the equipment, and setting up schedules that allow student time to explore are all classroom realities. Across time, teachers found ideas that work. For technological novices, merely linking computer lab resources to on-going curriculum was a forward step. For those more sophisticated, full-class simulations with cooperative learning participation seem effective. Those with the highest usage are implementing an each-one-teach one plan. The teacher selects several computer-literate students to learn a specific computer application or program. Once the procedures are anchored, the students become coaches to peers who in turn teach others until all in the classroom are proficient.

Second, teachers found that students needed more time practicing keyboarding skills than they had at first anticipated, compounding the previously mentioned time management problems. By mid-semester, this no longer appeared to be a critical issue.

Third, across the campus there is diversity in the types of multimedia being used beyond word processing; most teachers, however, have chosen to focus rather than experiment. Each seems to use one application many times rather than incorporating multiple applications into a given theme.

Fourth, while many comment on increased student involvement and motivation, only a limited number discuss student presentations, and little mention is made of higher order thinking skills. A few who have had extensive previous experience with computers reflect on their students' increased cognitive processing. It appears that participants must become familiar with the mechanics and logistics of incorporating technology into classroom procedures before they can concentrate on the ultimate desired outcome, stimulating students to reach high levels of productivity and cognition.

Discussion

Data from this study indicate that one week of instruction at the beginning of summer, followed by a loan of computers for the summer, and one week of training at the end of summer were effective in developing participants' computer skills and confidence in using multimedia technology to teach science and mathematics instruction.

Most participants perceived themselves to be novices at computers at the beginning of the project. Through the summer institute, they significantly increased their self-perceived levels of competency in Macintosh skills, as evidenced by significant gains from pre- to post-test on the Self-Report of Computer Competencies.

By the end of the Project SIMULATE workshops, participants also believed more strongly in their ability to use technology for science and mathematics instruction, as evidenced by increased scores on the Personal Efficacy subscale of the *Microcomputer Utilization in Teaching Efficacy Beliefs Instrument* (Enochs, Riggs, & Ellis, 1993). Scores on Outcome Efficacy did not significantly increase. Teachers did not change the level of their belief that their students' learning in science and mathematics would improve due to their use of technology. This result was expected, because participants had worked with students less than three weeks at the time of the third of three data collection points. It is hypothesized that the Outcome Efficacy levels will increase, now that teachers have had more time to integrate technology into their instruction

The journal entries serve as windows to the process of technology integration. Participants highlighted two factors which intensified their level of engagement as they experimented with new ways of teaching science and mathematics: (a) sustained collaboration with colleagues across the training and implementation phases of the project, and (b) focused instructional expectations to direct their efforts toward infusing technology into their science/mathematics curricula. Logistical and time management issues can deter implementation. While each teacher must find his/her own solutions, sharing of ideas seems vital to many teachers. It appears that teachers prefer to become competent with one given computer application at a time before branching into the range of available technologies. It is anticipated that, given the resources and collegial support, the teachers in this project will expand their repertoires of technology uses. This expansion is also expected to increase the opportunities they provide for student preparation of multimedia presentations and the emphasis they place on higher order thinking.

Conclusion

As a traineeship program, Project SIMULATE provides preservice teachers and university professors opportunities to work directly with practitioners and students in making technology a functional part of science and mathematics curriculum. As a collaborative project, it offers inservice teachers equipment, staff development, and continuing support to improve their strategies for effective instruction of science and mathematics. As an effort to promote systemic change, its focus is on in preparing today's elementary school students to meet the technological and processing demands of the 21st Century.

This project is funded by an Eisenhower grant through the Arizona Board of Regents. Appreciation is expressed to co-investigators from the ASU West College of Education: Ron Zambo, Keith Wetzel, and Ray Buss, and to Ruth Catalano and Peggy George of Washington Elementary School District in Phoenix, AZ for their contributions to this project.

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PROJECT PRIDE: PROMOTING REFORM THROUGH INNOVATION, DEVELOPMENT, AND EXPERIMENTATION

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Schools as societies represent a unique entanglement of social, economic, political, and educational concerns. Teaching effectiveness is at the center of the educational concerns and though there is no fixed definition of effectiveness, there are ambiguous and often conflicting demands placed upon teachers to become more effective.

Teachers are in a situational crisis which demands change. Do they become more effective by simply following state and district curriculum mandates, or are teachers more effective when they decide as professionals what is best for their students? Teachers are caught between the way they perceive themselves and their teaching effectiveness and what they perceive local, state, and national reform mandates expect from them. These conflicting demands and perceptions place schools and teachers at a crossroads. From one perspective, schools and teachers are expected to participate in continual change while the counterpoint shows that approaches to teacher training, teacher professional development, the school's hierarchical organizational structure, and top down operatives lean toward the status quo. So who makes the decisions regarding issues of improved teaching and learning?

According to Stiegelbauer (1992), the most frequently stated reason for entering the teaching profession is "to make a difference in the lives of students." Fullan (1994) states this rationale more directly by calling it a "moral purpose" which is concerned with bringing about change. Furthermore, he adds that to have any chance of making teaching more effective, teachers and educators need to have the tools to participate in change productively.

National programs such as Project Learn (Sagor, 1991) suggest that one tool is meaningful practitioner research. This can lead to effective classroom practice and become a stimulus for both cultural transformation of schools and restructuring of the teaching profession. According to a review by Clark (1993), effective teaching from the 1950s to the present has been researched from three perspectives: a) the process-product approach that focuses on the content, teacher-student behavior, and the achievement of students via test scores; b) the teacher thinking approach that focuses on the mental imaging of teacher planning, decision making, and beliefs that invisibly guide teaching and; c) the pedagogical content knowledge approach that focuses on the teachers' knowledge of subject matter and how the knowledge is transformed and translated into knowledge for their students. The 1990s provide a new emergent model for improving teaching and enhancing teacher professionalism, the teacher-researcher approach (Cardelle-Elawar 1993, 1992, 1990; Cunningham & Shillingon, 1990; McNiff, 1988; Cliff & Say, 1988). Findings from national programs such as Project Learn (Sagor, 1991) provide evidence for supporting the teacher-researcher approach by suggesting that it is "meaningful practitioner research" that will lead to effective classroom practice, serve to culturally transform schools, and restructure the teaching profession. Because of the complexity of public school concerns, there is a driving need for the proactive involvement of classroom teachers in research. To support teacher-researchers in their endeavors there is a need for collaboration between educational agencies as we attempt to move toward a more equitable education for all learners and enhanced professionalism of teachers.

So how can we as science educators bring quality mathematics and science into the elementary classroom through action research? How can we as science educators assist teachers to become researchers and decision makers in the elementary classroom with particular focus on mathematics and science? How do we collaboratively explore with elementary teachers their own classrooms or teaching practices. How do we assist them in identifying problems and related variables, in deciding on strategies to solve problems, and in evaluating the success or failure of the strategies?

Background

In this study, the authors report research on a partnership between an institution of higher education and local education agencies collaborating to enhance the knowledge and skills of K-8 teachers in mathematics and science through action research. The focus of this study is to explore thirty-three inservice elementary/middle school teachers' perceptions of science and mathematics teaching, equitable teaching practices, and their professional development through collaborative planning and the implementation of action research.

Shortly after World War II, the roots of action research emerged with Kurt Lewin (1946) who is credited with coining the term "action research" (Collins,1995). He viewed action research as cyclical spirals of research that begin with observations within a "field of action." Since that time, action research has undergone numerous extensions and variations that reach into many social, political, economic, and educational settings (Rapoport, 1970; Hopkins, 1993; Kemmis, 1983). In this study, action research centers on elementary teachers who begin cycles of inquiry from within their own classrooms and schools. They start with observations and descriptions of a situation, they move to problem identification, they reflect upon the problem and develop an action plan, they carry out their plans, then they reflect and evaluate the results of their actions and perhaps, begin again (Hopkins, 1993).

Action research for this study is conceptualized on two broad levels. One level represents the university researchers' perspectives of an action research approach for understanding teacher professionalism, school improvement, and factors influencing the process. The second level is the elementary teachers' perceptions of action research and the impact it has on their views of teacher professionalism and school improvement.

Participants

The participants included 34 elementary teachers and 1 middle school teacher enrolled in a four week long summer institute, Project Pride, in June 1995. The teachers received graduate credit for their participation in the institute, which included 80 hours of instruction with the two researchers and an additional 40 hours of professional development during the following year. Of the 33 teachers participating in action research, 1 was an African American female, 29 were Caucasian females, and 3 were Caucasian males. Participants' ages ranged from the midtwenties to the midfifties. The teachers taught a variety of grade levels ranging from first grade through eighth grade. Three teachers taught multi-age classes. During the summer institute, the teachers formed teams (3-6 members) representing 8 different schools. Two teachers worked individually within their schools and two teachers withdrew from the study. Initial analysis of artifacts, journals, and field notes reveal that this group of teachers view teaching as a complex, demanding, busy profession where teaching roles shift within any given situational context. They recognize and express concern over factors that influence learning in their classroom that they cannot seem to change or solve.

Methodology

An interpretative approach (Gallagher, 1991) was selected to make sense of the participants' words and actions regarding the development and progress of their action research. Predominant means of data collection included journal entries, audiotaped team sessions, surveys, audiotaped interviews, informal interviews, artifacts, documents, and videotaped class sessions. As advocated in interpretative approaches data collection and analysis progressed concurrently. Interpretation of the data was negotiated among the participants in reflective sessions to provide opportunities to discuss data from several dimensions. A constant comparative analysis (Glaser & Strauss, 1967) served as the primary method of coding. Data were perused for emergent categories. As categories unfolded they were compared across categories for the purpose of identifying new categories or relationships. Triangulation via multiple data sources and reflective sessions provides verifiability of interpretations through the various data sources, but does not promise a lack of bias. Thus, the reader is provided contextual insights for judging the merit of the data and the researchers' reconstructions. This in-progress study presents the design, development, and the progress of the bi-level action research framework, inservice elementary teachers' perceptions of the nature of science and mathematics teaching, the emergence and progress of elementary teachers' action research, and their perceptions of action research as a tool to enhance their professional development in teaching science and mathematics.

Professional Development

Project Pride is an on-going two year project. The first summer institute provided teachers professional development in content and pedagogy using: a) physical science concepts from the national leadership project, Operation Physics, highlighting matter and its changes, energy, and measurement; b) integrated mathematics concepts of problem solving, data collection, data analysis, data representation, probability, and statistics from the Used Numbers Series (Russell & Cowen, 1990); c) equity education using self assessment techniques from Teacher Expectations and Student Achievement (TESA,1980), and Gender and Ethic Expectations and Student Achievement (GESA, 1990), and; d) action research training directed by instructors' questions and concerns about doing action research which focused on basic research design, data collection, and data analysis. In addition, the teachers were involved in activity-based instruction regarding content knowledge, critique and integration of National Science Education Standards (1994) and the NCTM Curriculum and Evaluation Standards for School Mathematics National (1989) into curriculum, problem solving, and equitable science and mathematics teaching issues.

The discussions and interactions during the summer institute became the springboard for exploring action research. During this time, teams and individuals voiced their ideas, concerns, and questions on relevant issues regarding teaching science and mathematics. These questions and issues became more formalized during the following school year as teachers redefined their questions and action research plans for their schools and classrooms. The researchers began by helping teachers to assess in broad terms key aspects of classroom science and mathematics instruction. For instance, during the first week of the institute discussions and activities addressed: a) how we see ourselves as teachers; b) how we perceive science and mathematics; c) how we describe research and; d) how we define empowerment. In addition, integrated hands-on, minds-on physical science and mathematics activities were provided.

During the next four weeks the researchers assisted teachers in finding problems of concern within their classroom or school that would take them into a recognized role of teacher-researcher. By the end of the summer institute most teams and individuals had identified a problem or question to explore in their schools. The task of identifying a question was difficult for most teachers and teacher teams. Follow-up professional development sessions with the participants are continuing on a monthly basis (September, October, November, January, February & April) throughout the 1995-1996 school year. These professional development days focus on action research methods, equity issues, and action research plans. The morning sessions are conducted at each of the schools and the teams spend time planning, reflecting, collecting, and analyzing data for their research plan. The afternoon sessions are conducted as a whole group. The September professional development day was devoted to further refinement of the participants' research designs and strategies for collecting observational and survey data regarding attitudes and proficiency in science and mathematics. The October professional development day focused on analyzing observational data and conducting interviews. Each team audiotaped their morning session and presented updates on their research in the afternoon.

Many initial research problems emerged through brainstorming within teams. Then, as problems were identified, the instructors questioned the teachers about the origins and rationales underpinning their problems. Questions included what other external variables might influence the problem, what strategies might work in solving the problem or question, and what resources were needed to go about solving the problem. In effect, the instructors provided: a) support in assisting teachers to become decision makers with opportunities to evaluate and target areas for improvement in their classrooms and schools; b) information regarding the role of "teacher as researcher" while helping teachers to redefine their vision of teaching by giving them access to information regarding action research, its research base and; c) resources to conduct action research in their schools.

Initial Findings

The researchers' purpose of the study was to explore teachers' perceptions of teaching, empowerment, images of research, and the impact of doing action research to improve science and mathematics teaching in their classes and school on their professional growth.

Perceptions: Teacher's at Work

As part of this process, the researchers explored the participants' prior images of themselves as elementary teachers. Data analysis of the Draw-a-Teacher-at-Work activity, reflective statements, journals, and field notes on their images of themselves as teachers revealed that only two out of the 33 teachers included "researcher" among their descriptors regarding the work of teachers. Data analysis of the Teachers-At-Work activity revealed the following core categories and associated properties: a) **management** with the properties of time, discipline, organization, planning, gathering, zoo keeper, integration of subjects, and record keeping; b) **instruction** encompassing the properties of listening, questioning, integrating subjects, writing, guiding, facilitating, direct instruction, cooperative groups, zoo keeper, kid watcher, and supervising; c) **affective teacher traits** describing properties of caring, nurturing, patience, enthusiasm, life long learners, encourager, motivator, frustrated, stressed, creative and; d) **classroom climate** characterized stereotypically by children in chairs working alone, teacher at the board, cooperative groups with interactions among students, teacher smiling, teacher interacting with children, symbolic items include desks, blackboard with the alphabet or numbers on them, to do lists, books, clocks, computers, sinks, and windows.

Further exploration and discussion of these categories by the teachers further revealed that the origins of their perceptions of a teacher's work emerged from historical origins, self imposed expectations, social expectations, and simply out of necessity.

What we found is that ninety percent of the teachers in the study do not see themselves as researchers. Their image of teaching is a traditional one. They are simply " teachers of children," and the role of researcher is not part of that image. The notion that it is possible to conduct research in a class to improve teaching meets hidden barriers in their image of "teacher and teacher's work." These barriers include lack of time (How can I add one more thing to do in an already busy day?) and a fear of not being able to do research or an unwillingness to risk failure (I don't think I can do it, I am unprepared. I lack the necessary skills/ knowledge to make decisions regarding myself or my students). The "I am just a teacher syndrome," so labeled by King

(1994), echoes the images held by teachers in this study. Thus, many teachers joined this project with only a desire to gain hands-on, minds-on science and mathematics activities. Other teachers, while anxiously anticipating the idea of action research, were hesitant to make a commitment to the unknown. Still others seemed to have entered the project from a passive learner stance that we, the instructors, would just tell them what to do. So what were they saying to us? How do we act upon this knowledge? Do the teachers view the traditional hierarchical power structure as a barrier to the diversification of their image of a teacher's work because of their perceived status in the public education system?

As instructors, we constantly attempted to look at action research from the teachers' point of view and we soon found ourselves as the "keepers of the tool box." We symbolically became the keys to a tool box containing the power tools of knowledge, general information, support, and resources. According to Kanter (1983), we were the keys to gaining the "power tools" which are "basic commodities to be invested in action" (p.159). The power tools represent access: a) to information including data, technical knowledge, political intelligence, and expertise; b) to resources defined as funds, materials, space, time and; c) to support via endorsement, backing, approval, and legitimacy. Despite the teachers' perceived lower status in the established power structure, the desire to improve the quality of mathematics and science teaching for children nudged them to embrace the possibility of envisioning themselves in a new role, "teacher as researcher."

Action research is a vehicle that offers opportunity for decision making, exhibits immense variability, and promotes risk-taking and experimentation for redefining and expanding the professionalism of teaching. An emphasis on variability encourages experimentation and risk-taking to produce new knowledge and skills necessary for effective schooling. Decision making, empowerment, and diversification of job roles through broadened visions of the profession and professionalism are important for teachers to attain new power and authority. Power and authority, according to Sarason (1991), are crucial to sustained educational reform. He states, "Any educational reform that does not explicitly and courageously own up to issues surrounding changing patterns of power relationships is likely to fail. That prediction is based on the feckless consequence of education reform in the past half-century" (p. 31).

Perceptions: Teacher Empowerment

Exploring the roles of a teacher at work thus led to discussions on issues of empowerment. Journal entries showed that the majority of participants view empowerment in teaching as closely associated with decision making. Over half of the participants wrote about decision making directed toward themselves, their students, and workings of their classrooms. Typical responses for making meaning of empowerment included "the power to choose...or make choices," but some teachers voiced frustration and uncertainty associated with the inconsistent use of the term "empowerment" by administrators. For instance, June states that the term "empowerment" is

> one of those words bandied about when a person in higher authority wants to make his subordinates feel better. Usually it means that the subordinates may voice an opinion, not that the opinion will carry much weight. At worst it means that the subordinate receives the responsibility for something without the authority to carry it out.

Others like Jill say,

> empowerment makes me feel uncertain. When I'm empowered, I must weigh many factors and thus begin to question my rationale for the choices I make. It makes me unsure because at times I'm allowed to make choices, and at other times I'm not. Are the issues with which I'm allowed to make choices less important in the administrations eyes? Am I receiving all the information I need?

These passages send a message of tension and mixed feelings of distrust and a desire to be a valued, informed contributor. Jim, on the other hand, viewed "empowerment" in a positive way because of the support he received from administrators who encourage "new ideas and strategies" and "sharing" among colleagues. The diversity of views reflects the personal experiences and physical realities of each teacher and a desire to be a valued decision maker in the "eyes of the administration." This is best typified by Audry, who explained,

> Empowerment is having the power to make decisions. But in the case of teachers, our power to make decisions is usually limited by other people. For years teachers have been viewed as 'caretakers' rather than professionals. Our professionalism is not taken seriously because the parents and community are more empowered to run our schools than we are. Don't get me wrong, I believe the parents should be an integral part of schools, but when they can "make or break" the things we do in our schools, I become a little envious that teachers

don't have that same power. Teachers are accountable to many people and organizations. Sometimes it seems as though our jobs are to 'please' everyone rather than to teach.

This snapshot clarifies the view that outside people and external pressures chip away at the professionalism of teaching. This "weathering" of professionalism is influenced by its perceived accountability to multiple sources. Thus, the profession is reduced to one that pleases the greatest number of people without regard to the integrity of the teacher as a professional with principles, codes, and standards for teaching and learning. Finally, this snapshot sends a message that teachers recognize and seek to validate their image of teacher as decision-maker beyond the classroom, a role that is presently lacking in their view.

Perceptions: Research

In addition to views of empowerment, teachers were asked to explore their images of research and its role in education. Initially, the idea of action research was new to some individuals, who saw it as "collecting information to find answers to a question," while others believed it to be research that "causes some action, change, or activation of plans in response to a problem." Follow-up discussion brought out other dimensions of action research that emphasized its role in teaching and its ability to validate teacher professionalism through decision making and role diversification. The dialogue concluded by looking at the practical aspects of action research within the classroom such as, how to maintain objectivity through clarity and accuracy, where to and how to look for evidence, how to use a variety of data sources, and how to triangulate data for verification.

In this study, the teachers' prior perceptions of research often informed the types of questions they decided to explore and the data they were interested in collecting as part of their action research projects. In a "Think, Pair, Share" approach the teachers' images of research emerged with the following descriptors: collecting data, comparing, selecting, interest in an area or problem, looking for patterns, literature review, cause and effect, analyzing data, quantitative, qualitative, evaluative, and design. Translating these descriptors into actions, the teachers focused on and requested information about Likert surveys and questionnaires for the collection of their baseline data which reflects an emphasis on quantitative approaches as opposed to qualitative approaches. Rarely did the teachers exhibit an awareness that they collect data in qualitative and quantitative ways on a daily basis in their own classrooms. Their research projects were not viewed as a refinement of what they already do, rather it was an entirely new role, separate not integrated with teaching. This is unmistakable in June's reflections, "It has been difficult to think of myself as a researcher. I still think of myself as a teacher trying to make things better."

We emphasized the research nature of teaching through discussions and activities centering on research techniques that use classroom observational strategies, observation checklists, audiotapes, videotapes, and informal interviews that can be done quickly in the context of the classroom. We maintained that the action research plans need not be developed on a grand scale; we repeatedly stressed keeping projects small and simple. As instructors, we stressed that action research tends to fall into three broad categories: understanding, monitoring, and evaluation. We suggested doing studies that were exploratory in nature with understanding being the starting point. Most teacher teams, however, selected monitoring or evaluation as a central purpose of their research (see Appendix). What we found was, many of the action research plans were driven by the vision of improving science and mathematics teaching and learning using pre and post assessment with change being the operative term. Further exploration seems to suggest that the selection of the action research problems was driven by external forces, including the state assessment standards, teacher accountability for student performance, and local current reform efforts. Consider Ginnys' reflection,

> Ridgemont spent four years as a Quality Performance Assessment school.
> We began by looking at math assessment. Also we had data from the
> recent math assessments. Even with our student population changing
> this year we felt non-routine problem solving was an area that could be improved.

Clearly, this team's rationale for selecting an action research question is driven by mandates from the state and local administration.

Innovation Overload and the Need for Colleagiality

Another theme which emerged from the data was a sense of innovation overload, which we interpret to be related to the extensive action research designs created by the teams. Examination of team documents, informal conversations, and transcripts of audiotaped team sessions reveals a layering of innovative change within each team's project. Most action research plans combined the introduction of new teaching strategies for the classrooms and new research skills for data collection and analysis using quantitative and qualitative components. The combined layering effect triggers teachers' feelings of being overwhelmed. For instance, Babs stated, "Project Pride has been somewhat overwhelming to me. I feel like I'm stuck back in the '80s and can't quite catch up."

For Melany, action research poses similar thoughts, "The most difficult thing [in action research] is knowing where to start, then it's difficult to know where to go. Then it's feeling like you're caught in a giant snowball and going out of control."

Innovation overload is even more pronounced in several teams where teachers were moved to new schools after a reorganization of the school district. Thus, some of the teams were attempting to reestablish their school and teaching identities in addition to the innovations associated with action research. For instance, Myra found that,

> This research has not gotten much of my attention since school started because: We are in a new school!! It is rather difficult to get excited about discovering patterns in math and showing the infinity of numbers without a black board. I have made do...and have had some exciting moments!!
> I feel scared that I won't do it well. I also feel like I'm ready to start. I'm very thankful for the support group I have to work with. I'm rather unsure about the process, but I'm rather an optimist and I know we can do it.

Multiple changes created high levels of frustration and stress contributing to the slow start the groups exhibited early on in the process. Establishing a team identity and getting to know one another's strengths, weaknesses, philosophies, and views was necessary to overcome the initial stall in the process. As Ginny expressed,

> I was very unsure this summer as to where the Ridgemont group was headed. I felt like we left the institute with things hanging in the air.
> Wow! The school year began and the Ridgemont group took off... I work with three wonderful, bright, energetic ladies. We seem to drive each other.

It was that thought it would be easier for the teachers to conduct action research individually, however, most teachers opted to join their school peers to do whole group research. This is mirrored in the words of Reena who said, "I chose to join the other teachers in my building in pursuing a question about problem solving in general, in order to be part of the team. I feel comfortable with our building question, but may want to focus on a sub-question as our project progresses." Others voiced a need for team support in conducting research. Ginny stated, "It was great working with my (teammates) this summer. As we began working today we already had a history. We work well together." Others recognize the difficulty of team efforts in contrast to doing individual research. Melaney stated, "Working with other individuals is different. I've had to go with other ideas, be flexible, work as a team, evaluate, criticize etc...It's been a great learning experience, but not without its frustrations!" Thus, our data suggests that, innovation overload, time constraints, and peer support seem to be driving forces behind a team vs an individual approach to conducting action research. A team approach makes risk taking easier and less threatening when supported by peers in a climate of colleagiality. In a journal, Cheryl wrote,

> For several years I have had many questions about certain teaching practices. I feel much more secure in defining a question with a group of co-workers than by myself... I'm in a new job...new school...Yikes! The team pulls me along many days!

With so many innovations and changes at once, the need for other perspectives from peers may make it easier to move through perceived barriers. It was through continued interaction and communication with the teams and the instructors throughout the summer and beyond that teams began to "just do it." It appears that research projects stalled out temporarily in the initial stages, as each individual tried to accommodate and assimilate innovation upon innovation. As a counterpoint, a slow start may give rise to more rapid and effective curricular change in mathematics and science as well as overall school reform as teacher-researchers reflect upon the value and impact of their collaborative decision-making through research. Hanna sensed the potential impact of team research saying,

> I feel our question is great! Part of that enthusiasm comes from the people I work with, also I love science and love to incorporate it. Our question may overwhelm us, but as a team we can fine tune anything.

Furthermore, words such a these give rise to voices of empowered, informed teachers who serve as an impetus for change in their schools pressing for continued efforts for greater school effectiveness and reform based on evidence they have gathered and analyzed.

Perceptions: Impact and Benefits

Another theme the data unfolded was that the participants were highly aware of the benefit of doing action research for their personal and professional growth in a variety of areas. June voiced, "I feel that I am growing as a professional in many ways; being able to do research, being involved with my peers, and learning to help each other." These areas of personal and professional growth are sustained through interaction with their colleagues who are working with them toward mutual goals. Collaboration broke down the barrier of teacher isolation, centered on reciprocity and an on-going interactive dialogue that confirmed ideas, offered new design opportunities, offered support, maximized resources, and "widen[ed] horizons." This is supported by the following quote by Melany: "Project Pride is a day I look forward to each month. The design opportunities and the dialogue are both stimulating and meaningful." Other areas of insight reported by the teacher-researchers focus on self-revelations. After giving a survey to his students, Kevin said, "I do influence attitudes of children toward science through the science lessons I teach... I found out things I wasn't really looking for that will help me evaluate the way I'm teaching science." Another participant stated that it "causes them to reflect on what they teach." For instance, one teacher revealed the following, "I need to teach more process [skills]." In our study, it is clear that action research fostered reflective practitioners who look at self, teaching, and students in new ways.

The second area of emphasis reported by the teachers highlights the impact of action research into two broad categories centered around improving science and mathematics teaching and learning. The categories, represented by two questions include: a) What is action research doing for me, the teacher? and b) What is action research doing for my students? Reflecting on the benefits of action research upon their teaching, some teachers reported, "It made me question my instructional style," or "After giving a questionnaire, I gained new insights about what I do." One teacher stated, " It [action research] helps improve my teaching. I use the knowledge in my planning. It helps me to know I can do better and how to do it." The teachers also focused on the impact that action research has on their students. One teacher stated that doing action research made her, "feel like I'm understanding my students better when they have a difficult time understanding a new concept. I also feel like we are doing research to see if what I am doing is going to affect my students' learning. I feel it is helping me focus on some things that students need to know more about."

Tentative Implications

Because this is an initial analysis, perhaps we will leave the implications open. What influence action research has on those teachers who conduct and act upon their findings is pending. However, one teacher-researcher pointed out the critical issues addressed in any collaborative bi-level action research project such as we have undertaken here. Jim's view of the project reflects the struggles of teaching and doing action research from the stance of the teacher educator and the teacher-researcher further supporting emergent themes as presented in this work. Jim's evaluation reveals the following:

> I think there are two focuses [Project Pride]: the training of teachers to do action research and helping teachers become better science teachers. It is difficult to balance the energy of both. If you recruit teachers with a good understanding of science concepts, you can focus on the research. If you need to train the staff for a better understanding of science concepts, you lose out on the research. I also think that you need to have a supportive group of peers, a principal, or someone you can lean on and bounce ideas off or you would be crazy.

Clearly Jim's views reflect the the tradeoffs and concerns that face both teacher educators and classroom teachers as they attempt innovations requiring increased content knowledge, pedagogical content knowledge, research knowledge, and social knowledge of team approaches.

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Appendix

Summary of Teachers' Action Research Questions and Action Plans

PROBLEM	ACTION PLAN
BROSMAN Can we improve our students' reasoning in the area of non-routine problem solving?	Administer a non-routine problem in each of the math classes. The classes will have a problem of the week and use discovery and dialogue to address problem solving strategies. Portfolios will be kept on the students and a non-routine problem solving question will be given at the end of the year. Pre and post questions will be analyzed using team developed rubrics.
MIRES MILL Does teaching process skills in mathematics and science improve student attitude in those subjects?	Attitude data will be collected in 2nd, 3rd, 4th grades. Data will include drawings of scientists, mathematicians, and childrens' ideas of process skills. Students will keep journals. Four student journals will be selected each quarter for analysis. Video tapes of the process skills lessons will be conducted and later analyzed. A final parent survey will be used at the end of the year.
LEEDS Can we improve student communicated responses to open-ended problems?	Collect baseline data. Use 6-trait writing model to improve communication skills. Keep student and teacher journals, conduct interviews, collect student work, and make observations. Analyze data sources including state mathematics assessment scores.
RIDGEMONT Can we improve students' non-routine mathematics problem solving abilities?	Survey teachers in school who wish to participate in the research. Explore via survey the teachers' ideas on non-routine problem solving. Inservice with teachers using problem solver books, conducting weekly non-routine problem solving, and scoring state assessments. Do sociogram. Collect samples of non-routine mathematics problem solving questions from the classes including some communication questions and student math journals. Pre and post parent, student, and teacher surveys will be given. Data will be analyzed throughout the year.
EASTMAN Do students show increased competency in the scientific process skills?	Teaching emphasis on process skills will be implemented. Rubrics for evaluation of science process skills will be developed. Students will be assessed on a science experiment activity early and late in the year. In addition, student logs will be kept and analyzed.
CROSSROADS Did students' attitudes about science change from the beginning of the year?	Emphasis on process skills in teaching surveys given at the beginning of the year. Draw a scientist with oral description. Personal observation and videotape.
JOHNSON MIDDLE SCHOOL Does direct student involvement in assessment development increase student achievement?	Benchmarks for performance will be developed using state guidelines. Traditional assessment will be used also. Pre-post surveys of students feelings about science. Student interviews, videotape, journals, portfolios, artifacts will be gathered and analyzed throughout the negotiating process in developing authentic assessments for performance and observation checklist.

Appendix (continued)

GEORGE WASHINGTON ELEMENTARY

Can staff development positively affect school-wide scores on state mathematics assessment?	Staff development instrument with open-ended questions. Strategies for teachers to use to help their students communicate on open-ended questions. Use comparison scores of state mathematics assessment from 1995 and 1996.

MERLOW ELEMENTARY

Does the way we teach mathematics positively affect students' attitudes toward mathematics?	Data will focus on student journal entries, interviews, and pre-post attitude/interest surveys.

DOUBLE-A ELEMENTARY

Can we improve our students' use and application of process skills as a result of building level teacher inservice and a school-wide science fair?	Field observations, and interviews of parents, teachers, and students. Focus on data collected during the science fair (i.e.,. who attends, number of entries, parental vs nonparental support) via informal interviews and surveys.

COACHING REFLECTIVE PRACTICE AMONG PRESERVICE ELEMENTARY SCIENCE TEACHERS

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Learning to teach science can be likened to learning science. Prospective teachers enter into teacher education programs with beliefs, values, assumptions, and knowledge about teaching and learning that form their personal theories. Like students of science, students of teaching often adhere strongly to their ideas. Like teachers of science, science teacher educators are responsible for helping students clarify and refine their personal theories and for providing ways to perturb teacher's existing personal theories so that learning through accommodation can occur (Strike & Posner, 1982; von Glasersfeld, 1987). Coaching reflective practice in teacher preparation is a means by which science teacher educators may uncover and confront prospective teachers' personal theories and guide them through the process of conceptual change in learning to become a science teacher.

In this paper, we describe a reflection program that we have developed for our elementary science methods course. This program represents a reconceptualization of science methods teaching-- one which draws on the parallels between conceptual change teaching and coaching reflective practice. We begin our discussion with our perception of the role of reflection in teacher education and the parallels we see between conceptual change teaching and coaching reflective practice. Then, we illustrate how this link plays out in our practice by extracting one part of our science methods course to examine and describe in detail. We conclude with a discussion of the implications of using reflection as an integrated approach to science teacher education.

Reflection in Teacher Education

Our reconceptualization of methods course teaching is rooted in the perspective that the act of teaching is a form of professional artistry (Schön, 1983). As opposed to a perspective of technical rationality where teaching involves the application of scientifically derived theories and techniques to form a body of professional knowledge, teaching as professional artistry recognizes the value of tacit knowledge and intuitive understandings in making decisions and solving problems. Problems of practice and teaching decisions involving attitudes, values, uniqueness, and uncertainty are recognized as significant. No longer are these "indeterminate zones of practice" ignored (Schön, 1983, p. 6).

A reflective approach to teacher education holds promise for challenging the technicist views of teaching and acknowledging the artistic nature of teaching, while providing a way to fundamentally rethink the relationship between theory and practice (Bullough & Gitlin, 1989; Schön, 1983, 1987). Reflectivity leads to a dramatic shift in the way we prepare teachers for professional practice:

> From a position where scientifically derived knowledge was deemed superior, to a circumstance in which artistic and intuitive knowledge may have a claim to being equally appropriate; from an *a priori* instrumental view of knowledge, to one that reflects knowledge as being tentative and problematic; and from a view that presupposes answers to complex social questions, to one that endorses the importance of problem posing and negotiated resolution. (Smyth, 1989, p. 3)

In shifting the way we prepare teachers for professional practice, we enable our students to confront, shift, and/or refine the beliefs, knowledge, values, and assumptions that form their personal theories about teaching and learning.

Reflection helps beginning teachers untangle the web of deeply entrenched personal theories about teaching and learning. Prospective teachers no longer view teaching as a predetermined set of rules or "bag of tricks" to apply to any given classroom situation, but as a practice which is grounded in a system of values, theories, and practices (Schön, 1983). The notion of reflection involves *thinking and acting* on those aspects of teaching that frustrate, confuse, and perplex. The reflective teacher describes specific experiences in her teaching, while identifying and framing issues of classroom practice. In so doing, she begins to appreciate her own experiences in teaching and learning as a source of knowledge upon which she can draw in making teaching decisions. The reflective teacher responds to issues by recognizing both the similarities to other situations and the uniqueness of her particular situation (Ross, 1989). This awareness leads the teacher to realize the broader principles and theories that inform her teaching.

Furthermore, the reflective teacher is able to experiment with solutions to problems of practice and examine the consequences and implications of various solutions (Ross, 1989). Oftentimes, this results in reframing the issue, reexperimenting with solutions, and reexamining consequences. In essence, the reflective teacher reconstructs her teaching practices as she advances from intellectualizing an issue to taking action to improve and refine her teaching.

The thinking and acting process of reflection that we have described above is what we find very similar to conceptual change learning in science. We believe that if the act of reflecting is analogous to conceptual change learning (both are student activities), then coaching reflection is analogous to conceptual change teaching (both are teacher activities). In the next section, we examine the analogy between reflection and conceptual change.

Parallels between Reflection and Conceptual Change

As we developed our science methods course based on a reflective approach to teacher education, we recognized parallels between conceptual change and reflection. We begin our discussion of these parallels by first describing the students' activity in conceptual change learning (see Cosgrove and Osborne, 1985, for complete discussion) and showing how this activity is similar to reflecting on practice.

The science student engaged in conceptual change learning first pin-points her ideas about the given science concept. The student may do this by answering questions or engaging in discussion, for example. Next, the student explores the concept by experimenting with relevant materials, asking questions, and/or discussing the topic. She clarifies her own view of the concept in light of the evidence at hand. In refining her ideas, the science student considers others' points of view including those of scientists. She tests the validity of her understanding by seeking evidence. Once she has refined her understanding of the concept, the science student applies her clarified view to a new, practical problem and evaluates her solution to the problem.

Compared to the process that a student goes through in conceptual change learning, the process of reflection is nearly identical:

In conceptual change learning, the learner:
(Cosgrove & Osborne, 1985)
1. Makes explicit her ideas about the science concept; explores concept.

2. Clarifies her view of the concept; considers others' points of view; recognizes discrepancies among views and resolves the discrepancies.

3. Applies refined explanation to solve a new problem; may have to refine ideas and reevaluate solution.

In reflective practice, the reflective practitioner:
(Ross, 1989)
1. Makes explicit her personal theories; identifies and frames an issue of practice.

2. Clarifies her personal theory about the issue by recognizing the similarities to others' situations and the uniqueness of her own situation; resolves inconsistencies in her thinking.

3. Determines solution for resolving issue; implements solution and examines implications and consequences of solution; may have to refine ideas and reevaluate solution.

The above model for conceptual change learning and our proposed analog of reflective practice consists of three student actions: explication/clarification of existing ideas, modification/refinement of those ideas, and application of new understandings. Given these student actions, an active teacher role is essential. The teacher must appreciate students' ideas and offer activities that promote conceptual change/coach reflective practice:

In conceptual change teaching the science teacher:
(Cosgrove & Osborne, 1985)

1. Ascertains students' existing ideas about the science concept; involves students in exploration of the concept.

2. Provides experiences that perturb students' thinking; provides opportunities for students to compare their views with other students' and experts' views; assists students in clarifying new understanding of the science concept.

3. Provides opportunities for students to apply new ideas to practical situations.

In coaching reflection, the teacher educator:

1. Ascertains students' personal theories; guides students in identifying and framing issues of practice.

2. Provides experiences that perturb students' personal theories; provides opportunities for students to compare their views with other students' and experts' views; helps students clarify new frames from which they can interpret practice.

3. Provides opportunities for students to apply solutions and determine the consequences and implications of the solutions.

We recognize that this analogy breaks down in at least two places. In conceptual change teaching, the instructor guides the learner in understanding the *accepted scientists' view* of the concept. However, in the process of coaching reflection, the teacher educator is not striving to bring the beginning reflective practitioner toward one accepted view of teaching and learning. Teachers develop and refine solutions based on the community, school, and classroom contexts in which they are engaged. Hence, what works for one teacher in her given situation may be unique and not fully applicable to another similar situation. Secondly, in conceptual change teaching, the teacher generally focuses the students' attention on one scientific concept at a time. However, in coaching reflection, there are multiple issues on which the class or individuals in the class may be focusing. As they watch videocases portraying practicing teachers or reflect on their own field experiences, for example, no one student can attend to all facets of the classroom. The issues that the students choose to individually or collaboratively frame largely depend on their personal theories. Nevertheless, it is useful to consider our analogy in conceptualizing science methods courses and in bridging the gap between theory and practice in our science methods instruction.

Applying the Analogy to Elementary Science Methods

In this section, we describe the elementary science methods course we have designed based on the conceptual change/reflection analogy. In coaching reflective practice, we help preservice elementary education students construct and refine their ideas about science teaching and learning. Our elementary science methods course consists of four foci for reflection: (a) others' teaching, (b) one's own teaching, (c) expert opinions about teaching and learning, and (d) self as science learner. We address each of the foci for reflection with a corresponding instructional "tool" or experience: (a) integrated media materials, (b) field experiences, (c) course readings about science teaching and learning, and (d) science activities. The integrated media materials provide a means by which our students reflect on someone else's practice and begin to reflect on their own visions of themselves as teachers. The field experience complements this by providing the students with a personal and immediate teaching experience on which to reflect. Course readings about science teaching and learning stimulate reflection about the abstraction of teaching. Students are challenged to identify issues in science teaching and learning, clarify their perspective on the issues, and provide evidence for their perspective-- evidence from their experiences in the classroom as teacher and learner, as well as evidence from the classrooms they have observed via the integrated media materials or in person during their field experiences. Finally, science learning activities engage students in thinking about their own understanding of science, themselves as science learners, and the implications for their own teaching of elementary science. We feel that the weaving together of all four components creates a holistic fabric for coaching preservice elementary teachers in becoming reflective practitioners.

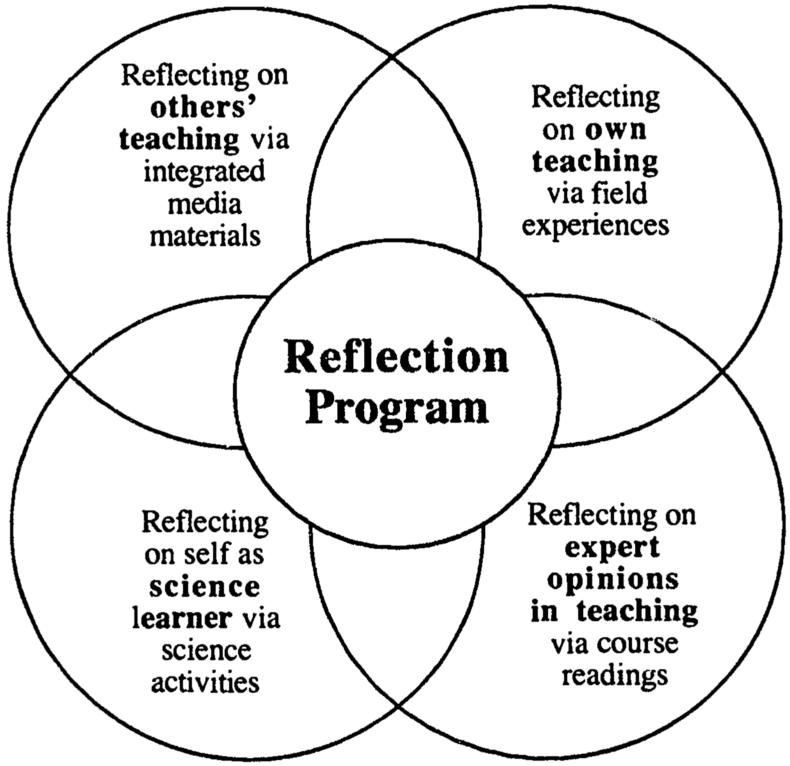

Figure 1: The four components of our elementary science methods reflection program

To illustrate how we coach reflection while concomitantly facilitating conceptual change about science teaching and learning, we will examine in detail our use of the integrated media materials.

Description of Integrated Media Materials

We have developed a set of three videodiscs (Abell, et al., in press; Abell, Cennamo, & Campbell, in press) portraying cases of teaching science for conceptual change for use in elementary science teacher preparation. Users have a choice of viewing elementary teachers and their students as they progress through a 5th grade lesson on inclined planes, a 5th grade lesson on levers, or a 1st grade lesson on seeds and eggs. The cases illustrate a variety of naturally occurring classroom events: student investigations, small group interactions, student record keeping, large group discussions, and demonstrations.

For the past three semesters, as we have infused the integrated media cases into the elementary science methods course, we have been engaged in developing a concomitant reflection program consisting of a series of written and discussion tasks. The reflection program is designed to help students of teaching uncover their local theories, develop new understandings, and practice the skill of reflection about others' and their own teaching. While viewing the integrated media cases, students try to interpret the case classroom teacher's beliefs and values about science teaching and learning, as well as examine their own local theories about science teaching and learning. They also begin framing classroom problems, trying to make sense of the problems from their own and the teacher's perspectives. Most tasks require the students to submit a written analysis of classroom episodes and to participate in a small and large group discussions. In the next section, we examine and describe in detail how we coach reflective practice using the tasks accompanying one of the integrated media cases, "Seeds and Eggs" (see Appendix A: Summary of "Seeds and Eggs" Case).

Coaching Reflection Using the Integrated Media Cases, "Seeds and Eggs"

Drawing on our previous discussion of the parallels we see between conceptual change teaching and coaching reflective practice, we present in this section the specific tasks we use with the "Seeds and Eggs" materials to coach reflective practice among our students. Appendix B, Reflection Tasks: "Seeds and Eggs" Case, displays an overview of the entire series of tasks we have developed for the "Seeds and Eggs" videocase.

In coaching reflection, the teacher educator ascertains students' personal theories and guides students in identifying/framing issues of practice. We implement several tasks in the "Seeds and Eggs" series that help students make explicit their personal theories, and help us as teacher educators to clarify and analyze the range of views held by our students about science teaching and learning. For example, we ask the students before viewing the first lesson, to describe what they expect to see in a first grade science classroom in which students are learning about seeds and eggs. We also ask them to explain the basis of their expectations. The questions that we ask help our students begin to think about their own theories concerning first graders cognitive abilities, the role of the teacher in a first grade classroom, and the organization and characteristics of a first grade lesson. In discussing what influences their expectations, the methods students begin to recognize those forces and experiences that cause them to think about science teaching and learning as they do.

Writing a personal science history is another experience that helps methods students uncover their personal theories about science teaching and learning. In this task, students describe their science teaching- and learning-related history. Students begin to identify the experiences they have had that shape their vision of themselves as teachers of elementary science.

To assist students in identifying and framing issues of classroom practice, we ask them to watch the selected episodes of the "Seeds and Eggs" lesson. For example, after they have watched several episodes, students respond to the the following question: "What are some issues about science teaching and learning that have come up while you have been watching these science lessons?" As beginning teachers, our students exhibit difficulty at the beginning of the semester identifying and describing issues. Hence, we also ask our students to find "decision points" in the video teacher's instruction and formulate "questions to the teacher." We coach students in their framing of classroom issues by asking questions that instigate issue-oriented discussions and illustrate the nature of pedagogical issues.

In coaching reflection, the teacher educator provides experiences that perturb students' personal theories, provides opportunities for students to compare their views with other students' and experts' views, and helps students clarify new frames from which they can interpret practice. We help students to clarify their own views and to compare their views with others' by facilitating small group discussions after viewing segments of the videocase. We guide group discussions with questions such as: "What are the similarities and differences among your responses?" "Why do you think there are similarities?" "Why do you think there are differences?" By encouraging our methods students to consider other points of view in analyzing education practice, we believe students begin to clarify their personal theories about science teaching and learning. Our students inevitably recognize that not all of their peers frame the same issues or take the same stance on an issue. Students begin to consider the reasons for the differences and similarities in their personal theories and what assumptions underlie their own point of view. As facilitators, we address questions to our students to illuminate and encourage them to ponder any inconsistencies evident in their thinking.

Watching the videocase teacher's reflection is a means by which we help students compare their personal theories to a veteran teacher's views and perturb the students' thinking about science teaching and learning. For example, after students write their expectations of what should transpire in a first grade lesson on seeds and eggs, they view the first day of the lesson and listen to the videocase teacher's reflection on her own teaching. This activity provides the students with an opportunity to compare their theories about science teaching and learning with a veteran teacher's theories-in-use. Many students find that their ideas about first-graders' abilities are directly confronted. For example, a number of our students are surprised by the first-graders' intellectual capabilities and social skills. Students' personal theories about technical aspects of the science classroom (e.g., student record keeping, groupwork, behavioral management techniques) also are confronted. These perturbations lead to rich class discussions, affording students the chance to weigh the pros and cons of varying views and to clarify their own ideas.

In coaching reflection, the teacher educator provides opportunities for students to apply solutions and determine the consequences and implications of the solutions. After our methods students complete their viewing of the "Seeds and Eggs" unit, we assist them in reexamining their new and/or refined personal theories. Questions that we use to encourage students to reexamine their personal theories include: "How have your expectations for a science lesson at this grade level changed or been enhanced after viewing the video case lesson?" "How has your vision of yourself as a teacher of elementary science changed?" We ask them to think about their new understandings in terms of their future classroom teaching: "Which of the teaching practices you viewed in these lessons would you feel comfortable using and which would you feel uncomfortable using in your own science teaching?" "Why do you feel this way?" Through these tasks, we begin to coach students to recognize elements of competent practice. Students create a list of practices that they feel characterize competent science teaching. These reflection tasks emphasize the idea that personal theories are not immutable and incontestable. Learning to teach involves the construction of new knowledge and the refinement of one's personal theories.

The integrated media materials are just one of four methods course components. Students explicate their personal theories, clarify their views, work through inconsistencies and determine solutions for resolving teaching issues within the context of the "Seeds and Eggs" lessons. We subsequently provide students the opportunities to make use of their refined theories by organizing field experiences at a local elementary school. Students not only have the chance to make use of their ideas in actual classroom practice, but they are encouraged to examine the extent to which the outcomes of their solutions/ideas are desirable. For many students, the field experiences affirm their ideas about teaching and learning, yet for many the field experience is a theory-changing step. After evaluating their refined/changed view, these students recognize that their personal theories are still in question and that they need to rethink issues which frustrate, confuse or perplex them.

Conclusion

Coaching reflection, like reflection itself, is a non-linear process. There are no prescribed, specified series of steps one takes in order to coach someone to develop reflection skills. Learning to observe and analyze one's own teaching; learning to isolate, frame, and reframe problems of practice; and learning to take action and interpret that action-- all of these skills take time and practice to develop. Hence, it follows that our use of these tasks in the elementary science methods course is not linear, but more closely resembles a spiral. Using the two other videodisc cases as well as other course components, we revisit many of the tasks cyclically throughout the semester, and also add tasks that address other facets of reflective practice. We purposefully sequence the tasks to encourage systematic reflection. Our sequence of tasks allows a gradual transition from simple to complex situations; from observing and describing teaching events to identifying the underlying issues and problems; from general to specific foci of reflections; and from concentration on others' teaching to concentration on one's own teaching. By revisiting tasks throughout the semester with different classroom cases, we continually provide students opportunities to make their preconceptions about science teaching and learning explicit, challenge these strongly held local theories, and engage in constructing new knowledge and refining personal theories about teaching elementary science.

Our goal in this paper has been to describe and illustrate our reconceptualization of methods course teaching. We set out to describe our beliefs about the role of reflection in science teacher education. Then, by drawing explicit links between conceptual change learning and reflecting on practice as well as conceptual change teaching and coaching reflection, we provided the theoretical framework upon which we based our science methods course reflection program. Beyond providing teacher educators with a set of activities to use in their methods course, we have presented a theoretical framework for the reconceptualization of elementary science teacher preparation.

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Appendix A

Summary of "Seeds and Eggs" Case

Mrs. Schwärtz introduces the conceptual change seeds and eggs module by presenting her first grade class with the task of sorting a group of objects into "seeds" and "not seeds". Students work cooperatively in small groups on this task. In a large group discussion, students share and compare answers and find that they do not all agree about which items are seeds and which are not. Mrs. Schwartz prompts them to think of a way to figure out if the items they disagree about are seeds or not. The students suggest planting them to see if they will grow, and proceed to make baggy gardens for the test. After several days, students examine their gardens, observing changes. They compare similarities and differences among their gardens and decide if the things they planted are seeds or not.

Mrs. Schwartz then presents what she expects will be a discrepant event to challenge students' thinking about seeds. She gives them brine shrimp eggs (labeled "little ones") and clover seeds (làbeled "big ones"). Students predict what will happen when the items are placed in water. They design and carry out a test, observing the little ones and the big ones over time. The clover seeds sprout, confirming student predictions that the big ones are seeds. On the other hand, the little ones begin to "wiggle and dance around," according to student observations. The students decide these must not be seeds. Someone suggests they are "eggs" and the students start guessing what the eggs will become.

The students agree that seeds become plants and that eggs become some kind of animal. Mrs. Schwartz asks the students to help her make a chart comparing plants and animals. To see if students can take their ideas about plants and animals and use them to solve a problem, Mrs. Schwartz presents them with two specimens: a water animal and a water plant. The children apply the criteria they developed in making the chart to decide if the specimens are plants or animals.

Appendix B

Reflection Tasks: "Seeds and Eggs" Case

Task #	Purpose	Video Segment	Student Activity/ Sample Questions
1	To help students make explicit and analyze their own beliefs, recognizing those forces that cause them to think about science teaching and learning the way they do.	Prior to watching Seeds and Eggs	*Out-of-class writing followed by in-class large group discussion:* You are going to watch a first grade teacher beginning a science unit called "Seeds and Eggs." Before viewing this teacher, think and write about the following: What do you expect to see in this first grade science lesson? On what do you base your expectations?
2	To help students identify, describe, and analyze a teacher's theories-in-use evident in an elementary science classroom. This task can also be used to help students discern between description and evaluation.	Seeds and Eggs: Day 1	*In-class writing followed by small group discussion:* What do you remember most vividly from the lesson? Try to focus on description, not evaluation of what you remember. Why do you think the teacher decided to teach the lesson as she did? What do the teachers' practices tell you about her assumptions, values, and beliefs about teaching and learning?
3	To help students uncover their personal science histories and visions of themselves as science teachers in order to (a) clarify their current beliefs about science teaching and learning and (b) better understand the connections between their science experiences, visions, and current beliefs.	Seeds and Eggs: Days 2 and 3	*Out-of-class writing before video segment; After video segment, in-class writing followed by small group discussion:* Before viewing: What is your vision of yourself as a teacher of elementary science? Describe a science learning experience from elementary school, middle school, high school, and college. What out-of-school experiences did you have? Why did you choose these experiences to describe? After reflecting on these experiences, which ones do you feel have had the greatest influence on your vision of yourself as a teacher of elementary science? Explain. After viewing: What do you remember most vividly from the lesson? What connections do you see between your own science experiences and what you focus on in the video?

Task #	Purpose	Video Segment	Student Activity/ Sample Questions
4	To help students recognize and define educational issues in a natural classroom situation; to encourage students to consider other points of view in analyzing educational practice.	Seeds and Eggs: Days 4 and 5	*In-class writing followed by small group discussion:* Writing activity: What issues about science teaching and learning have come up while you have been watching these science lessons? Discussion activity: What are the similarities and differences among your responses? Why do you think there are similarities? Why do you think there are differences? What is one "take-home" message based on your discussion?
5	To help students view classroom situations as complex, problematic, and personally constructed.	Seeds and Eggs: Days 6 and 7	*In-class writing followed by out-of-class writing:* In-class: As you watch the lesson, please note each place where you think the teacher is making a teaching decision. After viewing the lesson, choose one of the situations you described, and design alternative possibilities for decision-making. Out-of-class: What questions would you like to ask the teacher in the video lesson about science teaching and learning?
6	To help students move from reflecting on someone else's teaching to reflecting on their own teaching.	Seeds and Eggs: Day 7	*In-class writing followed by small group discussion:* Before viewing: Imagine that you are the teacher at the end of the series of science lessons that you have been viewing. On what aspects of the class would you be reflecting? After viewing: Record what the teacher focuses on in her reflection. In small groups, compare your reflections with each other and with the teacher's reflections. What could account for the similarities and differences?

Task #	Purpose	Video Segment	Student Activity/ Sample Questions
7	To assist students in confronting and restructuring their personal theories of science teaching and learning; to develop students' ability to recognize elements of competent practice.	After viewing entire Seeds and Eggs	*In-class writing followed by large group discussion:* Writing activity How have your expectations for a science lesson at this grade level changed or been enhanced after viewing this video lesson? How has your vision of yourself as a teacher of elementary science changed? Which of the teaching practices you viewed in these lessons would you feel comfortable using and which would you feel uncomfortable using in your own science teaching? Why do you feel this way? Discussion activity What practices do you feel characterize competent elementary science teaching?

ASSESSING CHANGES IN TEACHERS' CONTENT AND CONTENT-PEDAGOGICAL KNOWLEDGE*

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Capacity building in teachers is an essential component of the systemic reform movement. Advocates for reform, whether in the public or private sector, recognize the urgent two-fold need:

- to increase teachers' knowledge in the disciplines
- to increase teachers' pedagogical expertise

Changes in these two areas will transform classrooms so that all students have the opportunity to learn science in meaningful and challenging ways and so that teacher and student attitudes towards science will be positive.

Increasing teachers' knowledge in the discipline and their expertise in pedagogical techniques is both challenging and intimidating to many educators. In elementary education, i.e., K - 6, the deficit knowledge in science is particularly evident. Directly related to the knowledge deficit is the lack of comfort with science. Lack of comfort in science often results in a resistance to teaching science in dynamic and engaging ways. In science education, the problem becomes cyclic with the knowledge deficit fueling resistance both to teaching science to students and to learning more science as professional educators, which, in turn, continues the expanding deficit in teachers' understanding of science as the discipline grows and changes.

A major challenge for education reform activities in science is to increase science understanding of elementary teachers while providing them with strategies and techniques for instruction and assessment that will support and enhance their students' science understanding. Science PALs (Parents, Activities, and Literature) is a project designed to do just that. Although

*Funding for this project provided by the National Science Foundation under Grant 9353690. Any opinions, findings and conclusions or recommendations expressed in the paper are those of the author and do not necessarily reflect the views of the National Science Foundation.

there are many aspects of Science PALs worthy of discussion, the purpose of this paper is to present the assessment system designed to document changes in teachers' understanding of science, their attitudes towards the discipline, and their effectiveness in using their changing understanding and attitudes to transform science learning for their students.

Science PALs Project Overview

Science PALs provides teachers the comfort and incentive to enhance their science understandings through the use of language arts activities (e.g., stories, storytelling, drama, visual arts). These activities serve as scaffolds for building science concepts. Not only do they deliver science content in engaging, exciting, and personally relevant formats, but they reinforce a basic concept of science often neglected in the classroom--that is that a great deal of what scientists do is to communicate their ideas, their procedures, and their results to various audiences. Just as scientists communicate science understandings to others, so too should teachers and students. Science PALs offers a writing-to-learn science and a reading-to-learn science embedded in an experience-rich, integrated language arts/science environment to elementary teachers.

Science PALs is a complex and incremental project spanning four years. Phase 1 of Science PALs provides the data to be reported in this paper. Science PALs partners a university with a substantial program for the training of science teachers with a large education unit. Sixteen teachers serve as lead science teachers in each of the district's 16 elementary schools as the project moves into Phase 2. Ultimately all 275 elementary teachers in the system will participate in Science PALs. And, just as the project will change and grow as each phase is completed and the project staff and participants reflect on what has worked and what needs improvement, so too will the assessment model change. However, Phase 1 of Science PALs provides opportunity to establish the theoretical basis for the assessment system and the baseline year data against which to document change in teachers' understanding of science, their attitudes towards science, and their capacity to create engaging environments for the learning of science for all students. This assessment system will serve as a model for student assessment in those transformed classrooms during Phases 2, 3, and 4 of Science PALs.

Science PALs Assessment System

Implicit in the Science PALs project is the goal to model for the teachers an evaluation plan that has value to them as professional science educators and that is consistent with and supportive of constructivism for them. PALs participants are not a source of data--they are partners in a project to transform the way science is taught and learned in the elementary school.

These three agendas are complementary and substantial. They challenge the project staff to shape an evaluation design that has benefits to teachers and students as well as to the project staff and funding agency. They carry an obligation to redefine evaluation as a strategy for documenting change in understanding and attitude that can be adopted and then adapted for use in each participant's classroom. They also carry an obligation to think beyond the specific indicators to the desired behavior or response; teacher and student participants must be supported in the demonstration of science understanding and dispositions (attitudes) in multiple ways to be consistent with constructivism.

Because the Science PALs project focuses on the use of expressed ideas, science-based stories, and hands-on activities to transform how students think and do science, the assessment system reflects and models these same attributes. Likewise, it is important for the effective transfer of leadership from the project staff to the teachers/participants that they learn to value the assessment practices used in the evaluation component so that they model and reinforce this value in the classroom. Thus, the Professional Development System (PDS) (Table 1) was designed to document science understanding and attitude through the idea expression, science stories, and hands-on activities. The collection of the documented evidence (or artifacts) effectively defines a participant portfolio.

In order to ensure the credibility of analyses of change conducted in Phases 2, 3, and 4 of Science PALs, the portfolio has been designed to include a structured core[1] and idiosyncratic entries selected by participants for individual reasons (e.g., most challenging theme/topic to teach,

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[1] A term defined in theory and explored empirically in the 1992-1994 NSF study, Authentic Assessment for Multiple Users.

Table 1
Professional Development System

DIMENSIONS		POINTS OF EVIDENCE							
		Lesson Plan Data	Participant Field Notes	Videotape Analysis	Teacher Reflection	Student Work	Assessment	Other	Performance Level
Organizes Instruction	Goals								
	Materials								
	Strategies								
	Time								
	Connections								
	Evaluation								
	Resources								
	Reflective Planning								
	Science Component								
Implements Instruction	Student Differences								
	Student Understanding								
	Students as Self-Directed Learners								
	Parent Involvement								
	Reflective Teaching								
	Science Component								
	Time								
	Materials								
	Connections								
Leadership	Communications								
	Networking								
	Attitudes								
	Mentoring								

most indicative of professional growth). The tasks that provide the context for the teachers/participants' presentation of evidence of their understandings, their attitudes, and their pedagogical practices are deliberately tied to the content appropriate for the grade level being taught. Other tasks are more general in their content and thus are appropriate for the entire K-6 grade span.

Although some evaluation systems focus on variables empirically linked to student performance, PDS supports a less restrictive approach. Constructivism as a teaching and learning philosophy contributes to this eclecticism, and we have taken this to heart in the manner in which documentation is defined. Beginning with a structured documentation model and moving towards a model that promotes autonomy and empowers teachers to select the most effective and expressive mode/medium for demonstrating their science understanding and attitudes, the PDS also serves to enhance broader professional growth by maintaining a constant scoring framework across all forms of evidence.

Theoretical Rationale

The development of the Science PALs portfolio scoring rubric derives from the major research programs in teacher effectiveness beginning with Shulman's (1990) summarization to the work of Dwyer (1994) and the Model Standards work of the Council of Chief State School Officers (1992). Although somewhat obvious, it is not a trivial notion that the process/product research defines relationships between what teachers do in the classroom and what students do in those same classrooms. Furthermore, emerging from the recent research on effective teaching is the notion of "classroom as context." Shulman sites as a serious deficit early research programs which had the "tendency to ignore the substance of classroom life, the specific curriculum content and subject matter being studied" (Shulman, 1990, p. 53). Of particular interest with respect to Science PALs is a reference that Shulman makes to the work of Fenstermacher (1987). Fenstermacher argues that "(e)ducating a teacher is not a matter of inculcating a knowledge base in the form of a specific set of teaching skills and competencies. Rather, to educate a teacher is to influence the premises on which a teacher bases practical reasoning about teaching in specific situations" (Shulman, 1990, p. 80). Science PALs endeavors to transform science understandings and attitudes of teachers and students by changing the premises on which teachers make decisions about what is taught, how it is taught, and what represents learning on the part of the students.

Implementation of the PDS

In order to implement the PDS, definitions of quality within each dimension were developed in an iterative manner--first relying largely on the literature. Second, conversations about proposed definitions of quality took place among the project staff. The amended definitions resulting from these conversations were then re-evaluated against the research. Those definitions of quality that survived this process then became the frame of reference for each performance standard. From these definitions of quality, performance standards emerged.

Drawing upon the substantial literature in the direct assessment of writing and the relative efficiency and utility of scoring guides of various discrimination levels, the authors of PDS opted for a four-point common scale within each dimension. The highest level defines quality for each dimension. The traditional to constructivist teaching continuum underlies each dimension.

The evolution of these performance standards was similar to that of the definition of quality and the selection of which dimensions to include in this professional growth evaluation matrix. Like the dimensions and the definitions of quality work, the delineation of the performance standards began in the research on what good teaching should evidence. Next, discussions focused on the relative merits of the performance standards and then the feasibility of implementing them as decision tools for quantifying professional change in teachers. Finally, the participating teachers engaged in inter-professional development to critique the dimensions, the performance levels, and the domain of relevant evidence.

An example of how these performance standards are operationalized is shown for the "Reflective Teaching" (Table 2) dimension from the broader category of "Implements Instruction." Another example, from the broad category "Implements Instruction" (Table 3) is the dimension of "Student Differences." In both of these examples, the progression from the traditional to constructivist model is evidenced as one moves from the left to the right of the matrix. The "Points

Table 2

Implements Instruction

	Traditional	<------------------------	------------------------>	Constructivist	Points of Evidence
Implements Instruction - Reflective Teaching	External evaluation drives reflection. Teacher does not reflect on student understanding, and does not regularly use assessment information to inform instruction. • teacher questions are low level • lessons are planned a year in advance and no changes are made • no ongoing formative assessment	Teacher may reflect without external impetus. The teacher occasionally uses reflective information to modify instruction, but may or may not be able to justify why modifications to instruction were made.	The teacher regularly reflects on teaching and sometimes uses this information in future instruction. The teacher supports his or her judgments with evidence from teaching experience.	Teacher is self-motivated to regularly reflect on teaching and can accurately describe strengths and weaknesses in own process. Teacher regularly uses reflective information in future instruction and supports his or her judgements with specific evidence and/or from research on effective teaching. • teacher asks questions and uses students answer to guide instructional decisions-making • instruction reflects influence of outside factors (journal articles, conversations with colleagues, etc.)	• teacher journal notes * • lesson plans * • video tapes * • planning note to self for next year

Table 3

Implements Instruction (continued)

	Traditional	<----------------------	---------------------->	Constructivist	Points of Evidence
Implements Instruction- Student Differences	The teacher demonstrates a lack of interest in becoming familiar with students' background experiences OR misuses information such that there is interference with effective high quality learning. • all students viewed as relatively the same • cultural differences not considered	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.	The teacher demonstrates interest in understanding why it is important to become familiar with students' background and uses this information to enhance the quality of the learning experiences for all students.	The teacher demonstrates interest in understanding why it is important to become familiar with students' background and uses this information to enhance the quality of the learning experiences for all students. • teacher is aware of student home life and how it may influence classroom behaviors/learning • students are viewed as individuals. • students are not negatively singled out based on differences	• teacher journals * • teacher notes to students with feedback • letters to parents • video tapes *

of Evidence" column are illustrative, including but not restricted to specific or common points of evidence. Those that are common are marked with an asterisk.

As this example illustrates, the performance standards for each dimension include suggestions of types of evidence teachers may elect to use in building their own collections of evidence. In addition, common tasks are suggested as a basis for calibrating the rigor and appropriateness of evidence elections among teachers. For the Science PALs project itself, structured interviews provided a common "task" for this dimension.

In theory, the PDS is solid and convincing. However, the implementation phase provides the necessary empirical evidence for supporting continued use and refinement of this system.

During the field-test of the PDS, 16 expert elementary teachers participated in the inter-professional development project funded by the National Science Foundation. This cadre of teachers was recruited to serve as advocates for additional cadres of teachers recruited into the project. These advocates implemented constructivist learning theory in support of science learning for all students; they reorganized their classrooms, restructured curriculum, rethought assessment, and renewed their commitment to the belief that all students can learn at high levels. Because the base project (Science PALs) focused on elementary science, these teachers collected points of evidence for the PDS from elementary science experiences.

The points of evidence submitted by the advocates were not broad or diverse. A survey of artifacts submitted by the teachers as evidence indicated that lesson plans were most frequently used across a wide range of dimensions. Field notes and teacher reflections also appear to be useful in documenting behaviors across a wide range of dimensions.

Two different strategies of scoring these points of evidence were used. First, trained independent raters rated each of the points of evidence. Concurrently, the submitting teachers were trained to score their own selections. Both groups used the same scoring guides. However, the training of the independent scorers was more comprehensive than the training for the teachers. The impact of this difference in training is reduced by the teacher advocates' familiarity with the PDS and with frequent hands-on experience with points of evidence relative to the transformation from traditional to constructivist teaching and learning.

Findings

Based on the points of evidence collected and submitted, the dimensions and the performance standards within each dimension do appear to be working. As reported in Table 4, independently trained raters were able to agree exactly or within one score point for either 89% or 100% of the artifacts examined. The number of artifacts per dimension ranged from one to eight with the modal number of artifacts per dimension at three.

A comparable analysis comparing teachers' ratings of their own evidence compared to at least one of the trained project staff raters shows less agreement but still reasonable comparability. Based on the results reported in Table 4, the PDS is a viable approach to teacher evaluation. (However, clearly the teachers' perspective on quality is different from that of the independent raters.)

What is not known is whether the system will work across large groups of individuals. Agreement is possible among trained raters across a wide range of artifacts or evidence. Furthermore, the performance standards do indeed discriminate among these data points. However, without broader participation, there is need for further research to determine the meaningfulness and utility of this work beyond the field test sample.

Obstacles and Insights

To the extent that participants in this project are representative of public school teachers, the work and observations of these participants are not unique. Rather they support and affirm two realities. First, teacher perception of the level of effort required to transform classrooms from teacher-centered to student-centered is considerable. Furthermore, this work is frustrating, tiresome, and often more complex than the behaviors of interest. These findings are consistent with the survey of professional development models reported by Cornett (1995). Among the seven findings cited from the Southern Regional Education Board's Career Ladder Clearinghouse Survey, three are consistent with the findings from Science PALs' first year. Cornett says that:

Table 4
Rater and Teacher Agreement

	INDEPENDENT RATER		TEACHER RATER	
Teacher Entry	Percent Exact Agreement	Percent Adjacent Agreement	Percent Exact Agreement	Percent Adjacent Agreement
1	22%	67%	55%	22%
2	27%	55%	NA	NA
3	67%	22%	NA	NA
4	55%	38%	27%	50%
5	27%	61%	44%	38%
6	55%	38%	44%	0%
7	55%	44%	61%	22%
8	33%	67%	NA	NA

- Incentive programs that fundamentally alter pay structure based on performance can produce fundamental change.
- Without a guiding vision or state support, pilot incentive programs designed at the district level have resulted in few fundamental changes or lasting reforms.
- Given the choice, most teacher prefer to earn additional pay by working more hours rather than by having their performance judged.

In the Science PALs project, no pay structure was altered since compensation was only for additional pay for additional work. Neither was it clear at the time of this study if Science PALs would be endorsed for long-term implementation by the district. Nor was there a guiding vision or state support for this local effort. The Science PALs participants' hesitation to embrace the evaluation component of this project as a tool for their own professional development suggests that the teacher enhancement notion of teacher as leader within the school does not include accountability. As one participant stated, "I feel like I am going to the IRS for an audit." Certainly one of the important outcomes of Science PALs is to shift that notion in the minds of the participants.

In the interviews that accompanied the scoring process, it became evident that several teachers had no clear vision of why certain evidence was relevant and other evidence was not. Some teachers were uneasy going through the scoring process because of the relative scarcity of evidence--this despite the fact that most of the collection of evidence was under the exclusive control of the teachers. On a positive note, a few teachers were comfortable with all dimensions of the scoring rubric and spoke of this process as being valuable and as becoming an integral part of professional growth.

Final Remarks

Perhaps the insights and obstacles are one and the same. The PDS appears to be flexible, eclectic, and responsive to the individual preferences of the participating professionals in the classroom. Judgments can be made about points of evidence if independence and training are present. However, teachers may be as uncomfortable accepting the responsibility of self and peer evaluation as they are in accepting the responsibility for assessment of students in their classrooms. While the openness and flexibility of the PDS has encouraged the participation of some teachers, it has yet to capture the interest of all. One must ask: What is the key to professional development among educators--what is the inter-professional development component that will spark a valued paradigm shift?

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A YEAR OF COLLABORATIVE TEACHING IN AN URBAN SCHOOL: BARRIERS AND INSIGHTS

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Introduction

Urban schools do not necessarily require of their teachers a different set of skills than suburban or rural schools, but they do demand that teachers know the particular contextual issues that pertain to the urban setting. This situation creates a challenge for teacher education in general and for science education in particular. As teacher educators, we must prepare ourselves so that we can guide future teachers in learning about inner city schools. As science educators, we must meet the daunting challenges involved in preparing urban teachers to work toward the goal of science literacy for all students in the inner-city.

We describe in this paper the experiences of a science educator (the first author) who spent one year teaching in partnership with a classroom teacher in an inner-city school. We purposefully take an informal stance in writing this paper. Our goal is to communicate Meadows' experiences and to lay out much of his journal data. We want presentation participants to be able to go deeper with the issues we raise in Seattle, and we want to provide a foundation for future discourse about urban science teaching.

Methodology

We participated in a joint teaching collaborative between our comprehensive university in the American Southeast and a local, metropolitan school system. The collaborative teamed professors of education with teachers in urban classrooms so that the professors spent one day per week teaching in inner city classrooms. Meadows was paired with a veteran science teacher at Williams*

* All names of schools and people are pseudonyms.

High School and taught throughout the year in her physical science classroom. She is PJ, and she became his mentor and his friend.

The chief data source for our findings consists of a transcription of Meadows' audiotaped reflective log recorded on his way to and from Williams. Analysis focused on the development of emergent themes and was advised chiefly by Strauss (1987). Analysis occurred in two stages, open-coding and axial coding.

Open coding targeted micro-analysis, often in a word by word fashion, of sections of the journal. Open coding occurred over two sessions and developed categories as a way of discovering the major themes of the journal. Reflection on these categories generated five themes which could be treated as axes for the second stage of axial coding. During axial coding, each theme was used as an analytic focus in moving through all of the journal. Analysis generated dimensions and subdimensions of each axis and occurred over five sessions. At the end of axial coding, the dimensions and subdimensions were reviewed, organized, and collapsed to provide a description of each major theme. HyperResearch™ proved to be invaluable for managing the process of open and axial coding.

Synthesis of the data occurred by making a graphic of the organized axes, including their dimensions and their subdimensions. Developing the graphic revealed repetitions of categories and forced relationships between the axes and their components. Inspiration!™ was also invaluable during this process.

As we discuss the findings, we will shift from plural to singular to indicate the personal nature of the research. At this point in the project, Pierce moved to an advisory role, and Meadows conducted most of the analysis in solo.

Findings

Three key themes emerged out of my data: acceptance into the Williams school culture, classroom management, and students' view of education as an elective process. The categories supporting each of these themes can be grouped under the headings of barriers and insights.

Acceptance

Acceptance was the first axis that emerged from analysis of my data. Viewing my work as a cross cultural experience causes me not to be surprised that one of my highest concerns was on myself and being accepted into the culture. I was consistently off-balance while at Williams, especially during my first months there. I grouped barriers that fall under this theme as the stages of acceptance, and I grouped insights under this theme under acceptance builders.

Barrier: Stages of Acceptance

Analysis of my journal indicated different stages I went through in gaining acceptance: entrance, lack of acceptance, exploration, and rapport. My failure to recognize these stages on the outset raised initial barriers, and failing to progress through each of these stages would have perpetuated the barrier of lack of rapport. Other stages are possible, and more work at Williams would probably open deeper stages than rapport.

Entrance was the first stage, and my experience was one of a lack of acceptance as the following data indicate:

> Right now they have...a new permanent teacher and I have offered to work with that new teacher, mentoring her, but PJ called me this week. Mr. Capps said that he wants to give Mrs. Peyton, the new teacher, some weeks to get on her feet and that I will be working with PJ for now.

I really wanted to help Mrs. Peyton at that point, thinking I could help a novice get on her feet, but obviously the Williams staff didn't think that I would be of help. Their choices indicated to me a lack of acceptance.

As I begin to feel accepted, I begin to take small risks in and out of the classroom, exploring how much I was accepted. This stage I have termed exploration:

> I would like to begin switching gears a little; I'd like to begin shifting my teaching and playing with some stuff. I'm not content to teach the way PJ teaches. Although I'm content not to take a critical approach with her and try to get her to change her teaching style. I just kind felt -- I guess I feel like it would be unethical of me to teach the way she teaches because the way she teaches seems to disable— Actually to the students it's not enabling, it is disabling. They're not learning how they should learn, and they are not moving to higher level thinking.

The final stage that I reached was one of rapport with PJ and some of the other Williams staff. At times, PJ would talk with me at a new level of honesty:

> PJ was talking yesterday at lunch, and she said something that made me think she had just kind of given up. She was talking about fights with the system to get materials, and she just said that it wasn't worth it anymore to fight the system.

I was also able to ask her about issues that potentially could cause conflict between us:

> Talked with PJ at lunch today about going slow, and she said that I was not going too slow, and that I was not slowing her down...[She was] funny in a little way about it. I think she was being honest [but was she] being honest or telling me what I really wanted to hear.

Little things also indicated to me that rapport was building.

> My rapport with PJ still continues to get better and better; we're talking easier and easier. She's kind of joking with me [and] referred to me to the class—referred to me to the class as Dr. M. [She also] calls me "Doc". "Doc" seems to be a real big word [at Williams]. They call each other "Doc"; it's a -- it's a -- I don't know exactly what it means, but it's used in a good way.
>
> I [noticed] even from the other faculty, that other people there seemed more relaxed. Mr. Capps patted me on the arm today and in a manly sort of way -- you know a cross between a pat and a slap. Mr. Duckworth and I are talking easily. We are -- were joking about rednecks [recently]. Mr. Matthews seems to be more comfortable around me. It's almost like they are getting used to me being around

The rapport that pleased me the most, though, was that with PJ.

> Towards the end of the day, I really complimented her...teaching...and I told her that I would like to continue teaching and to continue to observe her for the rest of the month.... I could really learn a lot. And she acted really surprised, and I don't think it was playing. She didn't think she had a lot to offer, but she does....But I think I finally built a good rapport with her.

Insights: Acceptance Builders

Analysis of my data revealed several attitudes of mine that seemed to build bridges across the barriers to acceptance I felt at Williams. Chief among these are commitment, communication, flexibility, service, and showing concern.

My commitment to persistent presence at Williams I believe to be one of the major factors that eventually gained acceptance there. This need for commitment is plausible in light of the history of poor relationship between my university and Williams and its school system. Faculty and administrators at Williams expected me to appear briefly, use Williams personnel and students for my own purposes, and leave.

Consistently throughout my journal, I documented the tension of trying to maintain my commitments at the university while continuing a weekly presence at Williams. Competing pressures came from other research, my university's new emphasis on grant writing, the lack of adequate compensation for my time at Williams, conflict between course schedules and Williams schedules, and service commitments such as our NCATE accreditation visit. Throughout it all, though, I maintained a consistent present through thinking such as the following:

> I've got to turn my schedule around because I'm teaching mini-term in the morning and know that the 15th or something like that, I've got an afternoon meeting. But I don't need to miss school; I may need to go out there a couple times. I guess I could go out on...Thursday the 15th.

Commitment opened William's faculty to my presence there, but I used good communication to help me understand the issues involved with my being accepted there. My focus on communication grew out of my sociological training and prior cross-cultural experiences in western Europe and Russia. The following excerpts are examples of the type of communication I initiated:

> I'm trying to move slow with PJ. I'm trying to take whatever information she gives to me and build trust with her. I guess one thing I could do is talk with PJ about things I'd like to try. I'd like to try cooperative learning. I'd like to try hands-on science. But my biggest fear is throwing her behind. She seems to move so fast with a chapter a week. Anything I do I feel like I'm going to slow her down. I guess the best thing to do would be to plan with her to see -- to see what would keep from messing her up.

> I also talked with her about grouping ..... and she said she has done some things in the past with groups, but hasn't done it since she got in her new room because she hasn't been settled. But I asked her how she felt about my going to cooperative groups and she said that she it would be fine with her if I wanted to try it.

Related to communication is the flexibility required in cross-cultural settings. I realized that I had to consistently negotiate with PJ and other Williams faculty as well as with my own expectations. An example of this type of flexibility is that although I feel like students need to know much more than simply how to read science texts, I was willing to negotiate those expectations:

> But I don't mind moving -- I don't mind moving really slowly. Right now, I know that this will change, but right now I feel like that if by the end of the year the students were better able to read and understand scientific texts, that would be enough.

I was also willing to be flexible with what I actually did at Williams, even including my first day there:

> I walked in about 9:15 a.m. because I knew that I was going to have to catch [the principal], and I knew that I would not be able to catch him during first period of the beginning of school to see my assignment. I saw him; he didn't really know what exactly what I should do but he wanted to talk to PJ, the department chair....About that time PJ came out away from the phone, she had been trying to get a substitute, Ms. Jackson, the permanent substitute (because they hadn't put anyone in the position that Ms. Nelson held last year). PJ was coming out; she couldn't find a sub. There had been an administrative snafu. Ms. Jackson had left a note for PJ the day before saying that she wouldn't be there the Tuesday that I got there.... PJ didn't get the note until that morning, and she couldn't get find a sub. I looked at Marcus and Marcus looked at me, and I volunteered to sub for the day. So I was immediately thrown in.

Two other acceptance builders were service and showing concern. Service is related to flexibility, as the above anecdote about subbing on my first day indicates. Through my experiences at Williams, different science faculty members have asked me to do various things for them such as getting computer software, arranging field trips to my university, getting certification checklists, or trying to find tutors. Sometimes, I perceived these requests as tests of my commitment, and I felt that if I had failed to try to fulfill their requests, I would show a lack of commitment.

I also believe that showing concern for the faculty members opened doors of acceptance. An example would be when PJ's mother-in-law died unexpectedly. Many of the out-of-town family stayed with PJ and her husband during the week of the funeral, and she was exhausted one day that I went to Williams. I expressed verbal concern for her and offered to teach classes that day even though I was only supposed to be observing at the time. This show of concern was another bridge to acceptance at Williams.

Classroom Management

The second major theme that emerged from my data was my thoughts and struggles with classroom management. Classroom management has been a persistent theme throughout all of my work at Williams. Before my work there, I consistently told my teacher education students that classroom management was one of my strengths. My tenure at Williams has made me reconsider that belief, though, because I consistently struggled in this area. The chief barrier that emerged from my data was a lack of warmth, and my insights targeted cultural accommodations, negotiating with students, and control.

Barrier: Lack of Warmth

The chief lesson I have learned thus far in my interactions at Williams concerns the need for warmth, for overlaying all of my interactions with students. Furthermore, this was a lesson I learned this fall, almost a full year after recording the journal data from which this paper was drawn. My native classroom management stance is a no-nonsense approach of simply stating the rules and enforcing consequences of misbehavior. This approach did not work at Williams.

My style contrasted with that of PJ's. I consistently noted that she was upbeat with the kids, at times conciliatory, at times demanding, but consistently positive.

> I was impressed once again with her rapport, with her ability to discipline.

I, on the other hand, drifted toward confrontation although I was questioning that drift.

> I always tend to be much more tough. "You will do this. You won't." And that may be inappropriate. I may be missing the mark there

After my beginning weeks, I was frustrated with consistent disruptions while I was teaching. My strategy to deal with this involved giving and taking away bonus points.

> I told them at the beginning that they had five class participation points, and each time they messed up they lost points. That seemed to get things under control pretty quickly in second and sixth periods.

It was a novelty effect, though, because the bonus point system didn't maintain an effective classroom environment. I continued to have problems, even with getting the students' attention at the beginning of class.

> I wonder what would happen if when I went in there and the first thing I said was "Let me have your attention, please" and I took off points until they were quiet. "Let me have your attention, please," [and then] each time I took off points until they were quiet—until they learned to listen—and tie those lost points back to them. I'd probably have to prepare a grade and get it back to them the next day. I could even fax it over to PJ or just prepare it before I go.

I never arrived at a workable classroom management plan during my first year at Williams. Based on my subsequent experiences there, however, I now believe that warmth is critical to all my interactions with students at Williams, including classroom management interactions. Warmth was missing from my first year. I was concerned about the Williams students, but not overtly. I suspect now that this need to demonstrate warmth may be an artifact of racial tension. My tough stance brought to my students' minds prior, negative interactions with other whites, either personal interactions or interactions they had been told about. Warmth may diffuse some of this expectation for negative interactions.

Insights

Insights I developed to the issue of classroom management at Williams fall into three areas. Cultural accommodations describe shifts in my classroom management practices necessitated by the difference between Williams' culture and cultures I had previously taught in. Negotiating with students concerned my need to choose my fights with the Williams students, who mostly were not engaged in the education process. Control can be viewed as the negative side of negotiating with students in an attempt to maintain a supportive classroom environment.

Looking back on my first year at William, I see things much more as a cross-cultural experience than I did at the time. I realized that I was in an urban situation, but I didn't realize fully that I had crossed to a different culture. In retrospect, I can now classify some of my actions as cultural accommodations. Some entries in my journal indicated how I felt like I was relearning old lessons that I thought I had mastered while teaching high school full time. I was frustrated by the need to go back and relearn, but now I see that I was having to resituate these skills into a different cultural context.

The first of these was a strategy I developed to overcame my inability to pronounce and remember the students' names. My first attempts at this were embarrassing for me and the students, but I developed a small system that worked.

> I just developed a seating chart and carried that seating chart in my hand so that I can call on kids. That seemed to work real well. I wrote the kids names down phonetically based on PJ's pronunciation [during daily roll

call], which was just the luck of the draw type thing, but it worked real well [for] pronouncing the kids names correctly.

The strength of this system was listening to PJ's pronunciation, noting it, and then mimicking her as closely as I could.

I implemented cooperative learning into PJ's classroom on the days I was there, and achieved minor success. I developed the following strategy to deal with the high inner-city absenteeism:

> One thing that I'm going to have to include in forming groups is to make people whose attendance is irregular... either a fourth or fifth member of the group so that, so that, when if I have two or three people who are irregular in the attendance in the group, that group just would not exist if they aren't there.

I ended up settling on groups of five with roles of A, B, C, D, and E. The E's were always the persistently absent students, and I always structured the roles so that there was a back up person for the E's role, since that person was usually absent. I also began to learn about students lack of commitment to schooling. This was evident in having to skirt some confrontations with them:

> I think I may have just realized something about discipline. In the suburban schools you can hammer a kid down, you can lock them down and make threats....But what are you going to do in the urban schools? How can you really punish a kid? What are you going to do -- kick them out? Do they care about that? I think PJ has the right approach of dealing with the major things and drawing the kids along. Almost a . . . . school mentality if you're going to try and keep them in school. You don't have a captive audience

Incidents like those began to show me the need for the hard cultural accommodation of negotiating with students, the need to choose my fights. In my prior suburban teaching, I never negotiated with students. I set the rules, they followed. At Williams, that stance could lead to fierce confrontations. In this area especially, I followed PJ's lead. Sleeping in class is common at Williams, and at the beginning of my year, it bothered me a lot. I changed my views, though, because sleeping students don't cut up:

> I would say that thirty percent of students were asleep, which I allowed. I'd rather them sleep than to cut up, discipline wise.

I chose my fights in group arrangements, something I never consider before:

> The only criteria that I used in the groups...was I kept the trouble making kids apart. By fifth period I separated the... [troublesome] groups even to separate parts of the room.

I even practiced the subtle art of unspoken negotiation in classroom discipline.

> Also, I think I kind of did what PJ normally does, ignoring a lot of stuff. I just kind of avoided some of it.

My negotiation with students even continued to the point where classroom management merges with classroom instruction. I begin to let PJ fight many of my classroom management battles, such as letting her start class for me so that she could settle the students before I tried to teach. I also followed PJ's pacing example.

> I kept things moving real fast, just like PJ did -- kept the pace up.

A fast pace may not be the best for student learning, but it provided less lag time in which misbehavior occurs.

My final insight with regard to classroom management is thoughts about control in the classroom, and these insights foreshadow the final major theme of elective education. As I will develop below, I believe the Williams students view school as an elective process and therefore are not internally motivated regarding school achievement. Their lack of internal motivation often causes their teachers to provide motivation through control:

> Discipline still was a problem. PJ had to yell at them to get them quiet. I don't know what the handle is with them to get them quiet and get them on track.

As mentioned above in my thoughts about lack of warmth, I developed a strategy of giving and removing bonus points as a way of maintaining control. My fears about losing control begin to affect my instructional decisions.

> I still want to go in a more active learning direction. But I'm scared of the classroom management end. Maybe I'm getting entrapped in my own low expectations.
>
> Making the transition to cooperative learning is something I'd like to do, but I don't really know how to do it. I want them to be thinking. I would have to have a very structured event first. I would have to think of structured tasks that they'd keep on task with. I know that I'd have to come up with—work with PJ in forming the groups because of the personality of LD kids and things like that.

The biggest problem with control is that it works in the short run, but tightly controlled kids don't usually make good learners.

Elective Education

The third major axis emerging from analysis I consider to be the core theme. This theme is elective education, which is a term I begin to employ to show that the Williams students viewed education as an elective. This view differed markedly from my middle-class belief that a good education was the foundation of a good future. Elective education creates barriers of certain teacher characteristics, barriers in the area of student learning, and barriers from student characteristics. I developed insights in this area of the causes of elective education, and strategies providing short- and long-term repair.

Barriers

The first barrier produced by elective education was certain teacher characteristics. Teacher characteristics originally emerged as a major axis entitled teacher beliefs. I expected to see this axis take on major importance, but now I view it more as a result of elective education rather than a primary cause. Elective education strongly impacts the teacher at the front of the classroom, producing fatigue, burn-out, and lowered expectations.

Day-to-day fatigue is one issue. I felt fatigued often, even though I was there only one day per week:

> I sure am tired....I've been doing all of the teaching and part of the class has just been catching up on their sleep....I'm exhausted, and they're rested.

PJ would be really tired often, especially due to the tremendous energy she would expend trying to reach kids who viewed the whole process as optional. The day I was there after her mother-in-law's death showed well the juxtaposition of that fatigue and the energy she could call on because of her commitment to the Williams students:

> She looked ripped; she was tired; it seemed like that she had had a lot of family calling and coming in. Her neck was hurting, too. She taught fifth period. I offered to help her but she taught, and as she taught during the class she got better and better as that energy level got going.

This kind of energy depletion day after day, year after year naturally could culminate in burn out, however. PJ seemed consistently to deal with this thoughts of burn out, as mentioned above in her constant battles with the Williams system administration for teaching supplies. I also saw her making choices that could have resulted from burn-out or even post burn-out. She would miss school at times for personal reasons that I hadn't seen teachers miss for before.

> She going to be out...Monday also because Monday is her birthday. She'd already planned to be out.

She seemed unwilling at times to try new things, although she usually was open to anything I suggested. Although she had been in her current room for months, she didn't feel settled enough to experiment.

> She said she has done some things in the past with groups, but hasn't done it since she got in her new room because she hasn't been settled.

I can't throw stones, however, because I felt the same fatigue from trying to teach kids who often didn't want to learn.

> After second period today...(I think I may be tired) but part of me wanted just pack it in. I was sick of it, I was sick of trying to teach kids that didn't want to learn anyway.

The teacher characteristic that troubles me the most was the lowered expectations I saw. In the light of the children's lack of motivation, this attitude is not surprising, however. PJ didn't seem to expect the students to learn at high levels.

> All of PJ's questions seem to be low level. There was some comparison and contrast but nothing very high

I will return to the issue of lowered expectations below.

Elective education also raises barriers with student learning. As mentioned previously, the students are not learning how to learn. This problem results in part from the way the educational system pressures teachers to focus on concrete activities. I begin to feel that pressure. I consistently felt pressured to make my learning activities very concrete. PJ modeled this use of concrete learning activities for me when she discovered how well the students responded to getting stamps on their classwork.

> The kids did vocabulary work, and PJ stamped them. During sixth period they brought their work to her desk and she stamped them.... Rather than check for content, she checked them for [effort], and then at the end of the day, she said she was going to stamp them if they had taken their notes, and I don't remember her doing that but...She said the kids responded to the stamping. I've never seen as many kids on task as I did on yesterday.

> Basically as far as the kids having notebooks out and writing in their notebooks, being attentive to what's going on—it was happening.

I found myself implementing some of these concrete tasks even though I was wary of lowering my expectations.

> Today one thing I learned was to give them something to write on, [and] they do fine. I'd go to the outline that PJ's passed out and start giving definitions [and they write them down]. Then they'd quieten down, but a lot of them would be writing.

In implementing hands-on science into the PJ's classroom, I hit barriers each time I pushed the students outside the realm of concrete tasks.

> Did the density lab. I developed the lab. The biggest mistake was that I tried to get the kids to do too much. They had a hard time reading instructions, reading and following instructions. They really didn't understand about reading instructions and recording data two pages over on a data chart. Simply reading and following instructions seemed to be hard.

Many of my experiences with attempting hands-on labs with the Williams students caused me to wonder about their previous school experiences, and I begin to think that their prior school experiences also raised barriers.

Many of the students advanced to Williams from Kelly Middle School, a school that was having significant problems with a lack of discipline and inadequate learning. When they got to Williams, the students didn't know school basics such as remaining in their assigned seats, raising their hands, or taking notes. In her first months with them PJ had to transition them into the disciplines of school, in much the same way I had observed the teacher of my kindergarten age son, Benjamin, transitioning students who had never been in school before.

> I did notice that...the kids had changed, and I realized that based on an analogy. When Benjamin started kindergarten I ... thought the classroom was a little bit out of control until about two months into it when I realized those children...hadn't been in school before and Benjamin's teacher was having to get them use to the school thing. Then it hit me in talking with PJ afterwards—kind of a lightning flash—these kids had been at Kelly, and Kelly is a zoo. And so PJ had had to go through probably through the same transition of teaching these kids how to do the schooling process.

My experience with Williams' feeder schools is limited, but the Williams staff often perceives that they can assume no prior knowledge when the students reach them in ninth grade. The students' prior experiences seem to be overwhelmingly those of low-level rote learning and a focus on disconnected knowledge bites, all of which to me fall seriously short of preparing students for economic success.

I even began to realize that the whole school system seemed to be pitted against these students, who are the very clients that the system is designed to serve. Sometimes, this realization would come after a particularly frustrating day of teaching.

> By the end of the day I was beginning to see the fact that there are kids who are bright. They do want to learn; their minds are there. But then the whole system is set-up against them.

The administration consistently made choices undermining classroom instruction. Often, they would announce spur-of-the-moment assemblies that would take some or all of the students out of one to three periods of class, and these surprises would wreck PJ's or my planning.

> They were on activity schedule all day. Second period came in after the assembly...and I had them for about thirty minutes. And then fourth and fifth. Sixth period came in for about fifty minutes, maybe forty-five minutes, but twenty minutes of that time went to a test that PJ was having to make up because Thursday of last week they called an assembly during second period, which put them a day behind. And then Friday was an in-service day, and they couldn't take the test then. And she didn't give the test on Monday because she didn't want to give the test after a weekend.

The central system office would also make decisions undercutting learning at Williams. Three weeks into the school year, the central office removed a math teaching unit from Williams, and moved the teacher in that unit to the system's science and math magnet school. The Williams students formerly in that teachers' classes were rescheduled into other teachers' classes, and many of these new classes had over 35 students. The central office also refused to supply some of Williams' science teachers' basic materials as I found out in a situation involving PJ's good friend at Williams, Mr. Matthews, the chemistry and physics teacher. His chalkboards are so old that they have lost their surface and any writing on them is illegible:

> PJ and I talked a little bit about how they can't get things. We were talking about Mr. Matthews's chalkboards....They have tried to get chalkboards. Mr. Matthews has tried, PJ has tried, Marcus Capps has tried, and they couldn't get them.

Imagine trying to teach the calculations of physics and chemistry without a chalkboard!

The final set of barriers arising from the elective education mentality at Williams was student characteristics. In general, the students were not motivated to engage or persist with learning. They were not interested in the subject matter.

> I'm not connecting with kids. Maybe two or three kids at the most of each class began to show an interest in the differences in heat and temperature.

Often, they were quite bored.

> I was teaching as hard [as I could] and teaching from my heart. And from what I know [by] sitting in the back of the classrooms, they were bored.

Their attention spans were short.

> I only taught half a period...which may have kept it may be one of the reasons why things went well. There wasn't a whole hour for students to get off task.

They became frustrated quickly.

> A lot of them, when they couldn't do it, they just shut out. They didn't ask questions. They didn't do anything. They just sat there.

Often, the students' behavior was very erratic.

> But it seems like one thing that I have to be conscious of is that the way that PJ has described the kids they can be very erratic. The kids can be pretty together, doing good work, and then come in and just have a really bonkers day. She uses the term "flippin' out." And they can just be out of control, and then the next day, they're okay again.

Sleeping was a consistent problem, and a very natural response to something that the students perceived to be irrelevant to them.

> Part of the class has just been catching up on their sleep...I'm exhausted, and they're rested.

> A couple of them went to sleep. Frederick went to sleep in the blink of eye. I mean one minute he was talking to me and listening, the next minute PJ was waking him up. I had noticed he was asleep, but I was going to leave him alone. And there he was and then -- I have heard of that happening. I just -- I never really noticed it before because he was answering questions and on task.

Absenteeism was also a problem. I mentioned above how I had to structure cooperative groups in order to spread out the students who were habitually absent. The students would even take the day off from school before holidays.

> PJ said something funny—talk about cultural differences: It's the last of school before Christmas. The kids go to school on Friday all day. But PJ openly asked kids whether they were going to be in school on Friday or Thursday. PJ said they took a couple of days off—one or two days off from school early for Christmas. And it's a given that many of them will do that.

She also gave me insight one day that the students don't expect to bear responsibility in the future. She told me

> First some of them are used to getting a hand out, and they have no sense of having to provide they're own way.

At times, I considered trying to give them some kind of extra reward, almost a bribe, to get them to engage as a way of overcoming their view of education as optional.

Another student characteristic that was a barrier was their unwillingness to team together. This was especially an issue since I was trying to implement cooperative learning. Some problems were due to poor gender interactions, possibly a hold-over from middle school.

> I found that some of the girls did not want to work with boys, [a fact] which surprised me for ninth graders. But I tried to have the groups as gender balanced as possible so that I would not have an all male group or an all female group.

Discipline issues created barriers to team work.

> The only criteria that I used in the groups of three was I kept the trouble making kids apart. By fifth period I separated the...separate groups even to separate parts of the room.
>
> I was careful in fifth period to not have the LD students in the same...group.

Part of the teamwork problem can be directly explained by elective education because I had nothing to cause them to work together. Johnson and Johnson (1987) require positive interdependence as one of their characteristics of true cooperative learning, and I have created such interdependence in the past through bonus points. At Williams, I never found a way to motivate them to work together.

> There was also the problem [that] it wasn't true cooperative learning...it was group work. There was nothing pushing them together as a group—a sink or swim mentality.

I consistently wrestled throughout my year at Williams with assessing the students' abilities to think. Many times, I would see almost no thinking going on. This struggle begin for me on my first day at Williams when I used some mental games as a way to pass the day while serving as an impromptus substitute.

> We did the science games that I did with my [suburban] high school students when I was teaching....My first impression was that the kids couldn't think. They just could follow the reasoning I was having to lead them through. And then two of the classes...I began to realize that they really could think once they realized what I was doing. Got me to thinking a lot about a study that I heard about Brazilian [children] candy sellers. These kids know how to think. They have to have thought. They've survived thus far on the streets in once sense of the word....Do they know how to bring their thinking from the streets, their thinking outside, into the schools. When will they learn how to think in school?

Throughout the year, I returned to this issue. Sometimes I would think I could see school thinking; many times I couldn't. I did leave the year with a strong sense that the students' minds are sound, but they simply do not know how to use their minds well in the school setting. I saw some students who were very bright, some who were not, and many of average ability. Some wanted to learn, some were antagonistic toward school, and many were ambivalent. In these areas, the Williams students paralleled my suburban students, but the Williams students had not been given the same opportunities for training their minds that my former students had.

<u>Insights</u>

I developed some notions of the <u>causes</u> of students' attitude that school is elective. Some of the students may see everything as elective.

> PJ said two things in two different settings. First some of [the students] are used to getting a hand out, and they have no sense of having to provide they're own way.

Lack of realization of the responsibilities associated with school, therefore, may be simply part of a bigger set of similar attitudes. Additionally, the school system and administration at times perpetuates the students' elective view of education by failing to uphold an strong learning environment through practices previously mentioned such as impromptus assemblies, removing teaching units, or failing to provide necessary supplies. These two ideas are related to a third possible cause, a general lack of accountability. PJ first started me thinking on this concept when she explained one facet of the students' home life.

> PJ said that you gotta understand these kids come from a single parent home. And most of them do have a mom or dad (I guess it would be mom) who is working hard, and there is no time for them to be involved in the kid's life and teach the kids. (I think PJ said, "Teach them to do the right thing," or she didn't [say] "right from wrong" but teach "them to do the right thing"). Because the kids don't really have that kind of...I don't know what it it. Moral influence? Or anybody to be over their shoulder making them do the work, I guess, or helping them to see that success in school will get success in life.

I began to see this lack of accountability perpetuated in the Williams classroom.

> I'd like to know about...the agenda set by the actual evaluation, what the kids have to know.

The answers I found to those questions were often discouraging. Tests at Williams consistently focused on low-level knowledge, and cheating was rampant. Evaluation did not hold the students accountable for learning; education was truly elective.

Fixing the problems associated with elective education requires short-term repair strategies, which are mainly coping strategies, and long-term repair strategies, which attack the true underlying problem. Short term repair helps teachers and students cope in the classroom until the system begins to change because of long-term repair. Short term repair can be accomplished through concrete expectations, control, and additional, short-term reward.

Concrete expectations match the students prior school experiences. I realized this repair strategy partially from PJ's mentoring.

> I think she's staying on the simplified level, I guess.
>
> She had the content written out on the board, and the kids were copying down the notes
>
> I ended up watching PJ teach her first class. It was straight [teach] through the chapter and [copy] down the notes.
>
> PJ had them doing the chapter objectives.
>
> The chapter objectives were like define energy, list and explain the five forms of energy,...mechanical heat,...kinetic versus potential energy.

I began to follow this concrete approach in my teaching at Williams.

> I kept things moving real fast, just like PJ did—kept the pace up; I talked through the material just like she did. I didn't bog down into details.
>
> I'd go back to the outline that PJ's passed out and start giving definitions.
>
> I do know that I need to...I need to be very clear on my instructions.
>
> Did the density lab. I developed the lab, [but] the biggest mistake was that I tried to get the kids to do too much.

Control is also a short-term repair strategy. The other Williams teachers, PJ, and I all developed different strategies for controlling students who didn't see the purpose of school. Disciplinary control strategies ranged from yelling to keeping trouble-makers separated to my bonus point system. We also employed instructional strategies for maintaining control such as teaching at a fast pace and employing teacher-centered lessons. As you may guess, these are truly short term strategies, and they did not produce an ideal classroom.

I also pondered a third type of short-term repair, the effectiveness of novel reward systems that would serve as stand-ins for the intrinsic learning rewards I was used to in suburban settings.

> I wonder if I ought to go with a reward system as in elementary school. The kids are still kinda giggley, they're ninth graders. I'd have to come up with some good rewards, but I wonder if I can do that.

I pondered this throughout the year, but never implemented anything because of fear of lack of administrative support. PJ tried her own short-term reward system through stamping, as mentioned above, and it had some modest success.

I saw several drawbacks to these short-term repair strategies, and these drawbacks caused me to look toward more effective long-term strategies. Observing PJ's fast pace made me wonder if actual learning was taking place, even though the pace keeps kids under control.

> She presents the material. I don't know whether the kids get it or not, but she presents it. And by "getting it" I should say I don't know whether they understand it or retain it, but she does present it.

A focus on the concrete never develops abstract thinking.

> I want to balance being very discreet with my instructions with also giving them some latitude, [some] pressure to think.

Control never created motivated learners. At best, it created passive learners. Short term rewards also didn't work at all times. Once, when PJ had to leave the room, I could not maintain control, even after repeatedly docking bonus points from students. They didn't seem to care.

> They were giggling and laughing. It made me wonder if the points were even meaningful to them.

Long-term repairs are needed.

My notions of what would provide <u>long-term repair</u> to elective education are just beginning to form, but I propose three now: the importance of active learning, the importance of relevant content, and the need for rea'' '' , high expectations. Inherent in the nature of elective education is student passivity. They see eason to engage, and this passivity can begin a cycle of withdrawal. Active learning may break that cycle. PJ was pleased with what I viewed as limited success with my implementation of cooperative learning. We both saw students engaging who typically were passive.

Mariqua, one of the Williams students, taught me the importance of active learning. Mariqua could go to sleep as fast as Frederick, mentioned above. I also assumed from her usual glaze that she wasn't very bright. Mariqua was a different girl, however, when we did hands-on science. One day in particular was memorable. I brought in batteries, wires, and DC bulbs for the students to do simple bulbs-and-batteries experiments such as making the light bulb light in an inquiry fashion. Mariqua came alive! She stayed awake and focused on the lab throughout the part of class allotted for the lab, and when I asked the students to return to their desks to work out of the texts, she wouldn't leave her equipment! She had constructed a complex simple-parallel circuit and could explain how it worked. I realized that she was a bright, but kinetic learner. Seatwork disempowered her learning.

Applicable content also engages the students and may provide long-term repair. They need to work with content that they see as directly relevant to their lives.

> We were teaching on light: reflection, refraction, opaques, transparent, and color. And color kind of whipped them, Michael especially in sixth period. He was the one that started the question....I think I got him when I had on a bright red shirt today, and I said, "what color is my shirt?" And "Why is it

> red?" And "It was red because it absorbed all colors and reflected only red." Well, that really got Michael, and he kept on asking questions and pretty soon several of the guys were interested and were listening.

The discussion of color, since it was a part of the boys' lives, was something they engaged with.

The most powerful repair I see lies with the teacher's expectations, however. Pierce, the second author, tipped me off to this through her emphasis on how teachers get what they expect in the classroom, as Brookhart and Rusnak (1993) also indicate. A whole other paper is necessary to completely discuss this repair, but briefly here I'll discuss my final realization about the power of expectations. Urban teachers must recognize the realities of their students' past and match their students' needs through concrete learning and controlled environment, but they must also recognize the realities of the demands of the future on their students and hold high expectations. They must expect their students to think critically at high levels and learn deeply the knowledge and skills required by society. Otherwise, they will disempower their students.

Looking Forward

Our purpose in this paper was to lay out the most pertinent of Meadows's analysis and data as a way of opening up discussion about effective science teaching and learning in the inner city. Science education in the inner-city has daunting challenges. We saw classrooms without textbooks and bureaucratic hurdles concerning maintenance of supplies and updating equipment. Inner-city students have experienced science chiefly as words on the page rather than a process or as a body of knowledge relevant to their lives. Their passivity consistently raised high barriers to hands-on science in a collaborative environment.

The chief task ahead of us is translating our experiences at Williams into effective teacher education practice, but this effort is glacially slow. We face the barriers of the status quo and tradition at our home university and the tremendous challenge of adding the complexities of the inner-city to the already complex training of the preservice teacher. Ours are fledgling efforts. We welcome input from other teacher educators, especially those who have had similar experience or those who share our goal of preparing effectively teachers for the inner-city. Moving the goal of science for all Americans from rhetoric to reality will take a combined effort of a large group of teacher educators.

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Engineering Physics for Teachers: A Project Based Integrated Science Course

Bill Baird, Auburn University
Ralph Zee, Auburn University

Abstract

Auburn University has refined and implemented a new course to introduce upper division undergraduates to energy conversion principles and materials science for the 21st century. "Engineering Physics for Teachers" fulfills a three credit hour requirement in physical science for undergraduates, most of whom will become certified teachers of physics, chemistry, or general science in grades 7-12. Combining the disciplines of engineering and science education, it insures that science teachers solve real problems and use data collection devices that assess energy transfer in the home and automobile. A major team project applies concepts learned in the classroom to an open-ended problem. Two faculty members with high school experience have joined forces to teach this course – one from engineering and one from secondary education.

The course addresses a need to integrate science content, teaching methods, and state-of-the-art technology in an interdisciplinary approach to teacher preparation and classroom science instruction. Among the topics featured in the course are : (1) sources and types of energy; (2) energy conversion processes and laws; (3) energy transfer through conduction, convection and radiation; (4) efficiencies of common processes of conversion; (5) home electrical energy systems; (6) automotive energy processes; and (7) solar and battery powered automobiles. Expected outcomes are teachers who understand energy conversion processes, are able to work effectively on a sustained science project, know what their data imply and what it does not imply, and can explain current energy conversion technology in the designed world.

Preservice teachers in this course work together on cooperative team projects that require sustained effort to reach a conclusion, and then produce an oral and written summary report. These projects are shared with others in the class. We hope to refine the course for distance education in the region and beyond through electronic, video and print media. Regional

dissemination will be extended through an existing science van program and inservice centers that provide continuing education for teachers. We are seeking funding from NSF and other sources to extend this course beyond our campus.

Introduction

Traditional undergraduate physics university courses are taught to large classes, and have objectives addressing a variety of academic majors. They tend to be "survey courses", meaning that they cover a lot of physics themes without references to current technical applications of these concepts in the world outside the classroom. Class size restricts student participation in discussions of the everyday implications of physics. Laboratory experiences tend to confirm principles discussed in lecture. Lab reports are usually graded by teaching assistants, who use templates with specific "right" answers that are already known. The end result of this approach is the promotion of an expository style of teaching that is in direct conflict with teaching methods recommended in recent national guidelines (National Research Council, 1995; Glass, Aiuto & Andersen, 1993).

To improve the science content preparation of physics teachers, Auburn University has created a new course designed to introduce upper division education undergraduates to applied science and engineering for the 21st century. "Engineering Physics for Teachers" is for juniors and seniors in secondary and middle school science education who will become certified to teach physical science in grades 7 - 12. Prerequisites are university physics through the end of the introductory sophomore sequence. This three credit hour course partially fulfills the requirements for physics in the general science certification program. The course is jointly taught by a faculty member from the College of Engineering and a science educator from the College of Education. MTL 501 meets for ninety minutes twice each week for ten weeks, since Auburn is still on the quarter system. Auourn University is planning to change to the semester system, which will expand the time allowed for this course and provide for expanding the content.

Objectives

The five primary objectives of the new course are:

1) To provide pre-service teachers with information on state-of-the-art technologies so they can bring visible products of science into their classrooms. Special emphasis on the applications of physics and engineering knowledge to develop innovative systems for the 21st century.
2) To integrate physics, chemistry, mathematics and engineering with methods of teaching at the pre-university level.
3) To enhance the interest of teachers in science through interactive demonstrations of modern engineering concepts.
4) To provide current technology and teaching methods for preservice teachers.
5) To help teachers produce a set of resource materials for classroom use.

Instructors

The two instructors (the authors) are currently involved in promoting science and technology in the public schools. Dr. Bill Baird, Associate Professor in the College of Education, is certified as a secondary physical science teacher in two states, and has directed funded inservice teacher education programs for five years at Auburn. Dr. Baird's undergraduate experience began with three years of engineering preparation, including three quarters of co-op work experience in industry. He taught high school physics and chemistry for eleven years. Dr. Ralph Zee, Professor in Materials Engineering, has visited over 60 Alabama elementary and secondary schools in the past three years with his popular "Miracles of Materials." This stage program is designed to illustrate materials technologies for the 21st century. During the summer Dr. Zee hosts a one-week materials education workshop for high school teachers and their students, with NSF/ESPCoR support. This summer workshop emphasizes an inquiry approach where answers to locally relevant scientific questions are not known. Participants develop innovative ideas to solve real engineering problems. Drs. Baird and Zee collaborate regularly in grant writing and teaching.

Through their contacts with high school teachers and students, Drs. Baird and Zee have identified a need to integrate modern engineering with teaching methods for middle and high school. Future science teachers need experiences with physical science situations and a feel for scientific problem solving approaches. The authors believe that teachers who have experienced laboratory-based science and confronted real questions about energy and new technologies will become excited about science themselves and thus ignite the interest of their own students in engineering and the sciences. To achieve this goal two departments joined in developing and teaching this interdepartmental course for teachers.

Course design

One of the guiding principles in designing the course was to provide teachers with ideas for teaching physical science in ways that integrate physics, applied mathematics, and technology using readily available materials. The home and the automobile were selected as focal points for a study of engineering principles that should interest all learners. Energy sources and processes were chosen as a central theme for the course since these topics include a wide variety of physics and engineering principles. The first two class meetings introduce basic energy concepts, the First Law of Thermodynamics, some simple energy concepts, and energy conversion. The following six class meetings deal with home energy loss and uses — thermal energy loss by conduction, radiation, and convection, followed by descriptions of electricity uses in the home. After a midterm exam which counted 20% of the course grade, the course turns to the automobile as an energy conversion device — fuel sources, energy capacity, main components of the car, and future possibilities for more fuel efficient transportation. Group projects are assigned at mid-term, and help is available to each team as they begin to define their problem and analyze data. Appendix A contains a partial syllabus of the course.

Each of the 20 class meetings includes class demonstrations of physics and energy principles. Numerical problems are presented and solved by both instructors and the class. A problem set is assigned for the next class meeting, which begins with the solution of assigned problems. Appendix B presents sample problems from these homework sets, which counted 20% of total course grade. Demonstrations are done with materials that are safe and widely available to pre-college teachers. The class is run interactively, and participation counts as 5% of course grade. The five steps of the BSCS learning cycle — engage, explore, explain, elaborate, and evaluate — are used to insure that students construct their own meaning around the principles introduced.

A highlight of the course is the opportunity for students to work in three-member teams on a project that deals with one of the features of the course. Equipment is checked out from the graduate engineering research laboratories. Typical materials and equipment needed include infrared film, strip-chart recorders, remote sensing devices, photo-voltaic arrays, digital multimeters, etc. Both instructors meet with each team and assist in defining the scope of this four-week study. Projects (see Appendix C) are assigned to each team, whose membership is selected by the instructors. However, the team is responsible for determining appropriate procedures, obtaining and learning to use necessary data collection equipment, monitoring ongoing experiments, analyzing all data, and writing the report. Each team makes a 40-minute oral presentation of the project, including results and conclusions. The combined written and oral report is worth 25% of the course grade.

A final examination consists of six problems similar to those assigned as homework, and addressing each major theme of the course. Appendix D provides sample problems from the most recent exam. Results of the exam indicate that most of the ten students who took this course for the first time in the Spring of 1995 had mastered the content and numerical methods well enough to score well on the final exam, which counted 30% of the final course grade.

Featured topics of the course

Energy generation and transmission The first section of the course describes energy conversions involving fossil, hydroelectric, nuclear, and alternative energy sources for electrical energy. We demonstrate the relative efficiency of energy conversions with simple thermodynamic reference points using a desk-top steam engine, and loss of energy in transmission from point of generation to final conversion point. We examine primary types of energy end uses in the U.S. and the world, and the relationship between GNP and per capita energy consumption among developed and underdeveloped nations with implications for national security and long-term economic stability. This raises Science-Technology-Society issues related to laws of thermodynamics and international market forces. Transmission efficiency is compared using tungsten, copper and aluminum wires. Liquid nitrogen baths are used to demonstrate the effect of temperature on transmission efficiency and superconductors, along with the potential of superconductivity for future energy savings.

Energy uses and conservation After energy conversion the course examines the potential for "recovery" of energy through conservation strategies in the home, neighborhood, city, state, and nation. We work problems involving energy transfer through walls of a closed system, and how this may be controlled by adding insulation and storm windows. We discuss R-values, E-values of appliances and their meaning. We study augmented energy systems such as pre-heating water with solar collectors, heat pumps, solar greenhouses, etc. We examine energy audits and cost-benefit implications for homeowners considering retrofit improvements to R-values of wall and ceiling insulation, storm windows, caulking, and more efficient central heating systems. We work problems involving degree days and their effect on total electrical energy demand within the Tennessee Valley. We present infrared photography as a way of performing an "instant home energy audit." We calculate the estimated lifetime energy costs of various home and school appliances. We test the performance of solar cells (silicon vs. GaAs) of different conversion efficiencies, and visit the *Sol of Auburn* solar powered car that placed in national competition. Students obtain design specifications and write a report describing the battery system and solar array used to power the drive train, suggesting changes that could improve the car's performance.

Summary and Student Comments

Results from the first cycle of teaching "Engineering Physics for Teachers" indicate that students have achieved many of the objectives established for the course. Student comments were generally positive. Typical positive comments were

> "The content of this course has practical application of theory, a first for college. Keep up the good work."
>
> "The experiments were very helpful. I like seeing them done during the lesson."
>
> "I appreciate and learn better from all the visual demonstrations."
>
> "I find the lectures interesting and informative. Also, with two different instructors the class able [sic] to get different views of difficult concepts. I find this very helpful.

Students also suggested several changes to improve the course. The readings packet was criticized as being too long and not well related to class lectures and demonstrations. Working problems in class was considered quite helpful, but students wanted this to be done more slowly and carefully without leaving out steps in problem solution. Students wanted more time to work on their projects. They also suggested better general organization, and closer correlation of the syllabus with daily activities. Each of these suggestions is being incorporated into the plans for teaching the course for the second time during the Spring of 1996.

The authors invite comments and suggestions from those with experience developing content science courses for teachers. We are eager to learn of similar efforts to improve the preparation of teachers for integrated science such as work reported by Davis and others (1988). New initiatives such as TechPrep™ and Applied Biology/Chemistry™ will require teachers who are experienced in non-traditional approaches to science instruction and ready to solve problems taken from outside the textbook. Students too deserve better instruction in practical applications of science.

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Appendix A – Partial Syllabus

The complete syllabus includes details of each week's lesson and demonstrations used to illustrate physics and engineering concepts. Consisting of 268 pages, it was reproduced as a course packet by the university bookstore, and purchased in lieu of a textbook for the course. The partial syllabus below contains the basic structure of the course, objectives, and grading criteria.

MTL 501 – Engineering Physics for Teachers – 3 credits
Prerequisites : PH 207 or CH 207

Instructors : Ralph Zee, Materials Engineering – Bill Baird, Curriculum & Teaching

Ralph Zee, Materials Engineering Office : 201 Wilmouth Hall Office Phone : 844-3320
Office Hours : Tues. afternoons and by appointment FAX : 844-3400

Bill Baird, Curriculum & Teaching Office : 5016 Haley Center Office Phone : 844-6799
Office Hours : 8-11 a.m. Monday; 1:30-4:30 p.m. Wednesday Home Phone : 821-4448

Text : course packet available in AU Bookstore

Course Description

This course combines lectures with hands-on experiences. We will discuss materials already created and others under development for the 21st century with implications for science teaching in grades seven through twelve. Current career opportunities in engineering and materials science will be featured, along with each topic area : manufacturing; testing; metallic, ceramic and polymeric systems; optical materials; electrical/electronic materials; energy generation, storage, and transmission; energy utilization and conservation; and recycling. You will join a team to undertake a laboratory project involving one or more of these areas.

Basic structure of course

- The theme is energy and materials. Physical concepts of energy and materials will be introduced and discussed in terms of two most expensive investments we (Americans) make: HOME AND AUTO. Emphasis is on energy and its relationship to materials selection and properties.
- Structure of each lesson: Each lesson (1.5 hour) will begin with review assigned problems and previous class concept; return graded problems; take up problems assigned from last class meeting.
- Introduce new concept with engagement questions
- Explore new concept with possible implications and hands-on examples
- Explain concept with mathematical treatment
- Elaborate on concept and perform demonstrations with more examples
- Evaluate our understanding by working a problem to illustrate an application
- Discussion of what we have learned today – small group practice
- Assignment of problem set for next class meeting

Grades

Evaluation of course work:

•Attendance and class participation 5 %
•Problems assigned at each class meeting 20 %
•Project work completed in teams of three 25 %
•Mid-term exam to be taken in class (1 hour) 20 %
•Final exam (1.5 - 2 hours) 30 %

All homework must be on time. No late homework accepted.
If you are going to miss an examination you must notify us before the exam.
At a minimum the following numerical grading scale will be used.
90-100:A, 80-89:B, 70-79:C, 60-69:D, below 60:F

Class attendance is expected for all class meetings.

Instructor and Course Evaluation
The course and instructor will be evaluated by the entire class during the last class meeting.

Course Objectives

When you finish this course you should be able to :

1. Demonstrate competence in using the methods of science and scientific inquiry
2. Describe some of the ethical, technological, and environmental implications of physics
3. Describe key historical developments in energy applications of physics and their origins
4. Demonstrate knowledge of energy and matter, motion, mechanics, sound, light, heat, and electricity
5. Demonstrate knowledge of the role and implications of physics in daily life
6. Demonstrate an ability to investigate scientific phenomena, interpret the findings, and communicate them to others
7. Demonstrate an ability to apply scientific processes to the solution of problems encountered in daily activities

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Course Outline

Meeting 1	Introduction, basic energy concepts, and first law.
Meeting 2	Basic energy concepts and energy conversion
Meeting 3	HOME, thermal energy loss (heat conduction)
Meeting 4	HOME, thermal energy loss (radiation)
Meeting 5	HOME, thermal energy loss (convection)
Meeting 6	HOME, electricity use (electrical resistance and resistivity)
Meeting 7	HOME, electricity use (power and energy conservation and conversion)
Meeting 8	HOME. construction (mechanical structure for insulation)
Meeting 9	Midterm
Meeting 10	Review. Project assignments.
Meeting 12	AUTO, forms of energy sources for cars.
Meeting 13	AUTO, comparison of energy capacity.
Meeting 14	AUTO, main components of a car and its energy relationship

Meeting 15	AUTO, compare the impact energy absorption of different materials
Meeting 16	AUTO, compare the corrosion & temperature response of different materials
Meeting 17	AUTO, recycling of automobile parts
Meeting 18	Project presentations
Meeting 19	Project presentations
Meeting 20	Review and class discussion

Laboratory

Laboratory activities are integrated into class meetings, some of which will be held in research laboratories of the Materials Engineering Building. Each of these sessions will provide hands-on opportunities for students to use equipment designed to obtain data on issues we are dealing with that week.

Bibliography {reference materials not in course packet are on reserve in the LRC}

Appendix B – Sample Assigned Problems

At the end of each class meeting a problem was assigned for completion before the next class. These problems were designed to exercise students' conceptual understanding of physics principles discussed and demonstrated in class, and to provide both instructors and students with feedback on computational ability. Each problem was worked at the beginning of the following class. Grading was done by a graduate engineering student. These problems counted 20% of the final course grade.

Sample automobile problem. (From page 140 of the course packet.) According to the World Almanac, the mileage traveled by over 107 million passenger cars registered in the U.S. in 1975 was estimated to be 1.03×10^{12} miles. The population of the U.S. that year was 213 million souls. The energy content of one gallon of regular gasoline is equal to 1.25×10^{5} Btu. The average car in 1975 obtained 14 miles per gallon of gas consumed. The energy equivalent of one human being working full time at full output is 193 Btu per day. Calculate the average human energy equivalent to our per capita consumption of gasoline for use in passenger cars.

Miles per person per day =

Gallons per person per day =

Energy (Btu) per person per day =

Human equivalents per person =

Week #5 **Assigned problems.** Due on May 11th.

According to the chart on page 220 of the course packet, the relative energy cost per passenger-mile of various modes of urban transportation are as follows:

Mode of transportation	Btu per passenger mile	Total percent of U. S. transportation demand in 1980
Airplane	7,150	9.3
Automobile	5,400	88.4
Train	2,620	0.7
Bus	1,700	1.2
Walking (3 mph)	524	less than 0.1
Bicycle (8 mph)	310	less than 0.1

(1) The thermal efficiency of a typical automobile engine is 29%, meaning that for every 100 Btu of energy input to the engine 71 Btu is lost (out the exhaust, radiator, etc.) as waste heat. The mechanical efficiency of the engine is typically around 71%, meaning that the moving parts lose about 29% of the input energy due to friction and other energy conversion "costs". The rolling efficiency of automobile drive trains is around 30%, meaning that after the carburetor and combustion chamber (thermal conversion), the piston and cam shaft (mechanical conversion), the transmission and tires lose 70% of the energy they receive. (a) What is the overall efficiency of the car in converting gasoline into motion? (b) If a gallon of gas represents about 125,000 Btu of energy, how much energy is wasted from each 10 gallon tank-full we use? (c) There are 125 million registered automobiles in the U. S. Each is driven about 10,000 miles per year at a fuel efficiency of about 12 miles per gallon. Calculate the Btu's of heat energy "wasted" per year in the U.S. through automobile use. Could this help explain global warming?

(2) Assume that in the same year the above figures were valid that the U.S. public traveled a total of 1.2×10^9 passenger miles. Assume that the Btu content of regular gasoline for automobiles is 1.25×10^5.Btu/gal (a) How many gallons of gasoline were used in 1980 for automobiles in the U.S.? (b) What was the average fuel efficiency in miles per gallon for this fleet? Does this figure seem realistic to you?

Household Problem : Determining Heat Loss Through a Wall

Objectives : At the completion of this activity you should be able to :

1) calculate the heat loss through the walls of a building or apartment:

2) know the typical components of which a wall is constructed

3) realize the purpose of an insulating fill used inside the walls of buildings.

Skills needed:

1) how to measure the thickness of a wall;

2) how to use the basic heat conduction equation to determine heat loss through a wall.

Time: three lessons, or about 170 minutes

Grade level : high school, 11th or 12th

Subject : applied physics

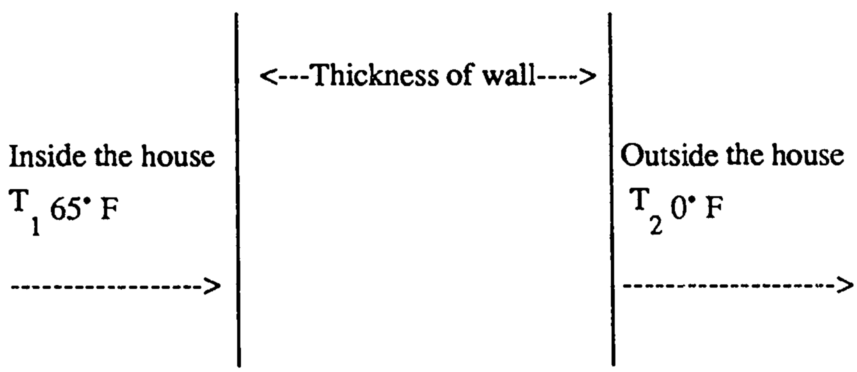
Materials : ruler, prepared worksheet

Lesson #1 procedure :

1) Teacher has on hand a display of common materials used in wall construction.

2) Teacher asks class to list some purposes of walls in houses. Expect answers like "to hold up the roof", "keep out the wind and rain", "keep out the cold", etc. When someone answers with insulation, invite them to help list some of the factors that would need to be considered in determining how much heat would be lost through a wall. Write these on the chalkboard as students list them.

3) Teacher demonstrates with a diagram how heat is conducted from the inside of a house to the outside through a wall. Remind students that heat always flows from a warmer body to a colder body by the Second Law of Thermodynamics.



Heat conduction equation

$$Q = \frac{K A (T_1 - T_2)}{\quad}$$

Thickness of wall

$R = t / K =$ **thickness / thermal conductivity**

$T_1 - T_2 = \Delta T$

Thermal conductivities (K) are listed in the CRC Handbook of Chemistry and Physics. Examples:

Material	Thickness (t)	K (BTU / hr - ft^2 °F / inch)
Face brick	4 inches	9.2
Common brick	4 inches	5.0
Fiber board	3/4 inches	0.34
Glass	1/8 inches	9.04
Gypsum lath	3/8 inches	3.3
Plaster	1/2 inches	8.0

4) Now do a problem on the board. Given data:

wall dimensions : 10 feet by 30 feet; window dimensions : 30 square feet; temperature inside: 65 degrees F; temperature outside : zero degrees F. The wall consists of 3.0 inch face brick, 4.0 inch common brick, and 3/8 inch fiber board. The glass is 1/8 inch thick. Calculate the heat loss through the wall and heat loss through the windows. Total both.

For composite wall the R-values are additive:

Face brick : R = 3.0 / 9.2; = .33 ft^2–hr °F / BTU

Common brick: R = 4.0 / 5.0 = .80 ft^2–hr °F / BTU

Fiber board : R = 3/8 / 0.34 = 1.1 ft^2–hr °F / BTU

R Total = 2.23 ft^2–hr °F / BTU

For glass R = 0.125 / 9.04 = 0.014 ft^2–hr °F / BTU

Subtract area of window from area of wall.

Qwall = A delta T / R = (10 ft. X 30 ft - 30) 65 /2.23

= 7830 BTU / hr

Alabama Power Co. Electric bills for Bill Baird's house in Auburn, AL - 1994

Month	Previous (kw-hr)	Current (kw-hr)	Energy Used (kw-hr)	Charge

Jan.	0802	1376		$44.59
Feb.	1376	1745		31.15

{monthly data are provided for the remainder of the year}

Alabama Gas Co. bills for Bill Baird's house in Auburn, AL - 1994

Month	Previous (x100 cu.ft.)	Current (x100 cu.ft.)	Energy Used (x100 cu.ft.)	Charge
Jan.	5608	5703		$69.49

{monthly data are provided for the remainder of the year}

Using the information provided on Bill Baird's home electric and gas bills for 1994, answer the following questions.

1) Determine and then graph the monthly electric consumption in kW-hr for the year.
   a) Write a one-sentence explanation that you believe explains the graph you drew.
   b) What is the average cost of electricity in $ per kW-hr for residential customers of Alabama Power Co.? If the use fell to zero, would the monthly bill be $0.00?
   c) What is the annual cost of electricity in this house of 2400 square feet?

2) Determine and then graph the monthly gas consumption in 100's of cu. ft..
   a) Write a one-sentence explanation that you believe explains the graph you drew.
   b) What is the average cost of gas in $ per 100 cu.ft. for residential customers of Alabama Gas Co.? If the use fell to zero, would the monthly bill be $0.00?
   c) What is the annual cost of gas in this house which heats its water with gas?

3) Does this house heat its living space with gas or electricity?

4) Does this house cool its living space with gas or electricity?

Appendix C – Final Project Assignments

Students were assigned to work in teams of four on projects that required their investigation of a technical problem that applied concepts learned in the course. Equipment was provided by the College of Engineering, and students had access to graduate laboratory data monitoring devices. The project timelines of about two weeks involved library work, construction of model devices, data collection and analysis, and writing of a final report. Each team presented to the class an oral summary of their study and results. Grading was based on both this oral presentation and the written report. Each team was presented with a description of the overall project objectives and a specific description of their project parameters as shown below.

Final Projects – Spring 1995

The final project is designed to challenge you to apply some of the science and engineering principles we have studied in this class. You will work with two or three others to study a problem and reach a conclusion supported by your own data. The descriptions below are intended to "draw a circle around the problem", not to fully delineate all the details. Thus, you must examine the problem statement carefully, consult with your partners, seek clarification where it is needed, and ask for any equipment you cannot locate yourselves. Of the 100 possible points for each problem, 60 will be awarded for simply doing what is specified in the written description below. The remaining 40 percent will be awarded for "creative sciencing", defined as applying your best means of solving the problem using ingenuity and common sense. There are no right answers in the back of the book. We do not even know the answers. But there are good answers! Your job is to find them, test them, and document them in your report. Your grade will be based on both the written report and the oral presentation {@ 50 points each}. For each part of the project, up to 30 points are awarded for solving the stated problem conditions, and up to 20 points for "creative solutions." All team members must take part in the entire process of library research, construction, testing, and graphing results. All project managers must sign the cover sheet of the report stating that you either have contributed equally to the final product or declaring your actual contribution. Project reports are due on Tuesday and Thursday, May 23rd and 25th. Your team would be wise to begin work at once and allow plenty of time for the natural frustrations that are an inevitable part of applied science.

Keep the heat

Project managers : <<students were assigned to each project team by ability and interest>>

Build a house with a single room of 2,000 sq. cm. floor space or less. Wall space must be about 1,200 sq. cm., with 15% of this used for windows. Wall thickness must be less than or equal to 1.0 cm. Use shingles for roof covering. Use a single type of wall insulation. Use plastic wrap for windows. Heat your house with a single 40-watt heat source, placed in the center of the house and not contacting any wall or floor. Monitor the inside and outside air temperatures over a 24-hour day, and calculate heat loss through the walls, windows, and ceiling (attic). Your house must occupy a foundation in Haley 2462 during the "winter" season, but the object is to keep the maximum amount of heat inside the living space. Temperature difference between inside and outside must be equal to or greater than 10 deg. Celsius. Building materials should be cardboard, fiberglass, plastic wrap, and fiberglass shingles.

Your final report must describe the building construction, energy input and loss, three cycles of 24 hour temperatures, and recommendations for next design based on your findings. Include information on home energy conservation of space heating. Include at least eight infrared photos taken of your building with the internal heat source "on" but all room lights off. [We will provide camera and infrared film.] Where was heat escaping most rapidly?

Solar photo voltaic array panel

Project managers : <<students were assigned to each project team by ability and interest>>

Monitor a photo-voltaic panel over three 24-hour cycles. You are to determine using a light meter how much solar radiant energy strikes the panel. You will simultaneously monitor the energy and power output from the solar array. Produce graphs that link the energy input and energy output. Calculate the overall efficiency of the panel for producing electricity. Correlate power output with local conditions over each 24-hour cycle. Recommend uses for this energy conversion device. What are its limitations?

Your final report must provide graphical evidence for the potential uses you recommend for solar energy conversion to electricity. Why is this the preferred choice for energy conversion in deep space probes? Using the data from monthly statements, how large would this type of panel need to be to supply the electrical needs of Bill Baird's house in Auburn? Your report must also include information about solar photo-voltaic energy conversions that come from your own group's library investigation of this topic.

How many ways can I heat water?

Project managers : <<students were assigned to each project team by ability and interest>>

You are to compare two traditional methods of heating water – electric resistance coil and a second, non-electric method. Use a simple, 120-volt immersion coil heater to heat 1000 cu. cm. of water from 20 deg. Celsius to 50 deg. Celsius. Calculate the efficiency of this operation. Do this three times and take the average of your efficiency calculations to be more sure of your answer. Now repeat the heating of 1000 cu.cm. of water through any temperature change, but your only source of heat must be non-electric. Again calculate the overall efficiency. You may use any second method of heating, but you must explain where heat is going, and account for differences in measured efficiencies. Repeat this process three times and take the average of your efficiency results. Compare both the energy input and output to produce the specified temperature changes using each energy source.

Your final report must contain all collected data for all trials. Display this in tables and show all efficiency calculations. Explain how you controlled for error of heat losses. Recommend in your report the "best" way to heat water for your bathroom based on (a) economy, (b) availability, and (c) wise use of resources. Do some reading and use common sense. Explain your recommendations.

Appendix D -- Sample Questions from Final Exam

The final exam accounted for 30% of the total course grade, and contained six problems similar to the two examples shown below. Students were permitted to use calculators, and were provided with constants and conversion factors. No other resources were allowed.

Example 1. I live in a very remote area where I have no city water. I have a well for my water supply. I use an electric motor to operate the well pump and a solar photovoltaic panel to generate the electricity for the motor. The pump is rated at 2 HP (needs 2 HP of electricity) and is 100% efficient. My solar cells are 10% efficient and provide sufficient power to operate the pump when the power density of the sun is at 500 W/m^2.

(a) What is the size of my solar panel in m^2 ?

(b) If my pump runs at 120V, how much current does it need?

(c) If my pump is 100% efficient in pumping water and my well is 100 m deep, how many kilograms of water can it pump in 1 hour? (Hint: The potential energy of any substance is related to mgh - mass times gravitational constant times height.)

Example 2. I recently bought an electric car (powered solely by battery) from Chrysler. It has a single battery at 100 V and it is rated at 50 A-h. According to Chrysler, the range of the vehicle is 120 miles if it is driven at a constant speed of 30 mph (miles per hour).

(a) How much energy is stored in the battery?

(b) What is the power of the motor (in units of Watts) when it is driven at 30 mph?

(c) Unfortunately I have a slow leak (or drain) in the electrical circuit. The current leak (or drain) is exactly 1 Ampere at all times. If I fully discharge the battery and then unplug and park it somewhere, how long does it take to completely drain my battery?

(d) The slow electrical leak (or drain of 1 Ampere mentioned in part C above) occurs when the car is turned off as well as during operation. What is the new range (in miles) of my electric car when driven at 30 mph?

INCORPORATING COMPUTER SPREADSHEETS INTO THE ROBERT KARPLUS LEARNING CYCLE

Paul B. Otto, University of South Dakota

An NSF Spreadsheet Physics Project

In 1992, the University of South Dakota was awarded a NSF Teacher Enhancement Grant for a project, Spreadsheet Applications in the Instruction of High School Physics. Twenty physics teachers from South Dakota and the states of Nebraska, Iowa, and Minnesota within a 150 mile radius of the University of South Dakota were invited to attend a summer institute on the University of South Dakota campus during the summers of 1992 and 1994. Follow-up meetings and Internet accessibility were available to the participants during the academic year.

During the summer institutes, the participants were involved in the development of spreadsheet templates, physics background enhancement, and the incorporation of pedagogy. Time was also spent on instructional design.

The model encouraged for the development of spreadsheet templates was the Robert Karplus Learning Cycle based on the tenets of Jean Piaget's developmental psychology. All participants were encouraged to adapt their spreadsheet templates to the Karplus Learning Cycle.

Teaching with the Learning Cycle

The Learning Cycle consists sequentially of an Exploration Phase, a Concept Introduction Phase, and a Concept Application Phase. The Exploration Phase provides individual time for the students to "set" their minds to the ensuing Concept Introduction phase. An important aspect of the "constructivist" model for learning is to allow students to make connections with their existing experiential background and areas of interest in order to challenge their minds. The Exploration Phase fills this bill quite well.

Concept Introduction involves teacher interaction with the students. This phase can allow the teacher opportunity to do the more conventional types of operations such as discussion, text book introduction and integration, and student questioning.

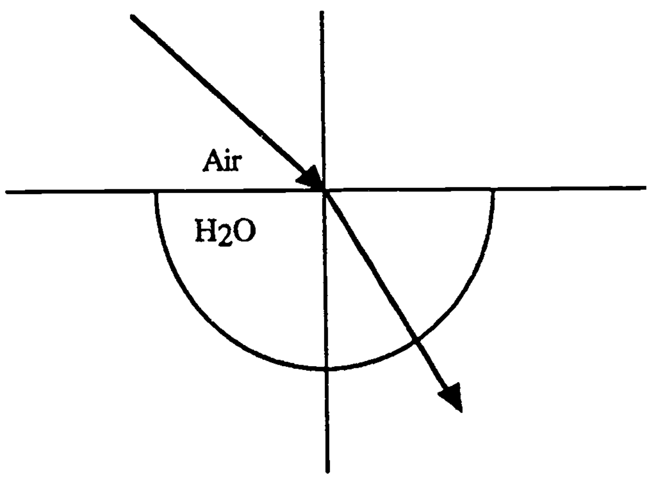
Students are given opportunity to practice and consolidate during the Concept Application

Phase. Typically, this is the part that is overlooked in conventional non-constructivist teaching. Students are exposed to material, usually through reading and/or exhortation, by the teacher who acts from a position of authority and as a purveyor of information. The next exercise is the test, without any opportunity for practice, application, or consolidation. Following the test, new material is presented and the sequence repeats itself. The Learning Cycle provides the "set" through exploration, the introduction of new material through the Concept Introduction, and concept consolidation and practice through the Concept Application Phase. Thus, it is imperative that the sequence takes place in the indicated order. To change the sequence is to nullify the Learning Cycle.

Use of Spreadsheets in the Learning Cycle

An excellent example of the utilization of spreadsheets in applying the Learning Cycle is demonstrated with the Snell's Law module developed during the spreadsheet project. The

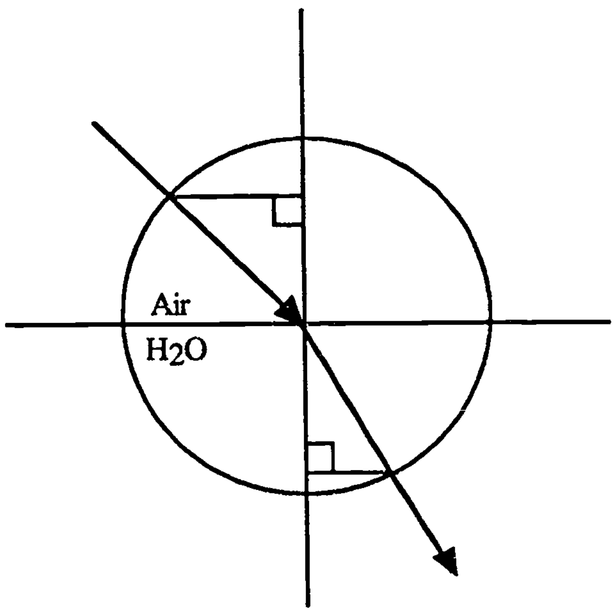
Figure 1
Semi-Circular Dish



Exploration Phase involves examining the path of light through a semicircular transparent plastic dish filled with water at different angles to the normal which are incident to the flat surface of the dish. After sketching the path of light on graph paper, the students quickly discover that the light is bent toward the normal.

In working through the second part of the module, Concept Introduction, the students sketch a circle around the outline of the plastic dish and construct semi-chords to the normal for each incident ray and each corresponding refracted ray. The identification of similar triangles leads them to observe that the ratio of semi-chords formed for the angle of incidence to the respective angle of refraction is a constant for relatively small angles.

Figure 2
Semi-Chords



Because the right triangles formed share a common hypotenuse (the radius of the circle), the two triangles are similar. With the realization that the triangles are similar, the students can easily make the transition from the ratio of semi-chords to the ratio of sines of the angles of incidence to the angles of refraction. The net result leads to the formulation of the equation

$$n_i \text{Sin } \O_i = n_r \text{Sin } \O_r$$

which is the law of refraction known as Snell's Law.

The Concept Application phase is supplied through the use of the student interaction with the spreadsheet developed on the basis of Snell's Law. Incorporated into the spreadsheet is a graphic of an incoming light ray incident upon the boundary of two transparent materials and a corresponding refracted ray. Through the use of the spreadsheet, students can manipulate the angle of incidence to observe the corresponding angle of refraction. Manipulation of the angle of refraction leads to a corresponding change in the angle of incidence.The index of refraction of the two transparent materials can also be altered to observe the corresponding change in refraction.

Students can also experience a unique feature of the spreadsheet by entering a series of increasingly greater angles of incidence in going from a material with a greater index of refraction to one with a lesser value of index of refraction. When the critical angle is reached, the law of reflection takes over as a result of internal reflection. The spreadsheet also has a built in table of the indices of refraction of some common transparent materials and their critical angles.

Summary

Spreadsheets are excellent devices for organizing and manipulating data collected in the laboratory. The data entered into spreadsheets can be enhanced by the construction of charts and the addition of graphics. The Karplus Learning Cycle is an excellent tool in using the constructivist model to incorporate laboratory activities with computer spreadsheets. Through such integration, the computer calculations, simulations, and representations are directly connected to the real world experiences of the student.

MEETING THE NEEDS OF HISPANIC LEARNERS IN SCIENCE THROUGH A MODEL INSERVICE PROGRAM

Katherine I. Norman, The University of Texas at Brownsville
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Rey Ramirez, Brownsville Independent School District
Eli Eric Pena, The University of Texas at Brownsville

A collaborative University/School District program was developed to enhance science, mathematics and engineering education in the Lower Rio Grande Valley of Texas. Educators from the University of Texas at Brownsville (UTB) and Brownsville Independent School District (BISD) combined their efforts to form a partnership in implementing the program. This paper presents a summary of the UTB/BISD Collaborative Partnership.

Location

Brownsville, Texas is located in the southernmost part of the continental United States along the northern bank of the Rio Grande River. It is adjacent to Mexico by its sister city, Matamoros, Tamaulipas. The current estimated population of Brownsville is 135,260, 90% of whom are Hispanic. The history of Brownsville includes Karankawa Indians, Spanish explorers, vaqueros (Mexican cowboys) and ranchers. Soldiers also populated this area during the Mexican-American War and the Civil War. The City of Brownsville was incorporated in 1853 and was named after Fort Brown Post Commander, Major Jacob Brown who died on May 9, 1846 as a result of an injury received defending the Fort.

The University of Texas at Brownsville, through its partnership with Texas Southmost College, offers bachelors and masters degrees, as well as associate degrees and certificates. In addition, the university has several cooperative doctoral programs. Located one block from the Texas/Mexico border on the grounds of historic Fort Brown, UTB was established as an independent institution by the Texas Legislature in 1991. The University has over 8000 students.

The Brownsville Independent School District is the 13th largest district in the state. Student enrollment for the 1994-95 school year was approximately 40,000 students. BISD presently has 26 elementary, one intermediate, seven middle, and five high schools. Other BISD campuses include one all-level and two alternative schools. Additionally, there are 10 private and parochial schools available in the city.

The University/School District Partnership

The University of Texas at Brownsville and Brownsville Independent School District Collaborative Partnership for Science, Mathematics and Engineering Education is an official cooperative agreement between The University of Texas at Brownsville and Brownsville Independent School District, with mutually agreed upon goals, activities, and responsibilities. This Partnership was officially established in December of 1993, and is a fundamental component of the missions of both the University and the School District.

Goals for the University/School District Partnership that emphasize science education include the following:

1. To support training and research that promotes the teaching of science and mathematics in elementary grades.
2. To provide teachers with the knowledge and resources that integrate mathematics, science, language and other elementary disciplines so that students are provided experiences that promote scientific literacy.
3. To develop a positive attitude in teachers toward science and mathematics which can be, in turn, reflected in student enrollment in quantitative mathematics and science courses.
4. To reach the underlying problems facing the teaching of science and mathematics at every level of elementary education.
5. To increase the academic performance of students enrolled in middle school science and mathematics coursework with respect to classroom and state performance measures.
6. To provide knowledge and resource activities during intersessions to insure that students having difficulty or needing enrichment can successfully complete middle school science and mathematics coursework.

A sampling of cooperative activities that emphasize science and science teaching are presented below:

1. Science and mathematics coursework and field experiences.
2. Research investigations for middle and high school students.
3. Elementary science coursework and field experiences.
4. High school coordinated thematic science coursework and field experiences.
5. Science and mathematics professional development training experiences.
6. South Texas Engineering Mathematics and Science Program.
7. Perkins Middle School Math and Science Enrichment-intersession activities.
8. University and School District joint appointments for science and mathematics research.

University Graduate Programs in Science Education for Teachers

The University of Texas at Brownsville has four new graduate courses in Science Education currently being reviewed for approval. When approved, these courses may be taken as part of a Master's degree major in Curriculum and Instruction, emphasis in Science Education.

University courses, workshops, and institutes are designed to meet the needs of the teachers. Many of these courses are developed through collaborative planning with BISD, and with input from teachers. Courses are taught late afternoons, nights, Saturdays, and during summer programs. The UTB Regional Collaborative for Excellence in Science Teaching is funded by the state Eisenhower Science Professional Development program, with matching funds from BISD's Project BEAMS: Brownsville Engineering Alliances for Minority Students. This program provides training in science content and instructional methodologies for middle school science teachers through graduate course offerings, science teaching conferences, workshops and summer institutes. Another project for teachers at The University of Texas at Brownsville is funded by the National Aeronautics and Space Administration, and is designed to prepare teachers to teach science to students with disabilities in inclusive settings. In addition, University faculty coordinate the Lower Valley Science Educators Association, a regional group that meets monthly for dinner and presentations by guest speakers.

BISD's National Science Foundation Project BEAMS

The majority of the funding for this program is from the NSF Partnership for Minority Student Achievement Project BEAMS. Additional international, national, state and local sources provide funding for complimentary projects that tie-in with the project, and together form a pipeline for change in science, math and engineering education. Project BEAMS has as its primary concern a systemic development of resources and activities which promote the general education for entry of students into science, mathematics, engineering, and technology (SMET) careers. Project elements include activities in curriculum reform; teacher enhancement; student activities; and science, engineering, and mathematics career access. (See Figure 1.) An essential element of the Brownsville project is the coordinated efforts of public schools, university, junior college and public sector to promote systemic initiatives to reach the goals and objectives.

Program Goals

Project BEAMS goals are designed to provide resources and programs which facilitate minority students' access to careers in science, mathematics, and engineering. These goals are highlighted below.

1. Develop, implement and manage programs that will systematically and comprehensively increase the number of pre-college minority students in the science, mathematics, engineering and technology (SMET) pipeline.
2. Influence the quality of mathematics and science education in grades K-12 as a way to improve science and mathematics education and SMET career preparation.
3. Form multiple network collaborations among the business and industry sector, community and parents. These networks include scientists, mathematicians and science educators throughout academia, government, industry and other private foundations and organizations that encourage

the entrance of minorities into engineering and technical careers through support to the Brownsville schools.

4. Improve the quality of education through SMET career preparation and access.

Objectives

Program objectives are designed to improve K-12 and college instruction in science, mathematics, engineering, technology and teacher education, and thus facilitate the entry of minority students into SMET careers. Program objectives are listed below.

1. To improve minority student achievement in mathematics and science in grades K-12 by expanding student access to participation in a high quality educational program.
2. To coordinate and provide effective science and mathematics professional development of both inservice and preservice teachers and access outreach programs designed to meet the needs of BISD students.
3. To challenge the students' scientific literacy rates in a exciting, inviting, and challenging venture through in-school and out-of-classroom efforts.
4. To integrate technology into the classroom instruction, instructional management, educational research, and communication infra-structure to include video tape development, instructional television presented to the community, schools and outreach to urban, suburban, and rural areas.

Population Description

Situated in the extreme tip of Texas, Brownsville, Independent School District provides a public school education for a peak student population of over 40,000. Of this student population, 97% of its students are of Hispanic descent. This percentage is consistent throughout all district schools. An expanding population has created a need to build a minimum of one campus per year. Currently the district is comprised of forty-three campuses.

General Issues and Insights

Many barriers affect BISD students' interest and entry into SMET careers. Generally children enter schools with a great desire to learn every subject that they encounter with great enthusiasm. As Hispanic students begin to develop an interest in science and mathematics, they encounter few individuals that support their interests. Most children come from homes where parents have a minimal science or mathematics background and where a dislike for science and mathematics is highly visible. The area has very limited experiences for students. Few museums highlight science and mathematics. Finally, few careers and role models are found within the geographic region. Access to Hispanics in science and mathematics fields is difficult. Most commercial organizations hire non-Hispanic individuals from outside the area, making it difficult to recruit or volunteer role models. In addition, many of our native-born scientists and mathematicians leave this area and never return.

Student Characteristics

The program desires to develop students with characteristics and skills which foster SMET entry. Students exiting public schools should enter rigorous SMET preparation programs complete more SMET coursework than required, and choose a SMET career prior to leaving BEAMS pre-college programs. Student activities have three goals in mind: (a) to increase access for students to SMET careers, (b) to improve the overall academic performance of students, and (c) to prepare them for successful entry into post-secondary education programs.

Student Activities

Two programs have given students an opportunity to reach these goals, Advanced Mathematics and Science Summer Academy and the South Texas Engineering Math and Science (STEMS) programs. The summer academy program is for all students wanting to improve their academic preparation in math and science. It provides hands-on, intensive and rigorous activities. Students have an opportunity to prepare themselves for the next year's courses or college entrance exams. STEMS provides career awareness and strengthens students' interests in math and science by involving them in projects and giving them academic preparation skills.

Professional Development Activities

The professional development programs supported by Project BEAMS are designed to change how teachers view and work with K-12 students. Activities are long-term and focused on enhancing background knowledge and instructional methodologies in mathematics, science and technology. These activities include university coursework, institutes and symposia opportunities.

The NSF project is an important part of the school district's initiatives. Without it the school district is not complete; and without the efforts of all other school district initiatives and programs the NSF project, Project BEAMS, would not be as successful. Therefore, positive results in this and all other school district programs can only occur when efforts are comprehensive and systemic.

Relating and Integrating Hispanic Culture to Science

Cultural awareness brings to light differences in language, values, socioeconomic status, gender, and behaviors. Meeting the science content needs of predominantly Hispanic learners challenges educators to develop greater cultural awareness. Through the University/School District Partnership program, relating and integrating the Hispanic culture into science is accomplished by: (a) teaching educators to pay attention to cultural differences; (b) making educators aware of differences in values; (c) including role models as science reinforcement to cultural differences; and (d) socializing parents to expectations in science. The process by which these objectives are met in this program include several components: cultural awareness through science curriculum development in biology and science education, parental involvement, and the inclusion of role models in program activities.

Science curriculum development includes activities that incorporate cultural awareness. Participants enrolled in Integrated Biology and Science Education graduate courses emphasize cultural awareness in their lesson plans. They accomplish this goal through the inclusion of the following strategies: cultural points of view, various teaching methods that take into account cultural differences, use of alternative assessment methods, parental involvement activities, interdisciplinary connections that tie to cultural experiences and knowledge, and inclusion of science terminology in Spanish.

Parental involvement, an important element in program activities, assists in socializing parents to expectations of their children in science. Through science activities, parents can (a) realize science is fun, (b) help their children experience success, (c) include science in their children's everyday experiences, (d) establish regular science time outside the school setting, (e) gather knowledge of content and activities, and (f) create an academic bond with their children. The parental involvement element also includes teaching science content in Spanish for greater parental understanding and for overcoming barriers to learning science.

Program activities include Hispanic role model presentations of science content and of science careers. Developing student awareness of science careers by introducing role models enhances student confidence to learn science and to pursue science-related careers. Including cultural awareness in the teaching of science content is a strategy that involves students in appropriate learning that enhances motivation.

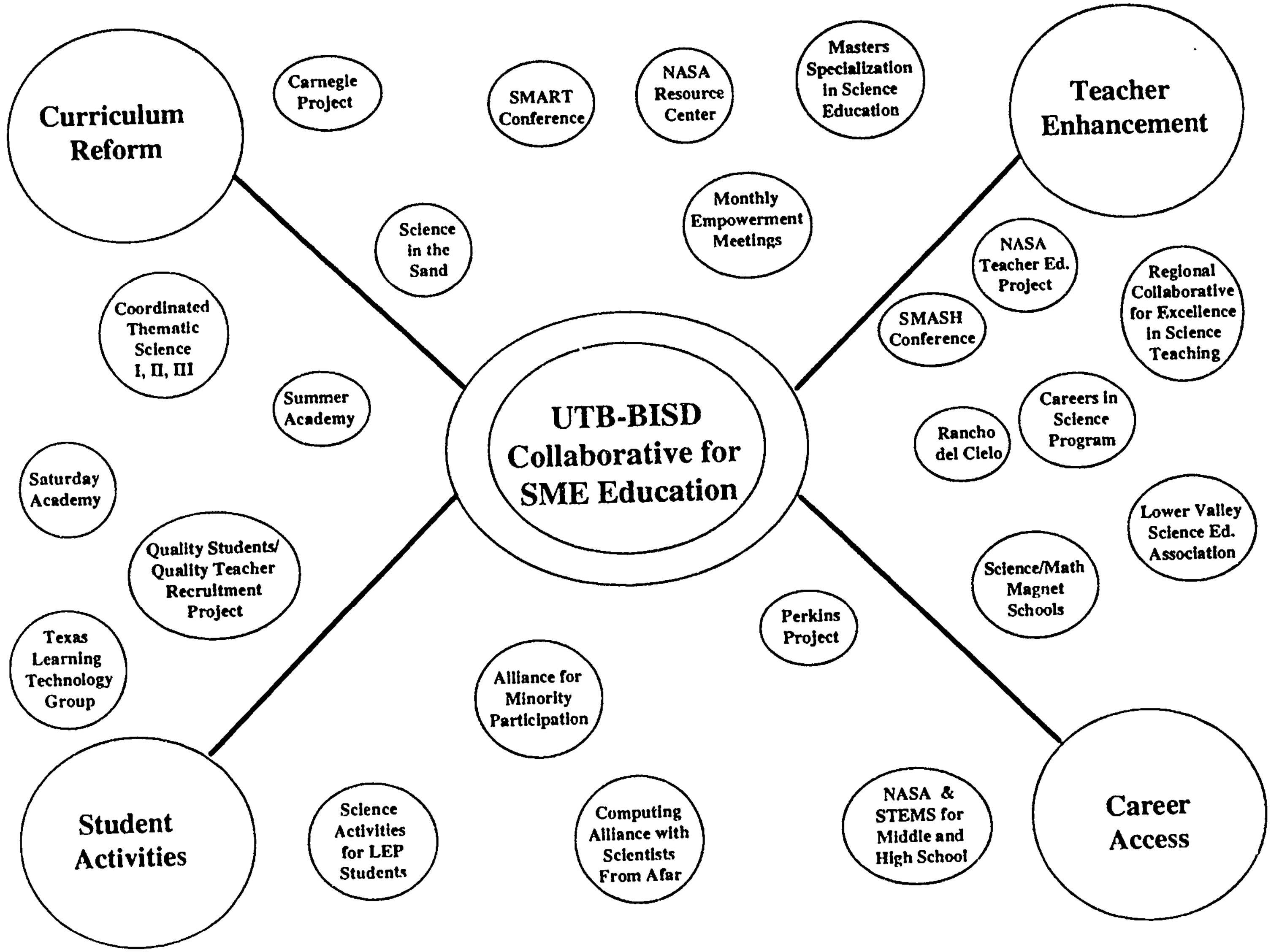

Figure 1. UTB-BISD Collaborative for SME Education

FURTHER VALIDATION OF THE CONSTRUCTIVIST LEARNING ENVIRONMENT SURVEY(CLES): ITS USE IN INTRODUCTORY COLLEGE SCIENCE COURSES OF BIOLOGY, CHEMISTRY, AND PHYSICS

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School reform issues continue to be at the forefront in the debate surrounding the future of public schools in the United States. Many school reformists point to the seminal report *Nation at Risk* as a benchmark and conclude that not much has been done toward improving public schools since its publication in 1983. The National Commission on Excellence in Education was appointed by then Secretary of Education Terrell Bell of the United States Department of Education during the Reagan Administration. Their report condemned American public education for producing a rising tide of mediocrity revealed in the scholastic achievement of youth. Since the report was published, a ground swell of private and public groups have proposed more than 300 recommendations for correcting the problems experienced in public education (Champagne, 1989).

One case in point is the article The Big Lie about U.S. Education, found in the October 1991 Phi Delta Kappan by Gerald Bracey. Bracey suggests that reports on the misgivings and perceived failings of the U.S. educational system have been offered into debate regularly, but began "pouring in after 1983" (p. 103). Bracey offers a contemporary premise that because many past and present accounts have negatively criticized the education process in the U.S., that a poor education "has become an assumption" (p. 106).

The debate is as fierce today. Chester Finn, a fellow at the Hudson Institute and former education official in the Reagan Administration claims:

Ever since a 'Nation at Risk,' there's been this little band of wishful thinkers and revisionists who've denied there's been a problem and who have been enormously popular within the education profession because of that denial. They get lots of prizes and speaking engagements, but everyone else ignores them (The wretched state, 1995, line 343).

The same point could be made in the case of many types of universities and colleges that offer science, mathematics, and engineering courses. Seymour (1995) reports that students are leaving the fields of science, mathematics, and engineering "at the rate of 40 to 60 percent" for nonscience majors (p. 392).

This paper will further examine the issue of why students leave science-related areas of study by examining the learning environments in three introductory college science classrooms: biology, chemistry, and physics. The data used for analysis were student and teacher preferences and perceptions of classroom learning environments from the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991).

The problem

Students are leaving science-related majors for nonscience majors in all types and sizes of colleges and universities across the nation. Elaine Seymour, director of ethnography and assessment research at the University of Colorado concluded a three-year study beginning in 1990 that investigated the reasons students leave science-related majors for nonscience majors. Seven major science, mathematics, and engineering(S.M.E.) colleges and universities, small to large, private and public, were chosen for the sample. "We presumed," writes Seymour (1995), "that the institutional context in which S.M.E. education takes place was likely to have some effect on retention and attrition . . . this presumption was not supported by our findings" (p. 392).

Morris Shamos, professor emeritus of physics and former president of the National Science Teachers Association, in his book The Myth of Scientific Literacy, discusses many possible reasons for the exodus Seymour describes. Shamos (1995) appears to have reached a very simple, yet vexing, conclusion for such a departure -- "*science is hard*"(p. 95). He discusses at length the reasons for science *being hard* and the rationale associated with such a judgment.

As a result, Seymour (1995) counters Shamos' claim by offering evidence that students who are choosing to leave science, mathematics, and engineering majors are not those who readily fit into to Shamos' categorization of students leaving these majors due to their difficulty. It appears from the data that students are consciously making the choice to leave S.M.E. majors based upon primarily pedagogical reasons and personal experiences while enrolled in S.M.E. courses. Seymour (1995) uses the titles of *switchers* and *nonswitchers* to define students staying in or leaving the S.M.E. majors in her research. She concludes her recent study by stating, "We did not find switchers and nonswitchers to be two different kinds of people. They did not differ by performance, motivation, or study-related behavior to any degree that was sufficient to explain why one group left and the other group stayed" (p. 396).

Perhaps the most troubling outcomes of the study were the highly rated, cross-campus reactions from the S.M.E. students about their classes. Seymour (1995) continues with, "Criticisms of faculty pedagogy contributed to one third of all switching decisions, and were the third most commonly mentioned factor in such decisions. Complaints about poor teaching were cited as a near-universal concern by switchers overall, and were the most commonly cited complaints of nonswitchers" (p. 398).

It appears from the Seymour study that Shamos' certification of science as *being hard* is not the primary reason for students leaving S.M.E. majors. The reasons, however, become more unmistakably clear based upon Seymour's research – contemporary students are not merely settling for *any* S.M.E. education. They are making very rational choices for leaving based upon their S.M.E. classroom experiences.

Constructivism and College Science Courses

Constructivism is defined as "an epistemology, a theory of knowledge used to explain how we know what we know" (Lorsbach & Tobin, 1992, p. 21). Lorsbach and Tobin maintain that:

> . . .constructivism asserts that knowledge resides in individuals; that knowledge cannot be transferred intact from the heads of a teacher to the heads of students. The student tries to make sense of what is taught by trying to fit it with his or her experience (p. 22).

Constructivist epistemology has influenced learning in science and mathematics, and many other academic areas. The value of constructivist epistemology upon teaching practice has also been identified and highly praised in many educational reform reports and papers published (American Association for the Advancement of Science [AAAS], 1993; Glynn, Yeany, & Britton, 1991; Pressley, Harris, & Marks, 1992).

Efforts in college science courses across the nation are underway to include more constructivist oriented teaching strategies. Lord (1994) outlines how the 5E model (Bybee, 1993) of constructivist teaching can be used to enhance student learning in a college biology course. Bybee's 5E model modifies the original 3 phases (exploration, invention, and discovery) of the learning cycle originally proposed by Karplus and Thier (1967). The 5-E's are easily remembered for lesson planning as Engagement, Exploration, Explanation, Elaboration, and Evaluation. Other college science instructors report of using various teaching strategies associated with constructivist teaching such as cooperative learning, discourse between instructors and students, and student interactions in class (Lord, 1994; Hartman, 1995).

Science education researchers have long been trying to identify and disseminate best classroom practice for science teaching. While many teachers presume they know what best practice is, and try to apply it within their classrooms, often times this best practice is hard to assess in classroom learning environments. Barry Fraser (1994) writes:

> Although classroom environment research has focused on the assessment and improvement of teaching and learning, it has done so largely within the context of the traditional, dominant epistemology underpinning the established classroom environment. Consequently, a new learning environment instrument is needed to help researchers assess the degree to which a particular classroom's environment is consistent with constructivist epistemology and to help teachers reflect on their epistemological assumptions and reshape their teaching practice. The Constructivist Learning Environment Survey (CLES) was developed to meet this need . . . (p. 527).

The Handbook of Research on Science Teaching and Learning (Gabel, 1994), published by the National Science Teachers Association, refers to constructivism as a "framework...to make sense of teaching and learning" (p. 85). If constructivist teaching practices are noted as sound for elementary and secondary science courses, then it follows to reason that they may also be appropriate for college science courses.

Method

This research is exploratory in nature. Originally, the intent was to validate the use of the CLES in introductory college science courses. As the data were analyzed, however, a secondary facet unfolded relating to Seymour's (1995) work . The data appear to have potential value in further validating not only the CLES, but also Seymour's research findings.

Sample

The samples for this study were samples of convenience from the biology, chemistry, and physics departments of a mid-sized western land grant university. The biology course data were gathered during the fall of 1995, which was followed by chemistry and physics in the spring and summer semesters respectively. The science courses' teachers were contacted by the researcher and asked to be involved in the study. It's interesting to note that not all of the teachers contacted were willing to take part in the study. Only one out of three chemistry teachers, and one out of two physics teachers accepted the invitation to be involved. Lack of class time was the typical reason given for their decision. The first biology teacher solicited agreed to take part in the study.

Each class was determined to be a typical college science course by this researcher. Every class meeting was a teacher led lecture format. Students were encouraged to ask questions of the teacher only after class. No time was given for student-to-student discussions in class. A new topic of study was presented at each class meeting. All assignments or laboratory work were prearranged by the teacher with no consultation with the students. All exams for the courses were multiple choice in nature. The sample consisted of females and males, including both science and nonscience majors as seen in Table 1.

Table 1

Self-reported number of males, females, and science majors in the introductory biology, chemistry, and physics courses

	Males	Females	Science Majors	Non-sci. Majors
Biology 100	34	60	9	77
Chemistry 100	14	14	3	22
* Physics 151	31	44	62	9
Totals	79	118	74	108

*Note -- An attempt was made in trying to secure a Physics 100 course to control for course level. No instructor (out of three) solicited would take part in the study due to a concern for loss of class time to survey their class. Therefore, Physics 151 was substituted.

Procedure

The CLES consists of two questionnaires, a preferred form and a perceived form. Each version surveys student opinions respecting classroom environments. The versions differ in content as to one's *preferences* and *perceptions* about being taught in a constructivist-oriented learning environment.

The preferred version of the CLES was administered to each science course during the first week of classes during the semester. The perceived version was then administered during the last week of regular classes during the same semester. The survey was given by this researcher and took approximately 20 minutes to complete. During this same time, a modified version of the perceived CLES was given to the teacher of the science class. The intent of the modification was to allow the teachers to assess themselves on their personal classroom teaching styles. The validity of the CLES was highly regarded and maintained. Consequently, only grammatical changes were made for the teacher CLES version. Instead of using the typical CLES stem of "In this class . . .", the teacher version was changed to "In *my* class . . . " All science teachers completed the modified CLES survey (n = 3). No treatment (e.g., changing teaching styles, classroom demeanor, etc.) was applied during each semester the CLES was administered.

Results

Cronbach's alpha, means, and standard deviations for the CLES sample can be seen in Table 2.

Table 2

Reported Internal Consistency (Cronbach's Reliability Coefficient) for the CLES Preferred and Perceived versions for Biology, Chemistry, and Physics science courses, and CLES Preferred and Perceived subscales (negotiation, prior knowledge, autonomy, student centeredness)

Course	Scale	Alpha Rel.	Mean	St. Deviation
Phys-pref	Negotiation	.90	3.50	.77
Phys-per		.89	3.10	.95
Chem-pref		.91	3.46	.81
Chem-per		.81	2.93	.72
Bio-pref		.84	3.59	.66
Bio-per		.89	3.48	.73
Reported-pref		.85		
Reported-per		.79		

Phys-pref	Pri. Knowledge	.63	4.22	.43
Phys-per		.75	3.22	.63
Chem-pref		.35	4.24	.36
Chem-per		.76	3.35	.55
Bio-pref		.61	4.19	.48
Bio-per		.75	3.37	.62
Reported-pref		.69		
Reported-per		.74		
Phys-pref	Autonomy	.73	3.54	.71
Phys-per		.79	3.55	.66
Chem-pref		.57	3.56	.41
Chem-per		.77	3.39	.61
Bio-pref		.74	3.32	.64
Bio-per		.73		
Reported-pref		.73		
Reported-per		.72		
Phys-pref	Student Cent'd	.70	2.46	.54
Phys-per		.63	1.92	.50
Chem-pref		.68	2.45	.53
Chem-per		.81	2.35	.60
Bio-pref		.69	2.45	.69
Bio-per		.68	2.17	.52
Reported-pref		.73		
Peported-per		.61		

The alpha reliability coefficients suggest that the preferred and perceived versions of the CLES have acceptable internal consistency when introductory college biology, chemistry, and physics courses are used as the unit of analysis. These results, however, are only reliable for these samples under study. Reliability analysis should be repeated on each sample in future studies.

The median CLES scores for each science class can be seen in Table 3. Median scores were reported due to the Likert-scaled data collected by the CLES (Gibbons, 1993).

Table 3

Median overall CLES perceived scores and subscale preferred by perceived median scores for biology, chemistry, and physics science courses

(model response for each subscale = 35; overall = 140)

	Negotiation Pref/Per	Pri. Know Pref/Per	Autonomy Pref/Per	St. Cent'd Pref/Per	Overall Pref/Per.
Biology	25 / 24	29 / 24	25 / 23	17 / 15	96.0 / 86.5
Chemistry	25 / 17.5	29 / 22	25 / 22.5	15.5 / 15.5	96.5 / 83.5
Physics	25 / 21	30 / 22	26 / 26	17 / 14	97.0/ 84.5

Conclusion and remarks

Taylor and Fraser (1991) caution that, "when analyzing results, it should be remembered that (a) there is no ideal mean score to be attained . . . (p. 5)." Taylor and Fraser's observation is well taken. Whether the CLES overall scores are acceptable is an individual judgment and a point of discussion for another day. The *overall* median preference scores were at the sixty-ninth percentile. One could infer that the students reportedly preferred to be taught along the frameworks consistent with constructivist epistemology. The CLES results, however, cause one to reflect more closely on Seymour's (1995) findings.

What I find intriguing is the drop in the student's preferences versus perceived scores regarding the course (e.g., 29 to 24). Champagne and Klopfer (1984) offer a profound observation in a review of cognitive psychology research that, perhaps, rings most true about the actual application of any epistemological framework employed in a college course: "When we teach, we assume students interpret text, lectures, and experiments as we intended them to be interpreted; the evidence is accumulating that this assumption is often not valid" (p. 186). These misread interpretations alluded to by Champagne and Klopfer are reflected in the science teachers' overall CLES scores. All teachers scored at 64 percent or better. This result is roughly five points beneath the students' preferred scores of 69 percent.

I suggest that this result is the key to the CLES. College science teachers who want to shift their classroom learning environments to become more consistent with constructivist epistemology should administer the CLES preferred version at the very beginning of the semester. At the end of the same semester, the CLES perceived version would be given. The CLES, then, could be used as a self-check for the teacher to measure the efficacy of their efforts in trying to move to more constructivist oriented teaching and learning environments.

The CLES appears to hold promise for assessing classroom learning environments in college science courses. College science teachers must begin to appreciate students' preferences for learning environments and value students who may want more of a negotiable, autonomous, and student centered classroom that focuses upon one's prior knowledge. If this were to happen, more students might choose to remain S.M.E. majors. School reform does not end in high school. If college science teachers do not choose to be a part of school reform, students will leave such environments in search of institutions of higher learning that do appreciate their needs.

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A LESSON FROM CASE STUDIES OF THREE NEW TEACHERS

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The Context

I have completed a longitudinal study of six new biology teachers who graduated from three successive cohorts of Cornell's Teacher Education in Science and Mathematics program. I started interviewing these TESM students when they were juniors and had completed the first TESM courses, and followed them into their first years of teaching. Two people only taught for two years, but the other four are still in the schools. In this presentation, I will refer to these people as new teachers, for as soon as they entered the TESM program they began to think of themselves differently, regarding themselves as future teachers even while still undergraduates.

This study was an interpretive study, not an hypothesis testing or quasi- experimental study. (See, for example, Erickson, 1986; Denzin and Lincoln, 1994). I did not have allegedly objective checklists or carefully developed questionnaires to be administered regularly. Instead, I had some general questions that would begin a focused conversation (Mishler, 1986) about the new teachers' work and themselves. What I hoped to learn were the details of their development described by the six new teachers. The areas about which I wanted to learn were their conceptions of learning and teaching, of themselves as learners and teachers, of biology, and their ways of thinking about their students. In the process of analyzing the data, I have developed case studies of each teacher, documenting their changes for the five or six year period. I have then begun the process of comparing the six different new teachers. One of the first things that became quite clear is that it is important to look at **how** the new teachers have thought about things, in addition to **what** they have thought.

The program

The new teachers I studied were all biology major who began taking TESM courses as juniors. They also worked in early field experiences as juniors. As seniors they continued early field work, completed educational foundations classes, and the requirements for their biology majors. They then enrolled in a masters' program, during which they did student teaching and took further biology or other science courses. I interviewed students after they took courses from me, so that I was not responsible for assigning grades when we talked. When they found teaching positions I visited them at their schools and spent at least a day with them, observing and using the observations to frame the interviews with them. I did a minimum of two hours of formal interviewing plus a significant amount of informal chatting during the course of a visit.

We designed the Cornell program in ways that we hoped would help our new teachers develop a solid grasp of their subject matter and an ability and commitment to help all learners understand the central ideas. Our work was, of course, strongly influenced by the work of Kenneth Strike and George Posner and the recognition that deep learning requires a conceptual change that may be akin to the paradigm shifts described by Thomas Kuhn (1970). We hoped our new teachers would become reflective teachers who would participate in the reform of science teaching.

I have now been involved with the TESM program since its beginning ten years ago, and have seen it evolve and develop. We all continue to be committed to prepare students to participate in substantive change efforts. As a teacher educator I continue to worry a lot about how we can help our students develop into the kinds of teachers who can participate in meaningful reform efforts. As I work in our local schools with teachers who have been involved with TESM for quite some time, I realize just how difficult the task of teaching has become. Not that it has not always been a demanding profession, but I think teachers now face some incredible pressures. Our hopes for the TESM students to engage in reform projects requires that they seriously challenge many pervasive assumptions about learning and school. It is, I believe, not enough for us as science teacher educators to convince our new teachers to embrace the need for reform and to commit to a vision for the reform. I believe that teachers, to accomplish reform, will need to learn to think about existing assumptions that dominate educational systems if they are to challenge them successfully. Today I want to illustrate what I mean by this to test my argument. But let me start with a story.

A new year's party

The high school in Ithaca, New York, has had some interesting things going on. I was at a New Year's Eve party this year and met several parents of high school students. Their views on recent changes provided an impetus for my thinking about this paper. The Ithaca High School biology teachers decided last year to revise their curriculum and to seek a variance from the Regents tests of New York State. In New York State students in college preparatory classes are required to take an exam at the end of the school year to show that they have mastered the material in the state-mandated Regents curriculum. These tests focus on the recall of minute factual detail, and/or the interpretation of convoluted multiple choice questions. However bad they are, these are high stakes tests. Teachers and schools are evaluated, at least informally, by the number of students successfully passing the Regents exams. It is therefore important for teachers to have their students do well on the exam, which all too often leads to teaching focused primarily on memorization of this large amount of content.

Before the present school year, the Ithaca biology teachers, led by a new department chair, applied to the State Education department for permission to develop their own curriculum and exams in place of the Regents. They received permission. Another part of the proposal eliminated the distinction between Regents and Honors biology classes. All college-bound students would take the same classes. Teachers developed activities to allow the pupils who wanted to explore some areas in more depth to do so. I should add that prior to the change, pupils chose whether or not to take honors classes. There were no admissions requirements, with the result that the vast majority of biology classes were labeled honors classes.

The parents at the New Year's Eve party were shocked and aghast that the teachers would so crassly neglect and abandon the honors students. I kept my mouth shut and spent my time trying to figure out what conceptions of knowledge and learning these parents held. I realized that they had a race track image of schooling, where knowledge was fixed and certain, and what you knew was more important than how you knew it. They wanted their sons and daughters to be the fastest on the race course, allowing them therefore to enter the best universities. Knowledge to them seemed to consist of the recall of the most facts, the more obscure the better. (For example, the classification of the worm in the tequila just brought back from Mexico kept the group going for a while until someone found the right answer in a reference book.)

The new year's challenge

This experience emphasized, for me, some of the conservative forces that constrain school change. I think these are forces that have a great deal of significance in light of some of the recent proposed reforms in science education that seek to ensure success for a wider spectrum of learners and that seek to move away from memorization of a vast body of content to a deeper understanding of less material. I think that had I tried to talk with any of those parents about the benefit of the new program, they would not or could not have understood. It would have required a real shift in their conceptualizations (Strike and Posner, 1992), and a New Year's Eve party did not seem the appropriate venue for me to begin any conversion attempt.

Response to the Challenge

In my work with the new teachers I have come to realize that the selves they bring to the enterprise and that they develop as teachers are central to understand the processes through which they become teachers. Much of the work on teacher development has identified the phases through which most teachers seem to pass, and there is nothing in my data to suggest that these are not helpful phases to think about. (See, for example, Huberman, 1993). However, I have sought to examine how each person, as an individual person, has negotiated their development. Development is complicated by that fact that each new teacher has had their own history and biography and each new teacher was in a different school system, with a different culture and history. All this variability has made it an interesting challenge to interpret these data.

Today I want to talk about one area that I have found particularly salient because helps understand concerns voiced by the new teachers, and also because it is an area that I have found extremely helpful when working with my current preservice teachers. This area involves thinking about the culture and social system of the school as it is enacted by students in the classroom and as new teachers become participants in that culture. Of course, students' actions are influenced by the cultures in which they are embedded and any classroom is influenced by the cultures of the school. First, though, I need to make more clear what I mean by culture and social system.

I believe that a cultural viewpoint is a very productive perspective from which to view schools and classes and the work of teaching. The social organization of a school is produced by humans, interpreted by them, and often operates at a non-conscious level. When we hope to educate teachers who will change the way science is taught, who will have new conceptions of good teaching, we put them into existing social institutions that have developed expectations, expectations that may well run counter to attempts to change. Greenwood and Santos present a concise explanation of the concept of culture as I wish to employ it.

> A specific anthropological view of the human condition guided [our] work. We view humans as beset by intrinsic tensions between our social existence and the interpretive sense we continuously try to make of it. We operate in specific social organizational contexts, playing roles and performing functions. Simultaneously the complexities of our environment and the vagaries of our social lives continually challenge us to make and remake sense of the world we live in. The world must make sense for us to be able to survive. It does not have to make positive sense; it only matters that the world be coherent and that reasonable cause and effect relationships hold in it (Greenwood and Santos, 1991, p. 9).
>
> While anthropologists agree that culture binds groups together, anthropologists emphasize that culture is a process, a making sense of the world. Culture is always at work, responding to experience, changing, diversifying and reunifying. The hallmark of a cultural system is the continual process of interpretation a group engages in, as individuals and collectively, in the process of daily life (Greenwood and Santos, 1991, p. 11).

The new teachers

The new teachers, in their student years and in their first jobs, were required to fulfill roles in established cultures or systems. These systems also contained many assumptions about what teachers should be and do. Because teaching requires so much personal participation, the new teachers were thus engaged in re-formulating themselves as they participated in the schools' social systems. The new teachers began their first jobs with different ways of understanding the social systems of schools. I think that those with a more explicit interpretation of the ways in which school and classroom social systems operated had an easier time of it because they had a richer analytic perspective to think about their work.

The new teachers I studied did not examine the cultures of their schools to the same degree. I want to present a few representative quotes from three of the new teachers to illustrate what I consider to be significant differences. I use pseudonyms in referring to these students, ones that they have approved. All of the new teachers have seen the transcripts of our interviews and had the chance to change or amend them. In reporting quotes, my comments will be in italics. Pauses will be represented by two periods. I use the usual conventions to indicate deletions.

George Frage taught for two years and then returned to graduate school in marine biology. George taught at two different private preparatory schools, one large and one small. George lived in the student residence halls on each campus. His first year he taught biology and his second year he taught chemistry and biology. He had done his student teaching in biology at a suburban high school. Maggie Deering taught for two years at a small public rural high school before moving into a region in which she could not find a teaching position. Maggie had done her student teaching at a small rural high school, and worked in chemistry and biology. Sylvie Andrews taught both chemistry and biology at a very large suburban high school for two years, then moved. In her new location, she began teaching at an urban high school, but left the school along with several other teachers because of the difficult working conditions. She then found a job teaching at a rural middle school. Sylvie had done her student teaching in biology in a small rural high school.

George

George was probably the most consistently articulate in his analyses of the culture of the schools in which he worked. As a teacher he appeared well-liked, relaxed, informed, enthusiastic, and confident. Working at prestigious schools, it was assumed that his students were bright, and he had few discipline problems. He also had some support for innovative teaching, particularly at his second school.

After he had completed his student teaching I asked George about characterizing students, and his description really focused on the culture of the school.

How would you characterize the students that you've seen, the kinds of students that you're worked with?

In terms of different categories you mean?

Yeah. Are there different categories? Are they all unique individuals? And if they are unique individuals, what are some of them like?

Hmm.. I think you expressed the question very well. I don't know if I have an answer for it. I guess I tried not to categorize students. That's why I don't have a quick answer for you. I could try right now.

If you could pull up some names?

Names of students?

I mean if there are some you could remember.

Well, I'm trying to think. Because I did my student teaching with honors students [top track] and I worked with a basic [lowest track] Biology class and I'm trying to think of differences between those two classes. I think one interesting difference between the two is something that you wouldn't expect and that's that the Basic kids challenge you a lot more than you might expect. If an argument isn't sound or something's not believable, they'll tell you about it, "What's up?"

But the honors kids seem to not have the sort of healthy skepticism that you might expect. And I kind of have a theory that that's how and why they're honors students, because they just kind of bought into the system. That's why they've succeeded in school, and they just spend all their energy trying to fit in to what the teachers want them to do. So, a lot of times the Basic kids are a lot more interesting. Because, I don't now, they just seem like a lot more real, down to earth people. Not anything against Honors kids, they're great kids, but I just found that interesting, I expected honors kids to be these enlightened, critically thinking students. (Masters year)

George continued in his description of students by focusing on their thinking, and in so doing seems also to be criticizing some of his own training.

Different types of learners. Let's see, there's the passive/active [distinction] and then there's the abstract/concrete distinction. Some students are perfectly comfortable with me just talking in my abstract way that I've kind of developed in talking to people at college for five years. Everyone kind of knows the ground rules and talks in these lofty symbols, and only you know what you're talking about and when you try to go talk to real people it doesn't make any sense. But some students are totally comfortable with that and others are very resistant to it, or just uncomfortable with it. And I think that one of the distinctions you can make between the honors and the basic, is that the honors are more comfortable with speaking abstractly about things. They're not requiring a lot of evidence or seeing proofs, they're much more interested in the actual concept itself, for the sake of learning it. Whereas the basic kids will challenge it and ask "How do you know that's true?"

Yeah, yeah, I'm having a thought here. It's a very premature thought but, you know me, the slow thinker.. I think maybe honors kids have bought into the system. And they're no longer struggling with the world. They've kind of accepted it as it is, and as everyone tells them it is. And now they're just kind of soaking it all in. Whereas the basic kids, a lot of times, are having turbulent times in their lives and . the world doesn't necessarily make much sense to them at this point. And maybe that's why they're always challenging and trying to piece it together. (Masters year)

In his first year of teaching, when talking with him about individual students, he again revealed the teacher's habit to think about students in classes. He noted that Mike, a student who moved into the class after the start of the school year, seemed to be having a difficult time.

> There is a sort of tightness to that class. For example, when I'm taking attendance I'll say, "Who's missing?" and they know immediately who's not there. And in my other bio class it takes us a few minutes to figure out who's not there. And Mike just always seems sort of amused/surprised/ by my antics and the rest of the class. [He] can't believe what he's seeing, some of the time. (Year One)

Here, George refers to classes as have a culture, but one in which he has a part - both he and the class behave in certain ways. He did not express any discomfort with being the teacher, but was clear in wanting to be a teacher who learned along with students, who did not merely dispense information.

In his second year of teaching, George reported clearly on a cultural norm that was honored at the school and analyzed how this norm could yield positive and negative results. He could then analyze how this norm influenced students' dealings with him, so that he was less disturbed by their actions than someone else might have been.

> A lot of students become really responsible and they can exert a lot of control over their peers in a positive way. And there isn't that huge gap between faculty authority and student submission. There's a nice sort of gradient. . . .It spills over into the classes. For example, there were a few grumbles in class today, "Can we have this test on Thursday?" And at the beginning of the year when I was young and naive and didn't know about these students who were out to manipulate me, they would have presented a case where it was unfair that I have the test. And I would have given in. And I'm realizing now that I've just been had a lot of times. They're just not doing the work at home, they're expecting you to teach every little thing to them in class and if that doesn't happen then it's unfair to have a test. (Year Two)

He also noted the action of another school norm. The school was committed to developing a community based on trust of each other, and this worked nicely in many ways. George noted an irony though.

> But it also has a strange effect on discipline because if you catch someone doing something it's kind of immediately "You violated my common trust."
>
> *I love adolescents!*
>
> They don't think about what they actually did, because you catch them **you're** the perpetrator. (Year Two)

It seemed to me that George's ability to examine the culture of a school made it easier to deal with student behaviors and challenges and reactions to him. Although it is never possible to identify any unitary cause for George's anthropological bent, it may be related to his description of himself as academically uninvolved until high school. He reported that his siblings and friends were not much interested in school and it was only when he was placed in advanced classes that he became interested in academic achievement.

Maggie

Maggie reported that she had always been interested in academic achievement. She was influenced by peers early in school when they teased her about wearing dresses to school. When the style changed, in later years, Maggie reported being stubborn and continuing to wear slacks rather than dresses. She was also very athletic in school, and reported wanting to succeed as a woman to show that she could.

She talked about school culture also, but not quite as explicitly as George. Generally she talked about the norms that she wanted to establish in her classes, sometimes analyzing the reasons or functions for existing student behaviors. As a junior, Maggie tutored Cornell freshman taking introductory biology classes. In describing their problems, she implicitly referred to college culture with its required courses and grade emphasis. She did not blame herself when she could not help all the students as they wished.

Most of the students who came in weren't in the class because they really wanted to be in the class, they didn't have much interest in the material. I think a lot of them just wanted to get a good grade. I think some students had trouble with study habits. They generally all would come in right before exams, and some of them would expect you to be able to help them bring up essentially a failing grade within a few days! [laugh] (Junior Year)

After field work during her senior year, she observed differences across tracks, though her analysis is less detailed than George's.

I definitely notice differences across the grade levels. The younger grades, the middle school, they're generally much more open, they're much more willing to answer questions and get involved in an activity they're not afraid. . . .or many of them aren't afraid yet to answer questions in class and to answer things. Whereas you get to the high school and they're less willing to answer questions. If you get the honors class, they're even less willing. . . .If they were asked questions they were all worried that they would give the wrong answer (Senior Year)

After her student teaching, she again talked about evidence of understanding. As I probed her ideas on this, she reflected on an aspect of school culture.

Let's see, you can tell if they understand by the questions they ask, by sometimes the gleam in their eye, what they do on lab reports or quizzes. Any other ways?

Well, I guess another thing would be by how many students come in after school. Because sometimes when we got to the more difficult topics, more students would come in for extra help. And then, especially then, you would have a chance to work one-on-one so you might be able to find out some confusion some people have that other students might also have but have been afraid to come in and ask. A lot of times they're not willing to admit that they're confused. (Masters Year)

As a first year teacher, Maggie had learned that she had to play a stronger role in setting expectations for her classroom. For example, Maggie learned that she had to develop more explicit policies on turning work in, and analyzed her initial attitude. As she learned more about students and their work habits, she had begun to develop strategies for dealing with these difficulties.

> I didn't come down hard on them in the beginning about getting homework done. By the end of the first quarter I started to realize that a lot of these students just were not mature enough to make that sort of decision. And so next year I'm going to, I can't take off points, but I think I'm going to come up with a policy where they will be asked to stay after school if they don't have a certain amount of their homework done. And possibly calling home.
>
> A lot of parents, I think, were very responsive if I called home and wanted the kids to get the homework done, but often didn't know the student had homework. . . . .So I think I'm going to make it - I'm probably going to send something home to parents, at the beginning of the year. Telling them the expectation. (Year One)

As a first year teacher, Maggie began to observe some of the effects of school organization on students in her classes. She observed the effects of grading policies and teachers on students. As with George, once she had realized this effect, she found it easier to deal with the students.

> And I had a couple students from there who, one of them almost always came in late, and then he was sort of the class clown type and especially once they realized that they failed a quarter, or two quarters, they loose hope and they don't feel there's any way they're going to pass the course, so why bother trying? And now I notice, looking back through the year, ... most of those students who were like that are students were freshmen? And they had two or three first year teachers.
>
> *Oh!*
>
> So I think that had a big effect, because I know for myself, in starting out, I was still going in with the idea of, these are sophomores, they've been through high school, they've had a science course already. So I was thinking of a little bit higher maturity level, I think. And experience level. And the freshmen . . . . weren't ready. (Year One)

As a second year teacher, Maggie had learned the benefits of more clearly establishing classroom norms and establishing rules for the classroom culture. She described herself as:

> I think definitely, sort of a happier more enthusiastic teacher, just because I'm not going home depressed every night going, "Ah these kids are so cruel." I think that with having the discipline better, and coming out stronger right from the beginning of the year, that the students are nicer and more considerate. . . . [Because I have policies worked out] I can come into class and be a little more happy, and joke around a little bit more. (Year Two)

In her second year of teaching Maggie had made changes in how she conducted the classes for the Regents students. She was in a school that emphasized performance on the Regents exams, so had pressure to cover the content. She had also found that in her first year of teaching, when she worked to use class discussion extensively, she would forget just what she had done in each class. Writing examinations that had content validity then became harder to do consistently. This need for uniformity was a condition of the school culture as it was organized so was a norm to which she had to adhere. Maggie was still working to change how things were done and how her students worked. She never explicitly referred to student habits as part of school culture, but did view them as malleable, and not as fixed traits.

> *In a typical class when you do notes, do you do as you did today with the overhead and a discrete amount of material at a time? And then discussion?*
>
> Yeah. We have to go through more notes in the Regents class so it's often a page or maybe up to two pages of the overhead notes at once before we go on to something else. That's another thing I'd like to change. I have tried to do that so that sometimes we're doing more worksheets from the book so that they don't have as many notes.
>
> For example, on the digestive system I did it as notes and I found that we just had so many notes, and it took so much time, that I felt like it was a long time before we could get in the practice. And I didn't feel that they were learning very much from the notes because they have a hard time staying focused. And I'm

noticing that the students who do poorly are the students who really have a hard time staying focused when we're doing the notes. (Year Two)

She was still ambivalent about doing lectures, giving notes, but some factors seem to push her to do this. These included students' inability to read and grasp the textbook chosen by the department and the unavoidable Regents exam. Interestingly, she returned to her own high school experiences as she talked about her dilemma, perhaps because she had not worked through it in terms of her own experiences as a teacher.

That's one of the reasons why I think the notes don't work, because they just blindly write down what I have up there and they don't really think about what it means. And I remember vividly, from when I was in high school, my history class, freshman and sophomore year. And in freshman year the notes were given to us, they were all just straight outline notes. And then in the sophomore year, in history class, he didn't give us notes at all. I mean he wrote a few words on the board, but everything else was done by discussion and he spent some time at the beginning of the year teaching us how to take notes from the discussion.

But in order to do that [discussion in class] I would have to be sure that they had done the reading first, and their textbook has so much information that's beyond what we cover, and has so much vocabulary, that a lot of them find it difficult to read and wouldn't know what to focus on. So we can't really have the discussions that way. So it's tough to have to give them notes, because it's still just me talking. (Year Two)

Sylvie

In her junior year, Sylvie also had tutored introductory biology students on campus. Her descriptions referred to few, if any, cultural factors such as a concern for grades, or beliefs about studying. Also, she reported feeling bad about her inability to help these students. She did not recognize that they could be at least partly to blame for their difficulties.

Do you have any category system in your head about the kinds of students you've worked with?

No, pretty homogeneous group. . . . I couldn't say upper middle class, but definitely they're all motivated.

How about in terms of the kinds of problems that they have in school. On their assignments?

Ah, negative attitude toward science. I can just remember feeling really bad. Just some people who in introductory biology just could not take the professor's tests, did really bad. I don't know what was going on. They studied and they came in to me for help, but just could not. I don't know, I can't, it's hard, I haven't had enough exposure. Just a bad attitude I guess. (Junior Year)

After her student teaching Sylvie noted differences between students in different tracks, but seemed to regard these differences as fixed and characteristic of the students themselves and not shaped by any social system.

> In [my student teaching school] there were two types. One type I'd say this, like the scum of the earth kids, like I don't mean that in a bad way, but you just know, the rest of the school thinks of them like the scum . . . .the non-Regents, the kids from rural families who you know don't plan on going to college; their greatest aspiration is to own a car. You can just tell they come from poor. . . .poor families. The other, the Regents classes, are just more typical upper middle class teenie boppers. . (Masters Year)

In further discussion of the students she worked with, Sylvie compared high school students to her fellow students in the university. Again, she did not comment on any differences between high school and Cornell culture that could help understand the students' actions.

Characterization of their intellectual qualities?

Uh, uh, very curious. . . Like I've noticed [for example] . . . now I'm taking anatomy and physiology [at Cornell] that no one ever asks the professor questions, whereas in the classroom kids were asking questions all the time. (Masters Year)

Sylvie had made some attempts to do innovative work in her student teaching, to break with the traditional practices of her cooperating teacher. Her attempts were not successful, but she did not see how students' socialization would have made them resistant to change.

> They're not very, I don't know what the word is, I want to say creative. Like if I gave them a problem, or asked them a question, they don't really... they don't really enjoy that. They kind of get angry. They say "Well you're the teacher, you tell us."
>
> *So if you tried to give them an assignment that wasn't pretty well structured, they didn't like it?*
>
> Yeah, and they'd get angry. I mean they got frustrated, and I remember saying once to a class as they were all working on it, "Well, frustration is good". And they were all "Well good we're all frustrated." But you know, so they got frustrated with things like that. I think it's a matter of just getting used to it. (Masters Year)

In some further discussion of the students in the lower track classes, Sylvie appeared to be grappling with issues of culture, but could never really articulate a position, falling back to an explanation that focused on individual qualities.

> *What makes you think it [traditional lecture method] works for the Regents and maybe doesn't for the non-Regents?*
>
> . . . I just don't think the non-Regents buy in as much, I don't know how to explain that. But also the nonRegents' attention is a lot shorter. But I think they're just as smart. Those kids could have been in Regents classes.. I don't think they would have done well in Regents class, but they certainly could have been in them --- you know. I don't know how to explain that. It wasn't like this horrible group of kids, I mean it was like they had chosen to be in there. But then again they might have gone to the Regents and been totally lost. (Masters Year)

During her first year of teaching, Sylvie talked about her students' low motivation and poor work habits, and about her work to develop classroom procedures and policies to deal with demanding students. When I visited her during her second year, she had begun to analyze the social system of the school and students' beliefs.

What's it like being a teacher this second year?

Uhm, good. (said tentatively, and we laugh)

Up and down?

Up and down. It's easier, but I still get discouraged. I went through long blocks of time getting really discouraged by the motivation of the kids. Now part of it was I just had to realize they were just average teenagers. And what happened was .... the SAT scores came out and they were all talking about them and I realized that of the kids I teach, none of them got over a 1200, and some were getting below a 1000. So, even though.... everyone always says the students here are the cream of the crop, it really isn't so. I mean the students I teach, school is not where their priorities are, they're typical teenagers. (Year Two)

In her second year of teaching, Sylvie observed other teachers as they fit into a social system more carefully, and had begun to realize that she had to forge her own identity and that techniques suggested by others might not be appropriate for her.

But in general, other teachers who teach the regular level have the same problems [that I do]. The teachers who are considered wonderful teachers, like X who got teacher of the year, they only teach gifted and talented students, so....

Hard to fail, isn't it?

So that's almost all they ever taught!

So ___'s advice is always, "You have to find what works." And what works for her will not necessarily work for me. (Year Two)

When I visited Sylvie in her third year of teaching, she was in a very different kind of teaching setting. She seemed finally to be putting her observations together into an explicit cultural explanation. One example occurred when I had asked her what kind of teacher she would like to be. She gave a description, then I asked:

> *There seems to be like kind of a negative image behind what you're saying. You say you want to be just a good teacher, you don't want to sacrifice everything.*
>
> Yeah.
>
> *What would a teacher who sacrificed, you know. Social life or personal life and sanity what would?*
>
> I just think they become bitter. Like I don't think they can last that long. I think that happened to A. She did sacrifice an awful lot for that school, and department. And she just about burned out, just became a basket case. She used to sacrifice so much. Whereas other teachers in that department were still good teachers, they probably were just as good teachers, but they weren't going on with the newest reforms. They could use older [materials] they weren't always doing the workshops and taking all the classes. So they were just happier, more content people. And I think students gave up on A. too.
>
> *So that you wouldn't want to be the kind of teacher that people say, "oh yeah, she's been to the latest thing and she's doing the absolute state of the art and this is the most--"*
>
> No, not necessarily. (Year Three)

Once Sylvie voiced this evaluation, I tried to determine whether or not she had had these misgivings when she was at the school, but had not voiced them to me.

> *And I just wondered if maybe at the time you were feeling guilty because*
>
> Yeah.
>
> *You weren't ready for that*
>
> Unh huh [yes]
>
> *And you were being pushed and pulled and*
>
> Yeah.
>
> *wanted to do this and that and it's hard as a new teacher to say "No I don't want to."*

Yeah. Yeah. Not guilty, but influenced. But now I guess I can say, "Well that's a good idea, I might try that." I probably would, I'd probably try anything new. Not that I would keep doing it . . . if it didn't work.

No, I had a lot of criticism over some things about the ways the teachers taught there. I didn't think they necessarily had clear type goals of what they were going to teach at the beginning of a unit. And there was an awful lot of curving tests [by adding points]. [The feeling] was kind of "Well, hopefully they picked up something." (Year Three)

Lessons for Teacher Education

I have realized that my longitudinal research has had a strong effect on my thinking and my own work with succeeding TESM cohorts. As I have seen some of the ways in which these new teachers have changed, I have changed. Kelchtermans (1993) has summarized research that uses biography to illuminate the selves that are involved in teaching. Kelchtermans makes extensive use of the work of Ivor Goodson and Jennifer Nias, among others, to clarify the extremely personal nature of teaching . Professional practice requires extended involvements with others so the self of the teacher cannot be hidden or ignored. In fact, "Nias found that teachers, when talking about their job, in fact always talk about themselves. She calls this 'persistent self-referentialism' [Nias, 1989, p. 5] (Kelchtermans, 1993, p. 200)."

Kelchtermans goes on, in this article, to develop the conception of self as a dynamic and interactive entity, not one that is unitary and stable. Rather, the self develops and changes continually through interactions with and interpretations of the immediate environment. (See also Britzman, 1991 and 1992). The constant negotiation of the self is inevitable in a profession require interactions with so many others.

Both George and Maggie could look at their students' problems and actions and analyze them using a cultural perspective. They could interpret behaviors as they had meaning to students within a social system, so were better able to examine their own roles in the social system of the classroom. They recognized their roles within the classroom social system, and could then contemplate possible changes they could make. Because they looked for reasons for students' actions, they also were less likely to view actions as reflections of inherent qualities of the students. Their notion of their students' identities, being flexible, enabled them to think about how to change the environment they established.

It took Sylvie a longer time to realize that she operated within social systems with established patterns of meanings. Some of these could be changed and some could not, but because she did not analyze them, she could not make these distinctions. Until she made these distinctions, she seemed to blame either her students or herself for lack of success. It took her some time to attend to the operations of the social systems in which she was embedded. She eventually came to see that being a teacher was an individual act, that her identity was something she had to forge and that others could not give her specific instructions on how to act. By her third year of teaching, she could voice a critical analysis of the school in which she had worked for two years, and could begin to name the inequalities and the unfair demands.

In line with Nias' notion of the "persistent self-referentialism" of teaching, I return to my own teaching, but I do so with the hope that what I am learning will be useful to other teacher educators. As I have proceeded on this longitudinal study, I have modified my work to make much more clear to pre-service teachers that they will be entering established social systems that may very likely resist their efforts to do things differently. When I work with student teachers, I am now quite explicit about the classroom and school social systems. Student teachers, for example, frequently worry that their pupils do not respect them. By pointing out to student teachers that they are now representatives of authority, and that adolescents are prone to challenge authority, the student teachers find it easier to deal with their pupils' troublesome reactions to them. I also find it beneficial to help student teachers to understand the often conservative experienced teachers in the schools in which they work. If we can examine the social system of the school and its history, we don't have to label these teachers as ba or burnt-out, but can develop a more dynamic explanation of their responses.

In my work with pre-service teachers in the very first TESM course that they take, I devote considerable time to an examination of social systems of learning. As I have written about elsewhere (Trumbull and Slack, 1991; Trumbull, 1991) students in my course do clinical interviews with Cornell students and with others not enrolled at Cornell. They repeatedly are surprised to learn that one thing Cornellians seem to have learned is that getting the right answer is of crucial importance. This belief often produces truncated interviews, because the well-socialized Cornellian refused to speculate and ponder out loud. They have learned not to think or question, similar to the observation George made about the honors students in Ithaca.

I also talk about social beliefs in the context of learned behaviors for participating in class discussions. I have them read Duckworth, (1987) who is eloquent about the need for learners to explore a wide range of viewpoints and interpretations before moving to a current accepted view. Such explorations can happen in discussions, but these discussions require that many people contribute and that people listen carefully to each other. Because classroom discussions at Cornell are usually used as opportunities for aggressive students to demonstrate their accomplishments rather than discuss confusions or learn from others, I will this point out and we then discuss how they learned this use of discussion. Usually, students improve over the course of the semester in their abilities to talk with each other, and not address discussion comments solely to me.

When we begin discussing well, if no one else mentions it, I will bring up the issue about why some people seem more comfortable talking a great deal in class and why others do not. From this, we move to consider what effect this differential participation has on our perceptions of the silent person's intelligence and motivation. These are all aspects that arise in the course of considering the research readings and their project presentations. I can never predict when they will appear, but address them when they do. And, since all the biology students now do field work in a middle school while taking my course, we can illustrate these points with examples from the schools.

I also have developed a strong focus on the ethical issues of teaching. One issue quite obviously relates to my concern with cultural systems. We discuss multicultural education in terms of the systematic exclusion of people with beliefs about proper academic activity different from those of the teacher. Because I refer to their own participation in our classroom, I can attempt to illustrate the complex number of factors that could lead to a student's decreased participation.

Another issue I have learned to make explicit and to refer to throughout my work with the TESM new teachers is raised by a reading from Noddings (1993). She argues that teachers have the moral responsibility to shape their pupils into more moral persons. My TESM students do not always agree with this, and interesting discussions ensue. These discussions require them to think about what kinds of learnings go on in classrooms other than the learning of specific content. Again, when we begin to identify these other learnings, we dissect social meanings and expectations and the culture of classrooms as they reflect particular moral positions.

So, to conclude, I believe that not only is it important for us as science teacher educators to convince our students of the need for substantive change in the ways science is taught. I believe that we must also help them analyze the ways that schools operate as social systems.
If we fail to help our future teachers analyze their schools' social systems and consider them thoughtfully, we will risk setting them up for failure, failure for which they can blame themselves and from which they cannot learn and through which they cannot grow.

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DEVELOPMENT AND UTILIZATION OF AN INSTRUMENT TO EVALUATE SCIENCE TEACHERS' ATTITUDES TOWARDS THEIR OWN PRESENTATION OF INSERVICE WORKSHOPS

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Within science education a wide range of attitudinal instruments have been developed. Some of these instruments are targeted at pre-college students (Ebenezer & Zoller, 1993; Steiner, 1973), while other instruments are constructed with preservice teachers in mind (e.g. Scharmann, Harty, & Holland, 1986; Woolfolk & Hoy, 1990). A third, and very important, category of instruments is those designed to evaluate the attitudes of practicing science teachers. Teachers, researchers, and teacher trainers have considered a variety of issues and have in turn developed a wide array of instruments for this group. For instance, Rubba and Bakar (1985) considered an inventory of needs survey, while Riggs and Enochs (1990) created an instrument that involved the measurement of self efficacy. Jones and Harty (1978) stressed instruction and classroom management of science teachers in their instrument, while Moore (1973) did some of the very early work involving teachers' attitudes toward the teaching of elementary school science.

This paper presents the results of developing and field testing an instrument to assess science teachers' attitudes towards the presentation of inservice workshops. Little formal work seems to have been conducted that aims to evaluate attitudes toward the presentation of science inservice programs. Therefore, this instrument may help fill a gap in the type of instruments available for those assessing teachers' attitudes.

Why Is an "Inservice" Instrument Important?

Presently many National Science Foundation (NSF) programs for teacher enhancement follow a general format of first inviting teachers to 2-, 3-, or 4-week long summer workshops. These summer workshops are then followed up with a number of meetings and communiques during the school year. At the National Aquarium in Baltimore such a teacher outreach program has been funded by NSF. However, a critical component of the Aquarium's program required the presentation of inservice workshops by those who attended the summer workshops. The Aquarium staff (and other groups) feel strongly that if science education reform is to spread, then summer workshops must affect teachers other than those who attend any one workshop. By requiring inservice presentations, the expertise of participants can be multiplied.

In theory the model of requiring teachers to present workshops in their home districts would seem to be a good idea. However, past experience by the Aquarium and other groups suggests that many of the inservice workshops either did not occur or were not of high quality. Qualitative feedback from other workshops suggested that the inservice needs of teachers attending the summer programs were not being fully addressed. As a result of this need, an inservice attitude instrument was developed. By having an inservice instrument which could be administered at the start and end of a summer program, as well as months later during the school year, it was hoped that the quality of inservice sessions could be improved. For example, concerns of teachers could be targeted during summer programs and during follow-up contacts.

Development of the Instrument

The 33-item instrument was developed using a number of pilot data collections and critiques by expert judges. A six-step rating scale was utilized. This scale consisted of three agree categories (i.e., Strongly Agree, Halfway between Strongly Agree and Agree, and Agree and three disagree categories (i.e., Strongly Disagree, Halfway between Strongly Disagree and Disagree, and Disagree). Respondents could circle any single category. Also respondents were not required to answer all survey items. A logistic model was utilized (a) to refine the instrument, (b) to calculate item difficulties, and (c) to calibrate mean respondent attitudes. Partitioning of data revealed reliabilites ranging from .79 to .89. The three pages of the exact instrument distributed to the teachers are shown in Figures 1, 2, and 3.

Results and Implications

The instrument has been administered to teachers attending a number of yearly 3-week long institutes held at the National Aquarium in Baltimore. Teachers completed the instrument at the start and end of each institute. In addition, the instrument was administered to teachers who attended inservice workshops presented by the summer participants that were offered during the school year. Figure 4 presents the attitudinal ordering of items when data from the beginning of the 1993 and 1995 institutes were analyzed. Figure 5 presents the attitudinal ordering of items when data from the end of the 1993 and 1995 institutes were analyzed. Analysis of data indicated that a number of items were consistently highly rated (easy to agree with) by teachers, while other items consistently received low ratings (were easy to disagree with). For example item 1, "I will feel comfortable conducting an inservice for colleagues in my district;" item 8, "I will look forward to demonstrating science

Name:______________ Today's Date (Day/Month/Year):______________
Grade Presently Teaching:________________
Are you a classroom teacher, trainer of teachers, or involved in informal science education? ______________

Aquarium teachers! Would you please provide some feedback to us by circling the response that best describes your view. Thanks!! Living in Water is abbreviated as LIW.

Strongly Agree=1
Halfway between Strongly Agree and Agree=2
Agree=3
Disagree=4
Halfway between Disagree and Strongly Disagree=5
Strongly Disagree=6

1) I will feel comfortable conducting a LIW inservice for colleagues at my school.
   1 2 3 4 5 6
   SA A D SD
2) I will feel comfortable conducting a LIW inservice for colleagues in my district.
   1 2 3 4 5 6
   SA A D SD
3) Teachers in my district will gladly attend a required LIW inservice.
   1 2 3 4 5 6
   SA A D SD
4) Teachers in my district will gladly attend a voluntary LIW inservice.
   1 2 3 4 5 6
   SA A D SD
5) During my inservice, I will be comfortable explaining LIW science content.
   1 2 3 4 5 6
   SA A D SD
6) Teachers attending my inservice will be comfortable with my explanation of the science content in LIW.
   1 2 3 4 5 6
   SA A D SD
7) I will be able to convince teachers attending my inservice that LIW curriculum should be used in their classrooms.
   1 2 3 4 5 6
   SA A D SD
8) I look forward to demonstrating LIW science phenomena.
   1 2 3 4 5 6
   SA A D SD
9) I look forward to speaking about LIW to other teachers.
   1 2 3 4 5 6
   SA A D SD
10) I look forward to physically helping teachers construct LIW labs.
   1 2 3 4 5 6
   SA A D SD

Figure 1. The first page of the instrument, items 1-10, exactly as presented to the teachers.

Strongly Agree=1
Halfway between Strongly Agree and Agree=2
Agree=3
Disagree=4
Halfway Between Disagree and Strongly Disagree=5
Strongly Disagree=6

11) I am willing to spend time to set up equipment for a LIW inservice.
1 2 3 4 5 6
SA A D SD

12) Teachers at a LIW inservice will probably ask me questions I cannot answer.
1 2 3 4 5 6
SA A D SD

13) During my inservice, science experiments will probably not turn out as expected.
1 2 3 4 5 6
SA A D SD

14) A LIW inservice will take a lot of my own time.
1 2 3 4 5 6
SA A D SD

15) A LIW inservice will take a lot of other teachers time.
1 2 3 4 5 6
SA A D SD

16) My LIW inservice will have a limited effect on attending teachers.
1 2 3 4 5 6
SA A D SD

17) During my inservice, I will be able to explain how to evaluate the success of using LIW.
1 2 3 4 5 6
SA A D SD

18) During my inservice, I will be able to explain how LIW instructional approaches could be altered by teachers.
1 2 3 4 5 6
SA A D SD

19) I know the steps necessary to present an effective inservice.
1 2 3 4 5 6
SA A D SD

20) I know how to effectively organize an inservice.
1 2 3 4 5 6
SA A D SD

21) I know how to narrow the amount of material I will present for an inservice.
1 2 3 4 5 6
SA A D SD

22) I know what teachers want out of an inservice.
1 2 3 4 5 6
SA A D SD

Figure 2. The second page of the instrument, items 11-22, exactly as presented to the teachers.

Strongly Agree=1
Halfway between Strongly Agree and Agree=2
Agree=3
Disagree=4
Halfway Between Disagree and Strongly Disagree=5
Strongly Disagree=6

23) The cost of materials for LIW makes me hesitant to present an inservice.
1 2 3 4 5 6
SA A D SD

24) The availability of materials for a LIW inservice makes me hesitant to present an inservice.
1 2 3 4 5 6
SA A D SD

25) Having a resource person at the aquarium available for the planning of an inservice is important.
1 2 3 4 5 6
SA A D SD

26) Practicing my inservice during the workshop would make me feel better about presenting the inservice.
1 2 3 4 5 6
SA A D SD

27) Being able to present the inservice as a team would result in a better inservice.
1 2 3 4 5 6
SA A D SD

28) Being able to explain how LIW fits into a curriculum will greatly affect the success of an inservice.
1 2 3 4 5 6
SA A D SD

29) My district will be interested in the LIW inservice I present.
1 2 3 4 5 6
SA A D SD

30) Other teachers in my district will feel threatened by my presenting an inservice.
1 2 3 4 5 6
SA A D SD

31) Red tape in my district will make the presenting of an inservice difficult.
1 2 3 4 5 6
SA A D SD

32) I view myself as a leader in my school.
1 2 3 4 5 6
SA A D SD

33) I am comfortable when confronted with questions that I have no immediate answer to.
1 2 3 4 5 6
SA A D SD

Figure 3. The third page of the instrument, items 23-33, exactly as presented to the teachers.

Items Administered at the Start of the 1993 and 1995 Institutes

1
Q1 I will feel comfortable conducting a LIW inservice for colleagues at my school
Q8 I look forward to demonstrating LIW science phenomena
Q28 Being able to explain how LIW fits into a curriculum will greatly effect the success of an inservic
S Q2ComfortConductInsM Q5ConfortExplainSciC Q9LookForwardSpeakin Q11IWillSpendTimeEqu Q29DistrictInterest
Q30TechersNotThreate **RATINGS ABOVE THIS POINT TEND TO BE THE STRONGLY AGREE/AGREE CATEGORY**
Q32IAmleaderInSchool
Q10LookForwardConstr Q33ConforttableWithQ
Q6TAttendConfortWith Q7WillConviTeachersU
Q18IWillExpHowLIWIns Q20CanOrgInserv Q22KnowWhatTeachersW Q25NeedResourcePerso
M Q19ICanPrese.EffectI Q21KnowHowToNarrowAb Q27TeamForIns
Q31RedTapeMakesInsNo
Q4TGaldAttendVolIns Q26PracticingImp
Q16InsWillNotHaveLim Q17IWillExplHowToEva Q23CostOfMaterialsNo
Q24AvailabOfMaterial
Q3TGaldAttendReqIns **RATINGS BELOW THIS POINT TEND TO BE THE AGREE CATEGORY**
S

-1 **Q13 During my inservice, science experiments will probably turn out as expected (reverse coded)**

RATINGS BELOW THIS POINT TEND TO BE THE DISAGREE CATEGORY
Q **Q15 A LIW inservice will not take a lot of other teachers time (reverse coded)**

Q14 A LIW inservice will NOT take a lot of my own time (reverse coded)
Q12 Teachers at a LIW inservice will probably ask me questions I can answer (reverse coded)

-2

Note. Reverse coded items from survey are 12, 13, 14, 15, 16, 23, 24, 30, 31

Figure 4. Attitudinal ordering of items.

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Items Administered at the End of the 1993 and 1995 Institutes

2
Q

Q1 I will feel comfortable conducting a LIW inservice for colleagues at my school
Q2 I will feel comfortable conducting a LIW inservice for colleagues in my district

1

Q8LookForwardDemonst Q9LookForwardSpeakin Q11IWillSpendTimeEqu Q19ICanPrese.EffectI Q20CanOrgInser
Q5ConfortExplainSciC Q21KnowHowToNarrowAb Q28ExplHowLIWFitsW/C
Q10LookForwardConstr Q22KnowWhatTeachersW Q29DistrictintInterested
Q7WillConviTeacher Q33Conforttable **RATINGS ABOVE THIS POINT TEND TO BE THE STRONGLY AGREE/AGREE CATEGOR**
Q6TAttendConfortWith Q18IWillExpHowLIWIns Q30TechersNotThreate Q32IAmleaderInSchool

0

Q16InsWillNotHaveLim Q24AvailabOfMaterial Q27TeamForIns Q31RedTapeMakesInsNo
Q25NeedResourcePerso Q26PracticingImp
Q4TGaldAttendVolIns Q23CostOfMaterialsNo
Q17IWillExplHowToEva
Q3TGaldAttendReqIns **RATINGS BELOW THIS POINT TEND TO BE THE AGREE CATEGORY**

-1

Q15 A LIW inservice will not take a lot of other teachers time (reverse coded)
Q13 During my inservice, science experiments will probably turn out as expected (reverse coded)

Q
-2

RATINGS BELOW THIS POINT TEND TO BE THE DISAGREE CATEGORY
Q12 Teachers at a LIW inservice will probably ask me questions I can answer (reverse coded)
Q14 A LIW inservice will NOT take a lot of my own time (reverse coded)

-3

Note. Reverse coded items from survey are 12, 13, 14, 15, 16, 23, 24, 30, 31

Figure 5. Attitudinal ordering of items.

phenomena;" item 25, "Having a resource person for the planning of an inservice is important;" item 27, "Being able to present the inservice as a team would result in a better inservice;" and item 28; "Being able to explain how the material fits into the curriculum will greatly affect the success of the workshop" were rated very positively. On the other hand, item 12, "Teachers at an inservice will probably ask me questions I can answer;" item 13, "During my inservice, science experiments will probably turn out as expected;" item 14, "An inservice will not take a lot of my own time;" item 15, "An inservice will not take a lot of teachers' time;" and item 24, "The availability of materials for an inservice does not make me hesitant to present an inservice;" were answered, on the whole, with disagree categories.

The responses furnished for these and the other survey items greatly helps one gauge the confidence of teachers with regard to their presenting science inservice programs. Furthermore, these data help those presenting summer workshops by providing guidance with regard to common teacher concerns. For example, it is exceedingly important that those running summer programs carefully think how their teachers should sell possible curriculum innovations during day-long inservice presentations (see item 28). Survey item 25, involving the need for a resource person, points to the necessity for follow-up and support to science teachers. Usually some sort of follow-up connection (e.g., e-mail or a newsletter) is provided as a part of summer programs, but the rating supplied by science teachers to this item highlights the critical nature of follow-up support. Clearly, if groups such as the National Aquarium want their inservice workshops to be presented (and to be successful) then true back up support must be available. One of the lowest rated items for this survey involved the issue of time to set up an inservice (i.e., item 14). This concern on the part of teachers helps suggest that ways of streamlining all that is needed for an inservice must be provided in some way to teachers during the summer program. This does not mean just the science behind activities, but rather the need to address logistical issues of setting up a science inservice.

In terms of the refinement of this instrument, an analysis of the specific attitudinal categories was conducted. Figure 6 presents an analysis of the categories utilized by participants at the start of the 1993 and 1995 institutes. Figure 7 presents an analysis of the categories utilized by participants at the end of the 1993 and 1995 institutes. These figures show that the Halfway between Strongly Agree and Agree and Halfway between Strongly Disagree and Disagree did not provide important measurement precision. Therefore, a refinement of the instrument might be one in which only the Strongly Agree, Agree, Strongly Disagree, and Disagree categories are used.

What were some results of this data collection with respect to the summer institute offered at the National Aquarium in Baltimore?

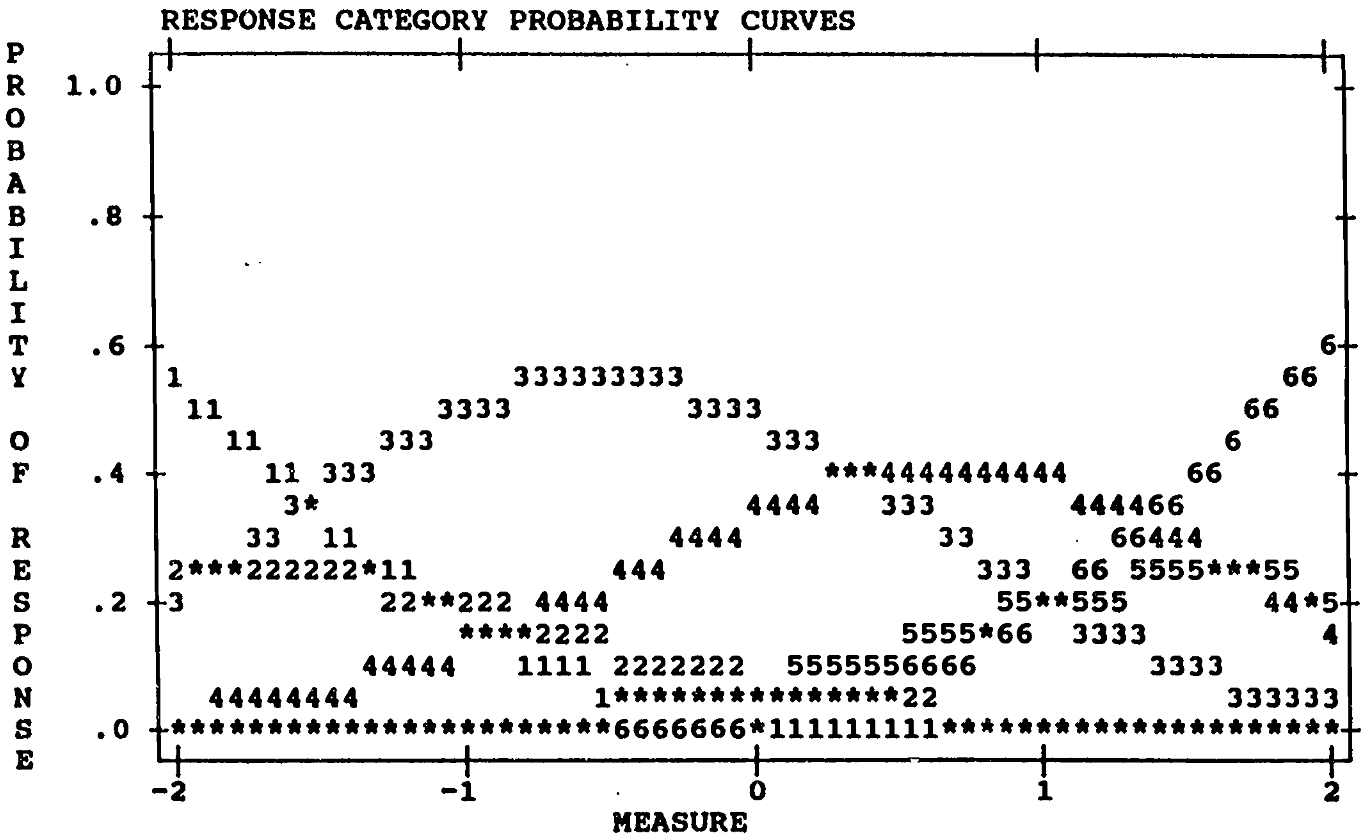
1) One kit with all purchased equipment and supplies is now shipped by Delta directly to the homes of all participating teachers. This is done during the week of the institute.

2) All materials that must be constructed (e.g., goggles, game boards, habitat cards, station cards for workshops) were completed during the institute.

3) All overheads needed for the inservice workshops were provided in overhead form (i.e., transparencies).

4) All handouts and evaluations for workshop participants were provided. Also, 100 copies of the curriculum were provided and shipped to the homes of the teachers.

<u>Items Administered at the Start of the 1993 and 1995 Institutes</u>



Strongly Agree=1
Halfway between Strongly Agree and Agree=2
Agree=3
Disagree=4
Halfway between Strongly Disgree and Disagree=5
Strongly Disagree=6

Figure 6. Analysis of the specific attitudinal categories.

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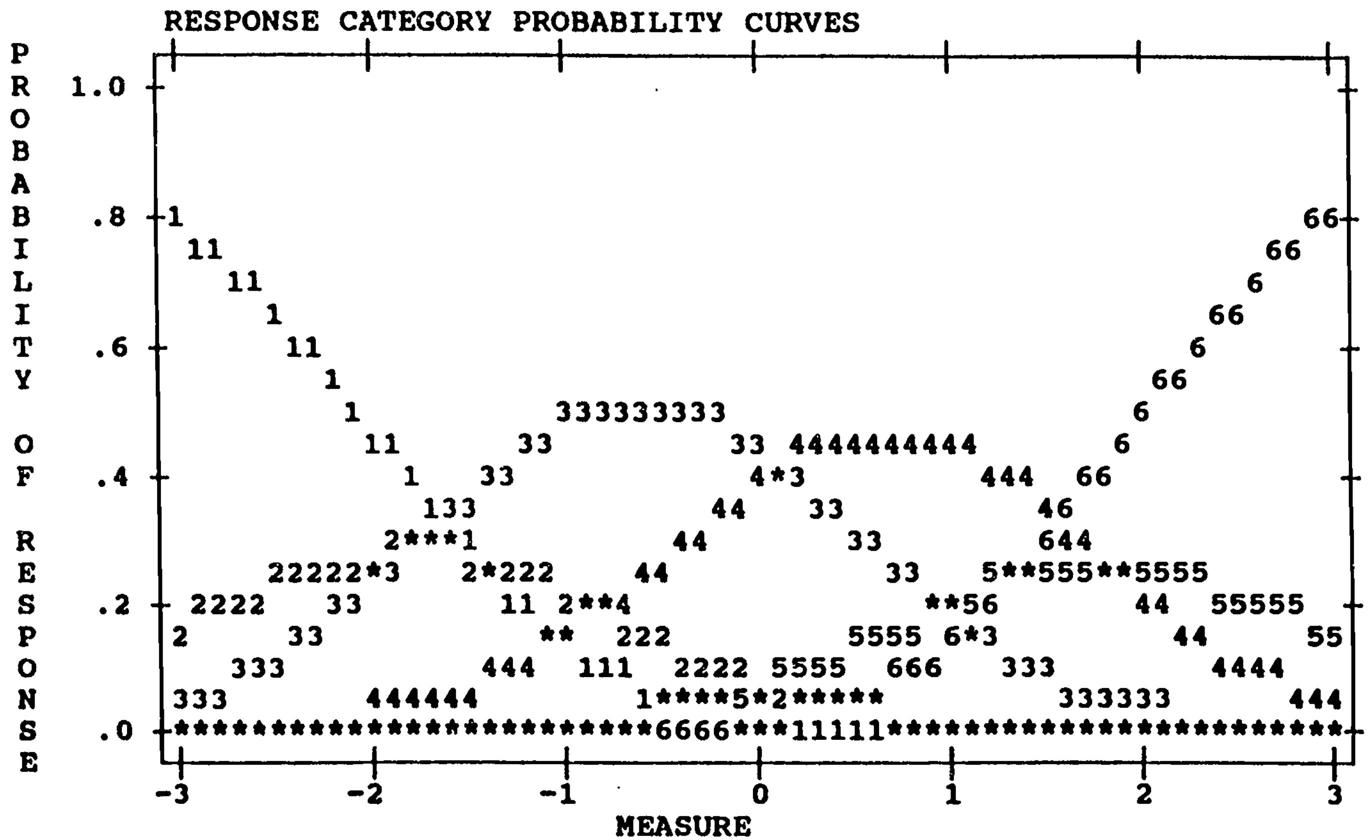

Strongly Agree=1
Halfway between Strongly Agree and Agree=2
Agree=3
Disagree=4
Halfway between Strongly Disagree and Disagree=5
Strongly Disagree=6

Figure 7. Analysis of the specific attitudinal categories.

5) The instructor of the institute set up a model six-hour workshop and participants shared instructional tasks. They were able to see, do, and lead a model workshop during the summer. They were then able to discuss instructional strategies.

6) The teachers were provided with copies of National Science Teachers Association short course proposal forms. These forms were distributed to encourage the presentation of other workshops.

7) The teachers receive a newsletter every four to six weeks. The letter shares teaching information, as well as social tidbits. It is chatty and fun, as well as informational.

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ELEMENTARY SCIENCE EDUCATION PARTNERS: A PATHWAY FOR PROFESSIONAL GROWTH FOR ELEMENTARY SCIENCE TEACHERS

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Abstract

The Elementary Science Education Partners (ESEP) pilot program began in September of 1994 with the intent of increasing the number of minutes elementary students engage in hands-on, inquiry science by creating a partnership between an elementary science teacher and a college student majoring in science. An unexpected development in the project was the increased interest in hands-on, inquiry techniques by the participating teachers and the subsequent request for in-service experiences which would increase their confidence and ability to do hands-on, inquiry science. As a result of the teacher's interest in summer workshops, a professional development component was added to the ESEP program. This paper shares the design, development, and implementation of the professional development component of the ESEP program.

Background

The lack of quality science education has become a point of concern in many academic communities. Elementary schools have been particularly noted because teachers often report that they are uncomfortable teaching science. The results, nationally, is that K-8 science is given little classroom time (NAEP, 1992), is often taught using textbook-based methods (Roychoudhury, 1994), and all too often is treated by teachers as an elective (Alberts, 1993). While manipulatives alone do not guarantee higher quality science, extensive evidence from the psychological and pedagogical literature suggest that the most effective learning occurs through hands-on, inquiry-based activities (Duckworth, et al., 1990; Tobin et al., 1994). The Elementary Science Education Partners (ESEP) program is based on the belief that: (1) children who achieve knowledge through inquiry-science approaches will retain it longer and will progressively expand and deepen their understanding (Helgeson, 1994) and (2) elementary teachers who participate in a partners program will become more interested in and excited about science instruction.

In the 1994-1995 pilot project, science majors were paired with elementary science teachers to help with science instruction. Very early in the project, the partner journal began to indicate that the teachers were becoming more involved in the lessons and were asking the partner if in-service opportunities were available. They appeared to feel empowered to seek help in strengthening a weak area because the partner had made science interesting instead of intimidating. Questionnaires given to the teachers at the end of the first term also indicated that the teachers were interested in increasing their own ability to teach science as they were seeing it taught by the science partner. A final conference with the principals of the participating schools reinforced the desire of the teachers for more science in-service. Because of the above data, the professional development component was added to the National Science Foundation proposal. Shroyer et al (1995) suggest a professional development model that includes (1) use of theory, demonstration, supervised practice, feedback, and coaching in simulated and real situations, (2) time to assimilate the new concepts, (3) on-going assistance and support, and (4) connectedness to school settings and to school-wide improvement efforts. This project attempts to meet the above criteria by: (1) having a partner in the science classroom each week for a year, (2) having workshops throughout the year allowing teachers to practice and refine new skills, (3) having an institute in the summer in relating theory to practice, and (4) working with district to revise science curriculum standards.

Goals

The professional development goals of the 1995-2000 ESEP program as funded by the National Science Foundation are to (1) place undergraduate science majors from Emory, Georgia State, and the Atlanta University Center in Atlanta Public School (APS) system elementary classrooms as change-agents to stimulate in teachers a wish to improve their knowledge of science and their science teaching skills, (2) provide in-service opportunities in hands-on, inquiry science methodology during the year and summer for Atlanta Public School teachers, and (3) move teachers into a new kit-based curriculum sanctioned by the Atlanta Public School system.

Procedures

The professional development component of the ESEP program includes the following three parts: (1) having a science partner in the elementary classroom for a full academic year, (2) participating in a two-day in-service workshop during the Fall, Winter, and Spring terms to familiarize the teachers with hands-on science and the specific kit to be used that term, and (3) participating in a two week summer institute to expand the skills learned in the Fall, Winter, Spring workshops and add more in depth equity training.

Undergraduate science majors are given the opportunity to take a 2-credit science course that has field placement in an elementary school classroom as a major component. After having an orientation session focusing on diverse populations and hands-on, inquiry science methodology, these students are paired with an elementary science teacher. Having a strong content knowledge but very little pedagogical knowledge, these partners help the classroom teacher by coming into the science class for 3-4 hours a week and acting much like a para-professional. With the help and guidance of the teacher, the partner plans active, inquiry-based activities to enhance the on-going curriculum. They then help the teacher (or the teachers helps them) as the activity is presented to the class. If the teacher has not been supplied with a kit, supplies and equipment are provided by the partner and are often borrowed from the university science departments. When a kit is available, the partnership works together to guide the pupils through the lessons. The presence of a scheduled partner means that science is planned in a collaborative manner, specific time is set aside for science, and active, inquiry-based lessons are produced. The science partner and the classroom teacher are encouraged to debrief after each science activity. This helps both the science partner and the teacher become aware of what has been successful and what has not.

In addition to the plan, teach, debrief cycle which occurs each week with the teacher/science partner, the teachers are given the opportunity to learn more about the science kits that are being infused into the elementary curriculum in the Atlanta Public School system by attending two day workshops during each term. The school system provides the funding for teacher release time and for the purchase of the science kits as well as a site for the workshops to be held. These workshops introduce the kits and model the use of a science partner. The emphasis is on getting to know the kit and being able to use hands-on, inquiry techniques with pupils.

The third part of the professional development is the two week summer institute. During the institute, teachers are again involved in working through the kit-based lesson that their pupils will encounter during the following academic year. In addition, more emphasis is put on equitable teaching methodology and inclusion of all pupils in science.

The Atlanta Public School system has establish a Committee for Science Curriculum Reform which has sanctioned the use of a kit-based curriculum for grades K-5. The kits that were recommended by the ESEP program and the Committee for Science Curriculum Reform have been selected because of their match to the Quality Core Curriculum objectives for the state of Georgia, their science integrity, and their emphasis on hands-on, inquiry techniques. These kits have been field tested by the manufacturers and are being used by several other NSF funded projects. Each grade level will eventually have a life science, a physical science, and an earth science kit (appendix A).

Results

As of the end of Fall 1995, 45 teachers from 16 of the 73 elementary schools in the Atlanta Public School system have had the opportunity to attend a two day in-service which introduced the first kit to be used by each grade level. The grades covered in the first round of workshops were second, third, and fourth. When it was possible, the science partner attended part of the in-service to also become familiar with the content and procedures of the kit. Forty-five teacher/science partners in 16 schools used a kit-based approach during the first term. The remaining teacher/science partners used activities from the ESEP activity manual or other sources to develop hands-on experiences for the pupils.

Two day in-service dates have been set for January and February for all the teachers in the first through fifth grades in the 16 schools with partners (Appendix B). The in-service will introduce these teachers to a kit that will then be used immediately with students. Summer workshops have been established with the help of Atlanta Public Schools for these teachers and for teachers in the next set of 15 schools who will be getting partners in the Fall. Assessment and evaluation of the project, including the professional development component, is being guided by the Assessment and Evaluation Department of Atlanta Public schools.

The data collected from students journals, debriefings with teachers, and pupil inventories indicate the following: (1) science partners are developing new ways of looking at science, (2) the teachers are energized and show an enthusiasm and interested in scien... ..at prior to the program was missing, and (3) the pupils show an increase in positive attitudes toward science and desire to study science.

Conclusion

The professional development component of the ESEP program is a strong and necessary part of the ESEP project. Having the partner appears to be the very important first step in helping the teachers decide that they want to know more about science and hands-on teaching techniques. In this capacity as change agent, the science partner starts the professional development of the elementary teacher. Having well planned and well implemented in-service workshops for the participating teachers has continued the growth of many of these teachers. The close collaboration between the ESEP program and the Atlanta Public School system has helped to insure the success of the project. As the kits are introduced, the teachers become more of a true partner in the relationship. The kits appear to act as an equalizer between the teacher and the science partner.

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Appendix A

ESEP/Atlanta Public Schools Proposed Matrix of Science Teaching Kits

GRADE LEVEL	LIFE SCIENCE	PHYSICAL SCIENCE	EARTH SCIENCE
1	Life Cycle of Butterflies (STC)	Solids and Liquids (FOSS)	Weather (STC)
2	Habitats (Insights)	Balance and Motion (FOSS)	Pebbles, Sand, Silt (FOSS)
3	Plant Growth and Development (STC)	Chemical Tests (STC)	Earth Movements (Delta) or Solar System (Delta)
4	Food Chen[illegible]y (STC)	Electric Circuits (STC) or Measurements (FOSS)	Rocks and Minerals (STC) or Weather Forecasting (Delta)
5	Ecosystems (STC or Human Body Systems (Insights)	Mixtures and Solutions (FOSS)	Landforms (FOSS)

Appendix B

Proposed Schedule for First Through Fifth Grade Kit Training

Dates	Grade	Kit	Number of Participants
Jan. 30-31	3	Plant Growth and Development	59
Feb. 6-7	2	Balance and Motion	62
Feb. 20-21	4	Food Chemistry	47
Feb. 27-28	1	Solids and Liquids	66
Mar. 12-13	5	Mixtures and Solids	46

UTILIZING SCIENCE FICTION STORIES TO REINFORCE STUDENT LEARNING IN EARTH/SPACE SCIENCE CONTENT COURSES.

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Introduction

My grade 11 and 12 high-school astronomy students watched in horror, amazement, or wonder as I walked over and dropped the day's exams into the garbage bin. Suddenly, the room burst with noise as several students whooped with excitement at the thought of not having to take a test, others loudly protested against the number of hours spent in preparation over a test that would not be taken and that could've been spent in other ways, while others sat silently dumbfounded at my uncharacteristic move. I dusted my hands together, pointed to the list of vocabulary words previously discussed, studied, and learned by the class in the past unit on the sun, reassured and consoled the students that in fact they were to have an exam that day, and began the explanation of what the exam would consist of.

This was the beginning of my intuitive move into writing fictional stories in a science content classroom. It wouldn't be until recent years that I would realize the magnitude of that step. Well aware of the importance of integrating a wide variety of teaching strategies into learning experiences, including the incorporation of writing in science, I was searching for creative outlets for my students to demonstrate acquired knowledge. I questioned the validity of using innovative strategies to teach content and traditional measures to assess. It didn't make sense. So, while driving the 45 minutes to school that early morning, I began to formulate the idea of having the students write stories.

From the onset of these first stories in my high school astronomy classroom, I continued to incorporate not only written science fiction stories, but also the reading of fictional books in which science was naturally integrated. Excellent examples of science in writing can be found in the works of such writers as Michael Crichton, Dean Koontz, and James Michener. Students gain a more solid background of contextual science knowledge by reading-in-science through a variety of formats such as text, scientific research articles, fiction, and by writing-in-science to formulate thoughts, organize and report data, and manipulate content via story form.

The addition of story narrative offers educators a more sophisticated picture of student understanding and application of learned concepts while providing an opportunity for students to develop writing skills. Stories should incorporate qualities of good science fiction such as creative descriptions using imaginative vocabulary; cohesive story lines focused around problems that need to be solve, drama to interest readers, and the added dimension of reflecting reality in other ways than we know it. Recent science education reform literature emphasizing scientific literacy as the goal of science education identifies written communications as key to developing this literacy (AAAS, 1993. NRC, 1994). The use of language in science is not a product of current reform movements, yet it is emerging as an active research field considered important to the establishment of scientific literacy through constructive teaching/learning practices. Science naturally is described and understood through an unique language, and the importance of being able to not only understand this language, but also demonstrate the ability to communicate this understanding through written formats is necessary to the quest for understanding science phenomena.

Much of the current literature dealing with writing-in-science targets elementary classrooms (Gallas, 1994); the work reported in this paper is a spin off of the writing-to-learn science with more mature science students to reinforce science content instruction and to model the use of this viable teaching/learning strategy to pre-service teachers (Parker, 1992; Unsworth & Lockhart, 1994; Woodford, 1967). When it authenticates scientific practices, writing-to-learn-in-science provides opportunities for learners to think about what they are learning, aids in clarification of that thinking process, and adds relevancy to learning situations (Bahns, 1989; Connolly, 1989; Feely, 1992; Holliday, 1992; Jan, 1993; Linek, 1992; Vacca & Scott, 1993).

This paper describes ongoing research involving science fiction story writing in science content courses for pre-service teachers that attempts to incorporate suggested components of writing-to-learn recommendations.

Background

Increasing scientific literacy through written communication

One of the eight major outcomes in science education, as defined by the National Statement of Science for Australian Schools, is that students possess the capacity to effectively communicate science knowledge. Literacy associated skills such as reading, writing, listening, and speaking are not only established as fundamental to science education. These skills must be an integral component of science education practices not merely a peripheral ability rarely considered. Science teaching that establishes links between learners' prior knowledge and experiences, provides analogies and concept labels between the two and that provides insights into the scientific enterprise through logic and clear examples will increase scientific literacy (Holliday, Yore, & Alvermann, 1994).

Constructivisim has provided a model of learning science that places a stronger focus on language in which a partnership between language and science can exist. This partnership along with gender inclusive science and scientific discourse has moved science education from a traditional prescriptive model to one that is interactive and reflexive (Parker, 1992).

Gender inclusive constructivist practices place greater emphasis on language and cooperative group learning approaches to humanize images of science and provide learners opportunities to be creative and participatory. A word of caution to science educators is to not assess constructivist teaching/learning practices with traditional means; it is important that assessment match specific teaching strategies. According to Woodford (1967) the enigmatic nature of scientific discourse presents two obstacles to effective use of language in science: students' development and expertise in the use of scientific discourse can camouflage their lack of contextual understanding; and, there is a profusion of grammatical problems involved with scientific English. Being able to adequately evaluate student conceptual progress through writing techniques contributes to an effective gender inclusive constructivist based teaching strategy, consequently when teachers anticipate what particular student problems with scienctific discourse may arise, they are better prepared in guiding students forward to sounder science conceptual understanding.

Even though writing in science benefits students in the learning process by guiding them to develop and construct contextual knowledge, convincing teachers to utilize writing in science classrooms presents another barrier. Some of this resistance relates to many teachers' own comfort levels with scientific discourse shown by their lack of understanding when reading poorly written, confusing, and verbose scientific prose such as texts and articles. Inferior writing of scientific articles leads to misconstruction of information, thus fostering teachers' belief systems of their own lack of scientific knowledge (Woodford, 1967).

While research is addressing problems inherent in learning scientific discourse, there is no consensus as to how science educators should resolve these problems. Parker (1992) suggests that science teachers interested in placing more emphasis in their classrooms on gender-inclusive and constructivist learning strategies, in which language is an essential component, systematically develop professional development programmes and establish on-going dialogue between English and science teachers. However, caution must be taken to introduce changes gradually into the curricula in order to raise teacher comfort levels with novel teaching strategies.

Writing-to-learn-in-science strategies will not be incorporated until the writing process is an important and valued element of all curriculum areas (Jan, 1993). In order to move educators closer to realizing the value of incorporating and the understanding of how to employ writing-to-learn strategies into their respective curricula, they should first understand the theoretical underpinnings of these activities.

Writing-to-learn in science

According to Howard and Barton (1986) writing involves more than just communication. Writing is: a symbolic activity that helps create meaning to what is being learned; a staged performance for others; and, a tool for understanding as well as communication (Howard & Barton, 1986). Writing provides learners opportunities to think about what they are learning (Vacca & Linek, 1992), clarifies thought, allows for analytical criticism, reflection, and further development of ideas. Once written, an idea reveals its validity or fault — after which it can be developed in greater depth or corrected to reflect understanding (Woodford, 1967).

Another positive benefit of teaching scientific writing is the strengthening of students' abilities to write more clearly, read more attentively, and think rigorously while developing sound reasoning practices (Bahns, 1989; Woodford, 1967). Clarity in writing is achieved when logic, accuracy of thought, and precision is present. Poor writing provides insight to student confusion or unsureness of thought regarding science concepts. Manipulation of learned science concepts through writing tasks permits students to develop their thinking processes on their own and not through simply regurgitating facts provided (Woodford, 1967).

Writing-in-science that is grounded in reason and authenticates scientific practice furnishes students with relevant experiences (Scott, 1993). When students are actively engaged in writing-in-science, they are able to move from lower order to higher order thinking, develop organizational skills, and apply learned knowledge in new situations that arise (Holliday, 1992). Writing allows learners to explain what they think is happening in a scientific encounter, may cause them to discover and correct mistakes, and consequently enable them to transmit their knowledge to others. Written communication provides learners access to their own thought processes. Feely (1993) suggests verbal communication precede writing practices in order for students to clarify their thoughts before putting them on paper. However, learners need actual experiences with which to think about science, rather than just receiving information from teacher lecture or text reading formats. Experimentation with scienctific phenomena, discussing results, brainstorming with others, and writing about these experiences offer learners more opportunities to insight into science concepts.

Along the same lines, Jan (1993) concludes that writing-to-learn-in-science requires authentic scientific circumstances in which learning can be organized, and that this process is important for all curriculum areas. Writing-to-learn tasks need to be more than just filling out charts and prepared handouts; instead these assignments need to incorporate composing, which requires active learner engagement in reasoning and thinking. Jan (1993) also determines that authentic scientific circumstances provide appropriate contexts for writing tasks that promote knowledge gain, control active thinking, and make connections to prior knowledge.

Teaching strategies that rely on traditional science lectures, text, and scientific article can push students toward rote memorization and mimicry, when learning contexts would be more meaningful and comprehensive if writing were used to develop student conceptual understanding. The use of language intrinsic in prior experience brings a certain fluency to science contexts thus increasing learners' abilities to construct conceptual meanings (Connolly, 1989).

Current research practices

Moore (1993) asserts that there is very little quantitative evidence supporting the notions that students learn science more effectively through writing, and that most conducted and reported research is purely anecdotal. However, science educators are addressing the lack of quantitative research in writing-to-learn-in-science through the areas of theoretical inquiry, classroom-based projects, and teacher-enhancement actions (Holliday, Yore, & Alvermann, 1994; Yore, 1996). Interestingly, Moore (1993), himself, demonstrated that science learning is enhanced when students write in science courses, and that when students are taught writing practices along with content knowledge, they significantly demonstrate greater understanding of science content material. In addition, the reflection of thinking demonstrated in effective writing points to the viability of using writing in other curriculum courses.

Despite Moore's findings that support writing-to-learn-in-science practices, he continues to imply that qualitative research data on writing-to-learn-in-science does not provide enough evidence to support better teaching and learning practices. When Unsworth and Lockhart (1994) conducted an observational study of common place reading and writing tasks assigned by teachers to science students in a junior primary school setting, they found that explicit teaching of grammatical forms of written language were not included in any science instruction and that there were no specific interrelationships between common sense understanding and generalized scientific understanding. However, teachers did provide structure in the process of helping students move from original language to written language. Unsworth and Lockhart (1994) were unable to reach any solid conclusions regarding their study and strongly recommended further observational study in the usage of writing-to-learn-science.

Chinn and Hilgers (Manoa Writing Project, 1993) studied relationships between instructor goals, instructional activities, and student assessment of their learning in natural science courses that used extensive writing assignments. Learners that had professors that treated them as apprentice scientists, assigned realistic writing assignments that were presented to an audience besides the instructors, and had frequent interactions with students achieved higher science scores and had better attitudes regarding writing-to-learn than students who had professors that acted as external evaluators and criticists. Liss and Hanson (1993) had similar findings to support the practice of using writing strategies as part of the learning process. Both research studies found that writing-in-science had more value when instructors gave numerous writing tasks, directed the writing, and encouraged peer collaboration (Liss & Hanson, 1993; Manoa Writing Project, 1993).

Connor, Prain, & Hand (1994) utilized two different teaching strategies in year 10 classrooms based on writing-in-science in which steps for successful writing were inherent to science instruction. One strategy focused on redrafting written work to extend student conceptual understanding and the other strategy focused on the verbal presentation of an individual student research project. Connor et al (1994) found that students engaged in relevant redrafting writing tasks became more aware of the learning process, monitored their own learning more successfully, and demonstrated more insight into scientific inquiry and its application to the global world.

Often the value of writing-in-science to facilitate the "minds-on" construction of knowledge does not reach its potential due to the enduring traditions of rote memorization and lecture style teaching strategies. Even though undergraduate students report that writing tasks are often difficult, time-consuming, and stressful, they find these tasks highly valuable in the learning process. Students tend to look upon writing tasks more favorably when they are used as part of the learning process rather than as the end-product (Liss & Hanson, 1993).

Research practices indicate that even though writing in science helps students develop and construct contextual knowledge, persuading teachers to utilize writing in science classrooms is not easy (Tobias, 1989). When analyzing personal student journals of her graduate classes of in-service teachers, Bahns (1993) found that many students felt ill prepared and not adquately qualified to teach science. Teacher modeling is important to successful writing-to-learn-science tasks; if teachers do not feel prepared or qualified to teach writing-in-science, they are less likely to be effective at helping their students develop sound scientific understanding (Feely, 1993). However, according to Feely (1993) science teachers do not necessarily have to teach students how to write; instead, teachers need to guide students to think and write as actual scientists would. University science content and content-pedagogical courses are an excellent arena to incorporate writing-to-learn-in-science techniques due to the valuable teaching strategy of instructor modeling and academic freedom in which to explore innovative ways of learning and teaching (Black, 1993).

Holliday (1992) suggests that when science teachers support writing classes that teach the correct mechanics of writing, they will be more successful in their efforts to include writing-to-learn strategies. Current research directs science teachers to spend more time helping students improve their writing through providing practice writing opportunities in which they can write about science as related to their personal experiences. It is also important that teachers help students realize that writing is a skill not solely related to English courses and encourage them to write more often in science. Instructor guidance in helping students plan, read, and revise their work in addition to offering ample feedback on writing assignments related to content acquisition and explanation of that knowledge, is helpful to successful writing-to-learn strategies. Finally, students should practice reading examples of types of things they will be eventually writing (Holliday, 1992).

Suggestions to help students write more effectively

Scardamalia and Bereitter (1986) offer the following suggestions for instructors to help students to write more effectively: supply opportunities for learners to articulate to others the knowledge they are gaining; help them begin to think like experts; and, model good writing in order strengthen the value of writing. Vacca and Linek (1992) and Yore (1996) recommend that science content be the focus of writing assignments and that assignments provide a synthesis for knowledge, not a regurgitation opportunity. In addition, an authentic audience for the writer's completed work is important and opportunities for students to play the roles of learner and researcher are advantageous. Talking or discussing ideas before writing contributes motivation to the experience, while peer revisions and multiple individual revisions allow for stronger synthesis of conceptual knowledge.

Morris, Francis, and Hill (1993) suggest that some students need to follow a writing guide that provides a sequence to sorting and ordering events. This "scaffolding" provides a temporary structure that gently leads students into the writing process and gradually turns accountability of the writing over to them. It is fundamental that teachers possess a solid understanding of different types and formats of writing assignments. Possibilities of writing tasks include: freewriting; focused freewriting; attitudinal writing; reflective, probative writing; "metacognitive" process writing; error explanation writing; questioning; summarizing; defining; creating problems; writing to read; learning logs; microthemes; and, paired problem solving tasks (Connolly, 1989). Newell (1984) identifies further writing, learning, and thinking tasks such as note taking, answering study questions and writing analytical essays. Rivard (1995) identifies two additional areas of writing to learn in science as expository writing which includes note taking, summarizing, analyzing and explaining, and expressive writing as informal journal and diary writing. The two areas can also be combined in the forms of daily journals, reading logs, short essay-type reports, cooperative writing, and lesson summaries. Burkhalter (1995) introduces the use of the "persuasive" essay based on Vygotsky's social interactionist approach to learning (i.e. zone of proximal development). Everett (1994) discusses the usage of portfolio entries and creative writing assignments to replace traditional report writing.

Students need to become “knowledge tellers” They need to be able to articulate acquired content knowledge to others. When students begin to think like experts they are able to follow and develop procedural techniques as experts do and are more likely to construct their writing in like manners. Again, when teachers effectively model appropriate writing strategies, writing-to-learn techniques are more valuable to learners (Scardamalia & Bereitter, 1986). Finally, Holliday, Yore, and Alverman (1994) state that WHETHER or not writing-to-learn-in-science is important to use as a teaching strategy is not a question. The question for educators to decide becomes WHEN is it appropriate. Writing should be a regular part of self-criticism and at the "very heart of a science curriculum" (Woodford, 1967. p. 744).

Science stories

Burns (1994) incorporated literature-based strategies into his science classes through reading and studying literature. He first used Isaac Asimov's *Fantastic Voyage* as a text for the human circulatory system. I have used Michael Crighton's *Jurrasic Park* to introduce Chaos theory; Hoeg's *Smilla Knows Snow* and Koontz's *Icebound* to teach glaciation; and have had students read novels with a science base to demonstrate science concepts in fictional writing (Black, 1994).

My original questions: "Why assess knowledge gained through non-traditional teaching strategies by traditional assessment practices?" and "What are some effective ways to utilize fictional writing to facilitate science content knowledge?" guided my entry into using stories in science. Few research examples as to effective results of writing-to-learn-in-science are found in current science educational research practices, yet there are numerous articles on ways and suggestions for incorporatiing writing in science. As far as I can determine, no prior research has been conducted in the area of writing-to-learn-in-science through writing science stories.

High-school story assignment on stars

In order to assess astronomy content acquisition, students were instructed to write individual stories during a 60 minute class session allocated for the unit exam. Directions were to write a story based on content taught during a unit on stars incorporating applicable vocabulary words and learners were instructed to appropriately use a certain percentage of these terms in their stories. Stories were written and turned in at the end of the session. In the following class session the next day, students worked together in groups of four to share their stories with peers, revise written work, and to write chapter introductions that would combine their stories into one.

Table 1a
Student Writing Samples

Once upon a time there was a teacher who liked to observe the sun from the Orbiting solar observatory (OSO). She would fly there every weaken [sic] and then report to class what she saw. Sometimes, though, she would take a trip to the Skylab and orbit the earth for a while in this manned lab.... He began to talk about a corona. We all got pretty excited because we thought he ment [sic] the beer Corona. What he ment [sic] was the outer atmosphere above the chromosphere, the suns corona.

Table 1b
Student Writing Samples

Along [sic] time ago, the chromosphere and photosphere lived their own lives. but as time passed the photosphere invited a sunspot, a dark shadow, to live with him.

Note: underlined words were assigned vocabulary to be included and used appropriately in the story.

University science content course for pre-service teachers

Upon shifting from teaching high-school courses to instructing university undergraduate science content courses, I developed the science story assignment to be appropriate at the higher content level of university learners. For university students in science content courses, directions were to take content provided during an astronomy unit and write a fictional story that could be presented to the class. During the first few terms, students would spend more time on creativity and presentation and less than enough on content. The assignment gradually progressed to where students were given a problem to solve, a galaxy to design, and then requested to present the story in written form and as a "reader's theatre" to the class.

Table 2a
Student Writing Samples

Narrator: In a solar system on the Cygnus arm of the Milky Way Galaxy, there is a planet called Zela. It is 11,960 km in diameter at the equator (Earth is 12,756 km) and is the third planet from its sun. its atmosphere is mostly carbon dioxide and is very dense. Because of the low gravity of this small planet, the beings living there grow to be very tall. The average height of an adult is 12 feet. The beings are also sightless due to the dense atmosphere, but they have sensory sonar wave receptors (like our bat on Earth).

Note: comparisons to Earth, switch from metres to feet, and attempt to employ a different visual system for beings based on what is seen in animals.

For the following sample, students were able to write stories based on their choice of any content presented during the entire Earth Science course. The following students chose to base their story on weather conditions throughout the world.

Table 2b
Student Writing Samples

..........A - Yeah, its amazing how different the rain in Thailand is compared to England.

M - That's due to temperature difference. It is cooler in England and warmer in Thailand. Remember, inThailand we went through so many changes of clothes, not only from the rain but also from high level of humidity.

S- Weren't you whining about wanting to go to a rice paddy and sit under a sun dryer because you were sick of being wet.

E - Ya, but you wouldn't do it because you were still holding a grudge about the mud incident and you refused to have anything to do with rice for the rest of the trip.

S - What is a sun dryer anyway?

A - It's when farmers utilize solar radiation to dry their rice paddies after the rainy season.

Note: the length of time for science content to become evident in dialogue, but the effectiveness of developing the creativity of the story to enhance understanding of certain concepts.

Current Stories

Introduction/Purpose of Assignment

This current assignment is a creative approach to problem solving and critical thinking. Content material is acquired in class sessions through lecture, student reading, individual research, team collaboration, story presentation, and final review. Science content knowledge is assessed through oral and written story presentation and a section of the final exam. Stories provide descriptions of student-designed fictional societies and their ethical or mechanical dilemmas. Stories are presented as skits, reader's theatres, or on video; the format is arranged with the instructor prior to presentation. Evidence of the group's ability to manipulate existing scientific theories in story form demonstrates assessable science knowledge acquisition.

Methods of content acquisition.

Space science content regarding stars, planets, galaxies, astronomical tools, and atmospheric conditions are taught during the unit through brief teacher lecture, class activities, and peer tutoring modeled after jigsaw learning strategies.

Methodology

Subjects: Subjects for current science stories explored in this paper were 145 pre-service teachers enrolled in an Earth science content course offered by the Department of Social and Natural Sciences (SNSC) in the Faculty of Education at the University of Victoria (UVIC).

Data Collection: Data included written stories collected each term from the 145 students enrolled in SNSC 145B sections.

Procedure

I. Students are given an imaginary situation set in the future in which they are directed to solve certain problems related to that situation (see Appendices A and B).

II. Further directions as to format of presentation, expected outcomes, marking expectations (see Appendix C), and important unit terms to be included in the story are discussed at the beginning of the unit (see Appendix D).

III. Solutions are to be written in story form which will be presented to a panel of experts during a 30 minute session in four weeks.

IV. Students are randomly assigned to a group of three or four members in which each student assumes a specialty role related to science content.

V. Each group has a representative who meets with the instructor before and after each class session. This provides an opportunity for nuts and bolts communication and problem shooting between instructor and students.

VI. Group delegations and responsibilities, story outlines, and rough drafts are collected at pre-arranged intervals throughout the term of the assignment.

VII. Final stories are presented to a panel of two to three faculty members informed in writing-to-learn strategies.

VIII. Marks for the presentation are based on originality, presentation, usage of terms, grammar, and connections between science content and story lines. Marks for written stories are given by the instructor (see Appendix E: Story Marking Grids).

Results

Student stories were analyzed based upon marking grids as described under procedures above. Story marks ranged from 72% to 99%, with an average group mark around 82%. I have noticed increased content mastery over time, but often find this rarely developed as often as rote "regurgitation" of facts couched in dialogue. However, recent final exam scores are tending to be higher at the end of each course with learners demonstrating greater strengths in astronomy content knowledge acquisition than noted in previous terms. When comparisons of stories are conducted between recent terms (1995 spring and fall) and past terms (1993 fall and 1994 spring), stories are showing marked improvement in writing style, problem solving capabilities, and content knowledge understanding.

Table 3a
Student Writing Samples

1. *The galaxy was formed over 20 billion years ago at approximately the same time as the Milky Way, our present [sic] galexy. The theory supported by the SNSC scientists working on his case is the Big Bang Theory. The scientists and myself believe that the universe was once a dense super massive ball which under went a cataclysmic explosion. Hurling material in an array of directions. Our new galaxy is receding [sic] at great velocities as it is far away from the centre of the universe.....*

Table 3b
Student Writing Samples

2. *Once you have cleared the Black Worm Hole, you can restart your engines. You will move toward the Ram Sam Sam Galaxy. You will pass by a group of beautiful, gleaming spherical clouds of gas. These planetary nebula are heated by a hot central White Dwarf, a smaller steliar star that was once a Red Giant that collapsed.*

An instructor-designed course evaluation is distributed to learners at the end of each term to ascertain course strengths and weaknesses based on student interest, difficulty, and value of any one individual assignment. Anonymous student comments regarding the story assignment center on difficulty of working with others in a group project and request more class time for writing. Student interest in the assignment varies slightly between terms, perceived difficulty of story assignment decreases slightly fiom one term to the next, and student value of the assignment remains constant at slightly below average levels for value. Based on current research recommendations, more writing activities along with increased levels of writing guidance will be incorporated during the next offering of the course.

Table 4
Student Perceptions

$\overline{X}$ values given from a 4.000 Lickert scale with 1 = low, 4 = high interest.

Term	Student Interest	Story Difficulty	Value of Assignment
Winter 95	2.750	3.235	2.313
Fall 95	2.500	2.185	2.313

Conclusion

Enhancement of science learning experiences

By utilizing writing fictional stories in science content courses for the past eight years, I have been going through the process of writing-to-learn in science by applying good teaching practices with measured success. As time goes on, I am able to see a definite improvement in student science content knowledge acquisition as a direct result of this exercise. Currently, the assignment of writing science fiction stories is enhanced by several writing projects prior to the unit in the form of lab reporting, daily written summaries, letters, focused free writing, reflective writing, and supplementary summarizing, questioning, and defining writing exercises (Holliday, Yore, & Alverman, 1994).

Continued research directions

Writing-to-learn in science does enhance the science learning experience; Writing science stories provides learners the opportunities to organize, clarify, and express knowledge they are gaining. It is clear that research in writing-to-learn science continue in order to determine more effective ways of using this strategies in science content courses. Suggestions for further research in writing-to-learn science include the following:

- Continued research into writing science fiction stories by manipulating content knowledge for content acquisition;

- Develop science content courses that provide multiple writing experiences in addition to the standard curriculum;
- Design curriculum for pre-service teachers that allows them opportunities to observe, practice, and value writing-in-science;
- Investigate elementary, intermediate, and secondary science classroom situations in which fictional writing is used as a strategy to enhance science conceptual learning;
- Develop writing-to-learn-in-science programmes for in-service teachers; and,
- Explore further application of writing-to-learn and reading-to-learn practices into science content courses.

While writing his book *Space* , Michener acknowledges his science knowledge in the following way:

> *Lacking specialized training in science, I was disadvantaged, but my long experience with mathematics and astronomy repaired some of the deficiency, and my work with various aspects of our program repaired other gaps. Most of all, I talked incessantly with experts, visited laboratories, and studied procedures.*

As Michener used his past experience and discussions with experts to write his novel, he conceptualized unfamiliar science knowledge to a point of knowing that allowed him to manipulate this knoweldge in the discourse of written fiction. His use of science through the written genre of science fiction thrills readers that have strong conceptual scientific knoweldge and enjoy seeing its uses in everday life.

Moore (1993) states that non-scientists use journal writing, brainstorming, free writing and other writing techniques to "create fiction, not knowledge". I disagree. In order for new knowledge about science to be assimilated and used by non-scientists, it must be associated to existing knowledge. Each learner must make these connections independently. Relevant science experiences explored through the written word affords each learner an opportunity to create these connections for sound conceptual science knowledge, not merely produce the residue of fiction.

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APPENDIX A

2523, Matril 16

PRESS RELEASE

Shocking news was released early this morning. Six scientific teams departed from our Federation in search of new galaxy systems that have planetary life essential to providing for human life. These teams were not scheduled to leave for another thirty years; however, students from the University of Victoria's SNSC 145B class took it upon themselves to solve the problems of environmental disasters once and for all. Their convictions, as reported on the airwaves this morning, are that by finding new areas to inhabit, the Federation will remain in control of the problems facing it.

An Intergalactic conference will be held ____*(dates)*______ where each team will be given 30 minutes to present their findings to the public and to provide descriptions of their newly found planet, moon(s), sun, stellar activity, and galaxy. As in all problematic situations, unexpected events occur. Earth scientists will attempt to guide each team during these situations, if and when they occur. Written reports will be provided in a special conference edition text.

The teams of _*(team leaders)*________ are specifically focusing on the location of these new galaxy systems, exploring the ways of transporting and relocating Earth's inhabitants, and preparing feasibility reports based on their findings. Two other teams directed by _*(team leaders)*_ ______ are directly researching and planning for the establishment of Earth colonies in the new galaxies with respect to food, shelter, and living conditions. The final two teams, under the leadership of________*(team leaders)*______, are reported as having traveled further ahead in time to report on the success of the established colonies after 50 years.

Interestingly, these students are armed with rich experiences in the formation of planets, especially geological processes. Each group of students consists of specialists in many scientific fields. It will be interesting to see what the outcome will be of these daring scientists as we await their reports at the next Intergalactic Congress sessions.

APPENDIX B

2523, Matril 15

INTERGALACTIC SPACE COMMUNICATION TO SNSC ESCAPE RESEARCH TEAMS

Since you and your colleagues have decided to take up the cause and search for new homes and together you feel you can offer the universe the needed solutions, as your governmental leaders, we assign you to carry out the following tasks:

1. Form together into six teams of four/five people in each team.

2. Identify your specialists that will explore the galaxies and planets you are searching for.

Individual specialist directions are outlined below.

SCIENCE SPECIALISTS

1. STELLAR FORMATION SPECIALIST- BIRTH, LIFE, & DEATH OF STARS (BLACKHOLES, NOVAS, SUPERNOVAS)

Your job as a solar specialists is to study the sun during Earth's time to determine what specific characteristics your own sun now has. You must look at all facets of the working of a sun. Remember the sun is a star. Be sure to include nuclear fission and fusion where necessary, light rays, magnetic fields, storms, etc. From this point you are to work with your team to determine how to solve your planet's ethical dilemmas. You are to determine current stellar formation in your galaxy. You need to be prepared to establish a new base for your planet in the event your existing sun goes supernova. You also need to determine distances from the existing blackholes and white dwarfs to be sure they do not affect your existing planetary system. From this point you are to work with your team to determine how to solve your planet's ethical dilemmas.

2. PLANETARY FORMATION, CHARACTERISTICS, & MOONS (ABILITY TO SUSTAIN LIFE)

Your job is to describe how your planet and your planetary system evolved. You need to know all the characteristics of your planet and its moons. How does it sustain life? What does it look like, how big is it? How does it compare to the ancient solar system that Earth was once a part of? From that point, work with your team to determine how to solve your planet's ethical dilemmas.

3. GALAXY SPECIALISTS - WITH EMPHASIS ON TECHNICIANS (COMMUNICATIONS, TRAVEL, OBSERVATIONS)

You are the galaxy specialists. You designed the galaxy you and your team now live in. What type of galaxy is it? How does it compare with other galaxies? What are your modes of travel and communication? How do other solar systems and galaxies know you are there? How do you know they exist? Work with your team to determine how you all fit together, how your society works, and how to solve the dilemma you are under.

4. ATMOSPHERIC SPECIALIST -

It is your quest to determine the atmospheric conditions appropriate to sustain human life on your new planet. Is oxygen, water, food, shelter, warmth, temperature, etc. available on your planet? Or do you have to control the climate in some way to insure viable living conditions? How does your system function? Re-generate itself? Work with your team to determine how you all fit together, how your society works, and how to solve the dilemma you are under.

APPENDIX C

NUTS AND BOLTS REGARDING ASSIGNMENT AND CLASS:

Purpose of assignment: This is a creative approach to problem solving and critical thinking. Content material will be acquired in class sessions through lecture, student reading, specialist research, team collaboration, story presentation, final review and assessed through oral and written story presentation and section of final exam. Your stories need to provide descriptions of your fictional society and its ethical or mechanical dilemmas. Stories can be presented as skits, reader's theatres, or on video; format is to be cleared by instructor prior to presentation. Evidence of the group's ability to manipulate existing scientific theories in astronomy should be clearly demonstrated.

Marks for stories will be based on the following criteria:

ORIGINALITY (15%)

PRESENTATION (be sure to proofread!!) (10%)

GRAMMAR (10%)

USAGE OF TERMS (50%)
Over 93 terms appear in chapters 17-20 in the Tarbuck text (list included). You are expected to use 45 of these terms and define them somewhere throughout your story. It is important that straight definitions NOT be used, but worked in as unobvious parts of dialog.

SOLID CONNECTIONS BETWEEN SCIENCE CONTENT AND STORY LINES (15%)

• **You are only required to be present during your thirty minute assigned time frame on**___*(date of presentation)*________. You are more than welcome to view any other group's presentations.

• **Class time will be given for group planning.**
However, class time will not be sufficient to produce the final presentation. You will need to establish roles, responsibilities, and outside meeting times right away. The better planned your group is, i.e. the more you delegate and take responsibility, the less you will have to meet outside of class. It is highly suggested that you PRACTICE your presentation.

• **Lecture sessions on content information will take place during the next three classes. It is imperative you read text assignments, attend all classes, and clarify any questions regarding the assignment or content material.**

APPENDIX D

Chapter 17 - The Earth's Place in the Universe

aphelion	astronomical unit	celestial sphere	
constellation	declination	ecliptic	
equatorial system	geocentric	heliocentric	
lunar eclipse	mean solar day	perihelion	
perturbation	phases of the moon	plane of the ecliptic	
precession	Ptolemaic system	retrograde motion	
revolution	right ascension	rotation	
sidereal day	sidereal month	solar eclipse	
synodic month	Copernicus	Tycho Brahe	Johannes Kepler
Galileo Galilei	Sir Isaac Newton	Stonehenge	

Chapter 18 - The Solar System

asteroid	Cassini division	coma	Pluto
comet	escape velocity	iron meteorite	
Jovian planet	lunar breccia	lunar regolith	
maria	meteor	meteorite	
meteor shower	nebular hypothesis	occultation	
stony-iron meteorite	stony meteorite	terrestrial planet	
protosun	ray crater	Mercury	
Venus	Mars	Jupiter	
Saturn	Uranus	Neptune	

Chapter 19 - Light, Astronomical Observations, and the Sun

aurora	bright-line (emission) spectrum	Hubble	
chromatic aberration	continuous spectrum		
corona	dark-line (absorption) spectrum	Caucasus Mountains	
Doppler effect	electromagnetic radiation	eyepiece	focal length
focus	granules	nuclear fusion	objective lens
photon	photosphere	plage	
prominence	proton-proton chain	radiation pressure	
radio interferometer	radio telescope	reflecting telescope	
refracting telescope	solar flare	solar wind	
spectroscope	spectroscopy	spicule	
chromosphere	sunspot		

Chapter 20 - Beyond Our Solar System

absolute magnitude	apparent magnitude	barred spiral galaxy
Big Bang	black hole	bright nebula
cluster	dark nebula	degenerate matter
elliptical galaxy	emission nebula	eruptive variable
galactic cluster	giant	globular cluster
Hertzsprung-Russell diagram		Hubble's law
hydrogen burning	interstellar dust	irregular galaxy
light-year	Local Group	magnitude
main-sequence stars	nebula	neutron star
nova	open cluster	parsec
planetary nebula	population I stars	population II stars
protostar	pulsar	pulsating variable
red giant	reflection nebula	spectral class
spiral galaxy	stellar parallax	supergiant
supernova	visual binaries	white dwarf

APPENDIX E

UNIVERSITY OF VICTORIA
SNSC 145B F01 95

SPACE SCIENCE STORIES MARKING

GROUP NAMES:

STORY TITLE:
DILEMMA:
PROBLEM:
WEATHER FOLKLORE:

PRESENTATION (50% of total mark)				
ORIGINALITY (15%)	1 3.75	2 7.5	3 11.25	4 15
PRESENTATION (10%)	1 2.5	2 5	3 7.5	4 10
USAGE OF TERMS (50%)	1 12.5	2 25	3 37.5	4 50
SOLID CONNECTIONS BETWEEN SCIENCE CONTENT & STORY LINES (25%)	1 6.25	2 12.5	3 18.75	4 25
TOTAL				

TEACHING AND LEARNING SCIENCE METHODS IN A LANGUAGE ARTS METHODS COURSE

Valarie L. Dickinson, Oregon State University
Julie Flanigan, Washington State University

Description of the Problem

Elementary teachers are usually very enthusiastic about teaching language arts and reading. They are confident about their own expertise in the subjects and are experienced at providing involving activities that interest their students. However, as evidenced by the 90 minutes a day spent on reading as compared to the 17 minutes per day spent on science (Enochs & Riggs, 1990), science is considered a lower priority subject in elementary school (Riggs & Enochs, 1990). Elementary teachers often feel reluctant to teach science because they believe they are inadequately prepared in how to do so, and they do not have enough content knowledge. Science is also not seen as something that helps moves students toward the goals of becoming literate readers and writers. Though most teachers agree that science should be taught in a "hands-on" fashion, they are unsure of their abilities to conduct such activities (Atwater, et. al., 1991). Even when using a curriculum designed to make teaching science teaching more accessible, many elementary teachers feel inadequately prepared (Bybee, 1991). Though teachers may realize they need to spend more time teaching science (Enochs, 1982), when time is short, science is often shortchanged in the elementary classroom (Cox & Carpenter, 1989). Teachers who do feel adequately prepared and confident will teach more science in the elementary school (Perkes, 1975). The challenge is to help elementary teachers use their enthusiasm, expertise, and confidence they have for teaching language arts to improve their science teaching.

Tompkins and Hosskison (1994) define language arts in the classroom as the development of reading, writing, speaking and listening skills in purposeful settings. They advocate having students discuss topics and listen to each other's viewpoints.

Students should read and write based on their experiences. Language arts shouldn't be limited to a prescribed time of the day, but be incorporated into other curricular areas. Science can provide purposeful experiences and topics for writing and discussion in language arts. Flick (in press) describes his study in which one experienced teacher strengthened her background in science, and used her expertise in language arts to provide good science instruction. In addition, the teacher's expertise in orchestrating discussions enabled her to uncover children's ideas about the science topic and to help students negotiate meaning. Roth, Peasley, Hazelwood, Hasbach, Hoekwater, Ligett, Lindquist, and Rosaen (1992) discuss that though their study of various curricular areas was not intended to be one of integration across the curriculum, the fifth grade students spontaneously drew connections across their writing, social studies and science classes. This occurred even though there was no thematic overlap of the topics in the different subjects. Students in the 1992 study stated that discussion with peers and oral and written questions from the teacher were much more helpful to their learning of science, and that grades given were not helpful to their learning of science. This lends support to integrating science within language arts. Mishler (1982) conducted a meta-analysis of various studies relating hands-on science and its effects on language arts skills by elementary students. Overall findings indicate that activities involved in hands-on science have potential for enhancing cognitive development. This paves the way for the most meaningful language development through reading, writing, listening and speaking. She advocates using an integration of science into language arts whenever possible because it helps develop cognitive skills beneficial to both science and language arts learning.

As a an elementary teacher very interested in science education, I (the first author, Valarie), was fortunate to find myself teaching a language arts methods course to preservice teachers. It gave me an interesting opportunity to find out whether science teaching of the preservice teachers could be influenced by integrating science within the language arts methods course. About three-fourths of my students were concurrently enrolled in a science methods course, which provided prime occasion to explore the question. Program goals included getting preservice teachers to (a) see the value of what they knew about language arts for teaching science, (b) think of language arts as a tool for exploring other subjects, in particular science, (c) see that by integrating language arts into science more time would be allotted in the classroom to teach science, and (d) recognize that skills in language arts can increase competence in science teaching. During the course of the class, students were developing teaching skills in language arts and gaining a commitment to inquire into the science subject matter to learn more about it.

This paper will describe how I, as the instructor of the course, integrated science methodology into a language arts methods course, and the outcomes of doing so. This paper will also discuss one preservice teacher's (Julie, the second author) use of the methodology in her science methods course and in her internship position.

Description of the Course

The course group consisted of 23 preservice elementary (K-8) teachers enrolled in a one semester language arts methods courses at a four-year research university. The purpose of the language arts class was to prepare preservice teachers to teach reading, writing, speaking, and listening skills in their future elementary teaching positions. The group was enrolled in the fall semester. There were only two preservice teachers with an intent to teach middle school science. One minored in earth science in which she took 22 credits of science, and the other majored in general science, in which he took 45 credits of science. The other preservice teachers in the course varied in their choices of four minors: reading, bilingual education, special education, or English as a second language (ESL). They were required to enroll in 6 semester credits of lower division math, 8 semester credits of lower division physical science, and 4 semester credits of lower division biology. Few of the preservice teachers had completed these requirements at the time of enrollment in the language arts course. The course was taught by one author who was an elementary teacher and enrolled in a doctoral program in science education. About 75% of the class was concurrently enrolled in a science methods course taught by a different instructor. To track student ideas assignments and interactions were recorded that were natural outcomes from the course. They included daily journal entries that were completed outside of class by the students, written and oral presentations of student work, and notes made of discussions, formal and informal, among students and between instructor and students. Videotapes were made of the students engaging in science explorations during their language arts class, and of their discussions of the relationships between the two disciplines as they were investigating. Contrasts between the science and non-science majors were made to illustrate how they have viewed the language arts course differently or similarly.

Writing assignments in the language arts course were selected to gain insight into individual thinking. Writing was chosen to provide students opportunities for reflection for three reasons. First, since writing is a component of language arts, it provided a model for how students could use writing in their own classrooms. Secondly, writing has been defined as a "tool for learning " (Mayher, Lester & Pradl, 1983). Personal writing, in which students choose their own words to discuss what they are learning will allow students to sort through and clarify their ideas. The emphasis in this kind of writing is on students' personal ideas, not on the "correctness" of the mechanics, enabling students to freely think through what they are learning. To capitalize on using writing to learn, students were assigned to keep an out-of-class journal in which they reflected on what they were learning about science content, as well as how they saw strategies presented in class may fit in their own classrooms. Reflection has been shown to be important in improving science teaching and learning (Baird, Fensham, Gunstone, & White, 1991). Fulwiler (1942) recommends using journals because it "generates ideas, observations, emotions" (p. 15). Journal writing focuses attention on a topic and makes it harder for students to remain passive. Journals allow teachers to read and respond to individual ideas on a private basis. They allow teachers to note developing ideas and to ask directed questions of students to help them further their thinking. Journal topics were assigned each class period, and the instructor read and responded to each and returned them the following session. Roth et al (1992) comments that the fifth grade students in her study saw journals as important to starting scientific arguments, and clarifying ideas to share and to "match up" with others. This relates to using the written word as a way to make meaning, and to develop concepts.

Components of the Course

There were five major components of the language arts course that were concurrently instituted. The components were chosen to help enable teachers to use strengths in language arts to improve science teaching.

Component One: Modeling Interdisciplinary Instruction

The first component consisted of the instructor modeling how science can be integrated into the language arts curriculum by leading the preservice teachers through science units. Topics were chosen that would be commonly found in the elementary curriculum, yet preservice teachers were encouraged to develop their own understandings of these concepts. They were not to focus only on the teaching strategy, or what they hoped children would learn from the teaching, but to also develop their own understandings of the content. The preservice teachers were lead through explorations in reflection, probability, states of matter, and optical illusions. They engaged in hands-on activities, and small group discussions of their understandings of the science content were videotaped as the investigations proceeded. Following the hands-on activities whole-class discussions were held concerning developing understandings of the science content, and where language arts (talking, listening, reading, writing) might fit, or may naturally be, within the lesson. They were then assigned to write in their journals their own developing ideas of the science content, and were encouraged to record language arts connections as well. Preservice teachers experienced using language arts to learn science.

Component Two: How it Works in a Real Classroom

The second component consisted of sharing similar investigations conducted by elementary children. Videotapes of first grade students undertaking investigations such as those the preservice students were conducting were shown. First grade students were shown engaging in whole class science discussions, during which many unconventional ideas were uncovered that surprised the preservice students. Preservice teachers commented that without the use of discussions they would not know of the alternative conceptions their children will bring with them to the classroom. To further the discussion on ideas children hold preservice teachers were shown the videotape "A Private Universe: Misconceptions that Block Learning." In this videotape high school students, as well as graduates of Harvard, reveal science misconceptions that have served them well and have stuck with them through their lives. The preservice teachers were asked to respond in their journals concerning their thoughts of alternative conceptions children bring to the classroom, how discussions may help to reveal these to the teacher, and subsequent steps the teacher may take.

Videotapes of the first graders investigating problems were also shown to the preservice teachers. In a discussion of these videos, students talked about what the children were learning, and how their small group discussions helped the children decide what steps to take in their problem-solving. Children were also shown writing in their journals, and samples of this work were shared with the preservice students. Preservice teachers were asked to reflect in their own journals of any usefulness they saw of journal writings in helping children to learn science.

At the preservice teachers' request, a hand-out describing a typical day in the elementary classroom of the instructor was provided. This gave an overview of how one elementary teacher chose to integrate science and language arts, among other curricular areas.

Component Three: A Comfortable, Risk-free Environment

The third component was to create a comfortable environment so preservice teachers would be willing to openly share ideas of the science content and pedagogy. They were encouraged to discuss science content and pedagogy in small groups. All ideas were accepted and encouraged. The instructor lead class discussions about connections preservice teachers were making between language arts and science, as well as their ideas of science content. Ideas were recorded on butcher paper by the instructor and preservice teachers, and posted in the classroom to show they were valued and accepted, and to allow students to refer to them. The instructor was willing and always available to discuss ideas on an individual and impromptu basis.

Component Four: Class Projects

In addition to the daily journal entries, the fourth component was to assign projects designed to allow preservice teachers to be open to incorporating other curricular areas into language arts. They were not required to integrate other subjects, but were allowed the choice to do so. The first assignment consisted of two reports on articles of professional teaching journals. Preservice teachers were allowed to choose teaching journals from any curricular area. They were asked to write a short summary of the article, and then a description of their reactions to the article. They were required to submit two of these during the semester. A second assignment was for preservice teachers to develop a thematic unit that included lesson plans for curricular areas other than language arts and then to teach a lesson from the unit to the class. They were not required to include science or math within the unit, but they were allowed to do so. For their presentation they were allowed to choose any lesson from their unit.

Component Five: Reflection

The final component was to encourage preservice teachers to reflect on their learning and to imagine how their ideas might work in their future classrooms. This was done through daily journal assignments and classroom discussions. They were asked to write an initial journal entry describing their definitions of language arts. They were also required to write an entry discussing how they believed children best learn. Subsequent journal entries throughout the semester were collected to record their developing ideas about language arts, its integration with science, and understandings of science content.

The journal also served to check preservice teacher ideas at the end of the semester through three final journal entries. These journal entries helped to show current views of language arts. First, they were required to make a list of things that reminded them of language arts. Second, they were required to write a description of their current definitions of language arts. Third, they were asked to discuss their ideas of why science could be integrated into the language arts curriculum. All data were analyzed for developments preservice teachers were making in how they viewed language arts.

Small and large group discussions were held to help preservice teachers share ideas and to see what others in their class thought about science, science content, and teaching strategies. They were encouraged to orally share with one another connections they were making to help them further develop their own ideas.

One Teacher's Use of the Methods

In December, 1995, I graduated from Washington State University with a bachelor's degree in elementary education and a supporting endorsement in special education. Throughout my college courses, practicum, and student teaching, I have noticed education continuing to move in the direction of full inclusion. I now realize that the range of ability levels in any given classroom is going to be very broad. By integrating language arts into other subjects, students are given more opportunities to learn in different ways. For more abstract or difficult subjects, like mathematics and science, language arts helps to read all different learning styles and ability levels.

Throughout an elementary language arts methods course, Valarie, the course instructor, used science activities to help us learn different ways of teaching language arts. Consequently, through language arts, we learned different ways to teach science. Prior to this course, I had viewed language arts and science as entirely different subjects, and integrating them was something that had not occurred to me. However, as the semester progressed, I found it easier and more effective to integrate science and language arts.

Using the Methods in a Science Methods Course

During an elementary science methods course at Washington State University, preservice teachers were required to present a week long thematic unit on a science topic of their choice. Four of my classmates and I worked together to develop a thematic unit on the solar system. Throughout the lessons, we used some of the ideas encouraged in our language arts course to more effectively teach about the solar system.

We began this unit by inviting the students, our peers, into our "space shuttle" for a "tour" of the solar system. This video "tour" took the class from the sun to Pluto and back to Earth. Once the "shuttle" landed, students were instructed to make two lists in the journals provided for them. The first list was to include five things they knew about the solar system, and the second list was to include five things they wanted to know more about. In later lessons, the class used journals to hypothesize about the Earth's rotation and tilt, why we only see one side of the moon, to ask questions about our solar system, and to record vocabulary definitions.

To address listening and speaking skills, students were asked to describe a picture to a partner while their partner drew what was described. Because objects in the picture could not be named, the describing student had a difficult task of finding accurate and descriptive words to communicate the picture to his or her partner. Drawing a picture from a verbal description proved challenging. These student needed to listen carefully to their partners in order to draw all of the details included in the picture. After this activity the class discussed the importance of accurate word usage when communicating ideas and concepts. They realized that as scientists we must learn to make careful observations and express ourselves accurately.

In another language arts related activity, we divided the class into eight groups and assigned each group a planet (excluding Earth). The groups were all given information on their planets and asked to work together and create a creature that could live there. Students needed to think critically about the planetary conditions and how a creature might survive under those conditions. Each group presented illustrations of their aliens to the class and the audience had opportunities to ask questions of their peers.

For closure, we asked the students to list at least five things they learned about the solar system. When they had finished writing, the class arranged their chairs in a circle to share one thing they had each learned. From start to finish, the students actively engaged themselves in a variety of reading, writing, discussion, listening, and thinking skills. As preservice teachers, we feel that language arts strategies were successfully integrated throughout our unit on the solar system.

Using the Methods in a Third Grade Classroom

While student teaching in Auburn, Washington, I found several opportunities for integrating language arts and science in my third grade classroom. During the development of my lessons I thought of a number of ways to teach both language arts and science concepts through a unit on the skeleton. Some topics addressed included creative writing, journals, observation, critical thinking, hypothesizing, listening, discussion, reading, and cooperative learning. The resulting thematic unit consisted of a series of lessons that aimed to prepare students for a final day of "Skeleton Stations."

Students were introduced to the thematic unit on the skeleton by filling in the proper names of the major bones in the body on a worksheet and playing "Simon Says" using the bone names. After students were given this information, they were required to write in their journals at least five things they knew about bones. Like the unit I taught to peers on the solar system, the whole K-W-L process was used. However, to emphasize the language arts criteria, students were asked to write their responses in complete sentences, including capitals, punctuation, and a complete thought.

For a fun creative writing activity, I read "Funnybones" by Janet and Allan Ahlberg to the class. When I reached the sentence "Suddenly something happened..." I stopped reading. The students were asked to return to their desks and finish the story as they thought it would end. Once all the students finished writing their versions of "Funnybones," we gathered back on the carpet and read the real ending. The students came up with some very creative endings, including skeletons in the book growing skin!

At the end of the unit on the skeleton, students were given booklets that went along with six centers around the room. The first station was an "About the Author" and "Dedication" page where students wrote a little about him or herself, drew a self-portrait (as seen by an X-ray lens), and then dedicated the booklet to someone. Station Two took the children to the listening center where they each listened to "The Skeleton Inside You" and answered questions about the book. At Station Three a plastic model skeleton waited for the students. The object here was for students to name the major bones in the body, find them on the model, and then on themselves. Once they finished the page foı Station Three, they moved on to Station Four where they had the opportunity to use magnifying glasses to look at real bones. In the book they drew and described what they saw under the magnifying glass. When their drawings were complete the students compared them to the drawings at the station. At Station Five students learned about fixing a broken bone. After I formed a cast around one finger, each student worked on a reading and comprehension page about bones. At the final stop, Station Six, students were provided with different types of macaroni for them to build a skeleton for the outline of "Mr. I 'acaroni Skeletoni." For one entire afternoon the students worked hard in their small groups to complete their skeleton booklets and enjoyed the chance to learn about the skeleton in a variety of ways. Through these different ways they learned the form of the skeleton, and the functions it performs.

My third grade class reacted very positively to learning science concepts through language arts. Activities required involvement from all students and different learning styles were addressed by a variety of assignments. From a teacher's point of view, the students seemed to enjoy the challenges presented to them and jumped at every opportunity to learn more about "bones." Overall, my supervising teacher was very pleased with the success of the thematic unit and the students' enthusiasm toward it.

During student teaching I also sought to integrate subjects other than science and language arts. At the opening of each math lesson students were instructed to solve a given story problem in their math journals, and write down new math vocabulary definitions in their "math dictionaries." Additionally, I used social studies concepts the students were learning to develop story problems for math. Using a whole language approach to teaching gave the students more opportunities to learn the concepts presented.

<u>My Reaction to Interdisciplinary Teaching</u>

While I have always found science intriguing, I never felt qualified to teach it. Also, because it requires hands-on inquiry and is often very abstract, I considered science difficult to teach effectively while continuing to reach students of all ability levels. The teaching experiences I have had so far have helped me to realize that teaching science through language arts gives the students more exposure to the concepts presented and increased their opportunities for learning. Students seem to improve in their learning of science as well as their learning of language arts. Through observations and assessments, I have found that the ideas learned in my elementary language arts methods course can help to make science more comprehensible and appealing to the students as well as to the teacher.

Overall Findings

The development of the preservice teachers' ideas about what constituted language arts can be described as a process over a continuum. From their own explorations studying science through language arts, their views began to develop. They began the course talking about language arts as a way to teach reading and writing. They later related how discussions during science lessons were incorporating language arts because students were listening to others, and talking out their own ideas. They also discussed the importance of writing through use of journals. The preservice teachers minoring in reading, bilingual education or ESL appeared to adapt to the strategies quite well. They seemed to embrace the idea of using language arts to help teach science. The science minors were comfortable using the strategies as well, because they were able to use their areas of expertise in their language arts methods course.

About three-fourths of the language arts class was concurrently enrolled in a science methods course taught by a different instructor. In their science methods course preservice teachers were required to teach a week-long science unit. Many of them included language arts methods to teach their unit, and the strategies were accepted by the science methods instructor. Two methods that were especially well-received were the use of journals as a learning and assessment tool, and the use of K-W-L. "K-W-L" stands for "What I Know, What I Want to Know, and What I Learned." Some preservice teachers used the K-W-L method to collect their peers' ideas and their development during the week-long unit. They would make three-column charts, and at the top of each column was listed either K, W or L. As their peers were learning from their explorations, the language arts preservice teachers would list science student responses under the appropriate column. This technique was modeled in the language arts course. Preservice teachers also chose to have their science course peers record observations, results, and discuss their changing ideas, in journals they made for the week. This mimics what they were required to do in the language arts course. Both strategies were adopted by students in the science methods class who were not in the language arts course.

Preservice teachers were also required to read two articles in professional teaching journals. They were asked to report on the journals in a way they might discuss articles with colleagues. They were allowed free choice of teaching journal. For the first paper all preservice teachers chose to report from a language arts journal, such as *The Reading Teacher* or *Language Arts*. For the second paper they expanded their journal selection to include those from other curricular areas, such as *Science and Children, Arithmetic Teacher,* and *Technology Review*. Preservice teachers would invariably include in their reflection paragraph reasons that their "unorthodox" choice of journal really did relate to language arts. This practice in "convincing" someone that science, math, or technology had some relationship to language arts should be helpful for their inservice years during which they will wish to continue to incorporate other subjects into their language arts program. They will be able to justify their teaching methodology.

One-half of the preservice teachers in the class chose science-related concepts such as weather, space travel, or water, on which to develop their thematic unit. The others chose either child-centered topics such as "myself," or social studies concepts such as "Japan" or "Native Americans." Within each unit preservice teachers included science connections. Over half of them chose to present a science lesson to their peers during their oral unit lesson presentations.

Definitions of what constituted language arts developed as evidenced by the preservice teacher responses to the final three journal entries. The list of things that reminded them of language arts included "M & M's" (from a mathematics and technology unit), "journals," "K-W-L," "Oobleck" (science unit), "talking, listening, reading and writing," " reflection and optical illusions" (science unit), "fits other things in (to the curriculum)," and "science." From their journal entry describing their new definition students discussed language arts as "incorporating all curricular areas," "a tool for learning other things," and it could be made "more interesting if kids have a purpose for writing about things." To why science was integrated into language arts, the responses varied from "to show us how easy it is to integrate language arts," "to show us how a teacher needs to teach in order to fit everything into the day," "to show us how to 'make time for science,'" to "because you love science."

Implications

The integration of language arts and science methods show several implications for teacher education programs. First, it was possible to develop the views of some preservice teachers in their definition of language arts by including science content in their curriculum. They saw language arts as a tool to explore other subjects, rather than only an end to itself. They saw the language arts period as a time during which other subjects can be incorporated, and were able to defend their choice to integrate other subjects. They saw the connections between using writing, reading, listening, and speaking during other curricular areas as being a purposeful use of language arts. Secondly, they saw the importance of using the reflective skills of language arts to help their own students develop their ideas because this is how they proceeded through their methods class. They saw discussions as important in helping to see the unconventional ideas students bring with them to class. This influences their teaching of science because they are aware of the importance of knowing the ideas their students already hold. Several students said they believed that journals would be indispensable in their own classrooms because they are so helpful to the children and their learning, and helpful to the teacher in assessing the development of student learning and in knowing which direction to proceed with future lessons. Third, in this time of educational reform during which teachers are being asked to integrate subjects and give purpose to their lessons, the preservice teachers experienced such interdisciplinary instruction, and were able to relate this through their own reflective thinking in their journal entries to their future classroom experiences. Fourth, their science teaching is improved, or at least enhanced.

They were able to take the language arts methods with which they were comfortable, and use them to successfully teach science content in their science methods course. In addition, other science course students not enrolled in language arts methods chose to use the strategies by their peers who were enrolled in language arts. This suggests that the methods are not only comfortable for the students to use, but are also fairly simple to implement, and may increase time spent teaching science.

Several future studies are suggested by outcomes of this exploration. First, preservice teachers in this course were able to learn science content through the language arts methods, and then chose to take these methods to their own content teaching in their science methods course. This could lead to finding a way for teachers to learn more science through learning a variety of teaching methods. Teaching science through the comfortable and familiar setting of language arts could encourage teachers to learn more science. Secondly, students in these classes became aware of the importance of knowing the ideas children bring with them through their own developing expertise in conducting discussions. They realized that without holding discussions about science concepts they would not know the ideas their students will bring with them, and wouldn't really understand what the children were actually learning. This instruction in discussion techniques in language arts combined with science instruction could lead to teachers becoming aware of, and seeking to address, their own students' ideas and science misconceptions. Thirdly, preservice teachers in this type of course would need to be followed to see how they implement the strategies learned in their own classrooms, and whether these teachers would be more comfortable with science and would choose to spend more time teaching science. It would be essential to check the understandings of science concepts held by these preservice teachers' students to see what impact it had on student learning.

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MODELING SCIENCE AND SCIENCE LEARNING IN INTRODUCTORY COLLEGE LEVEL SCIENCE COURSES

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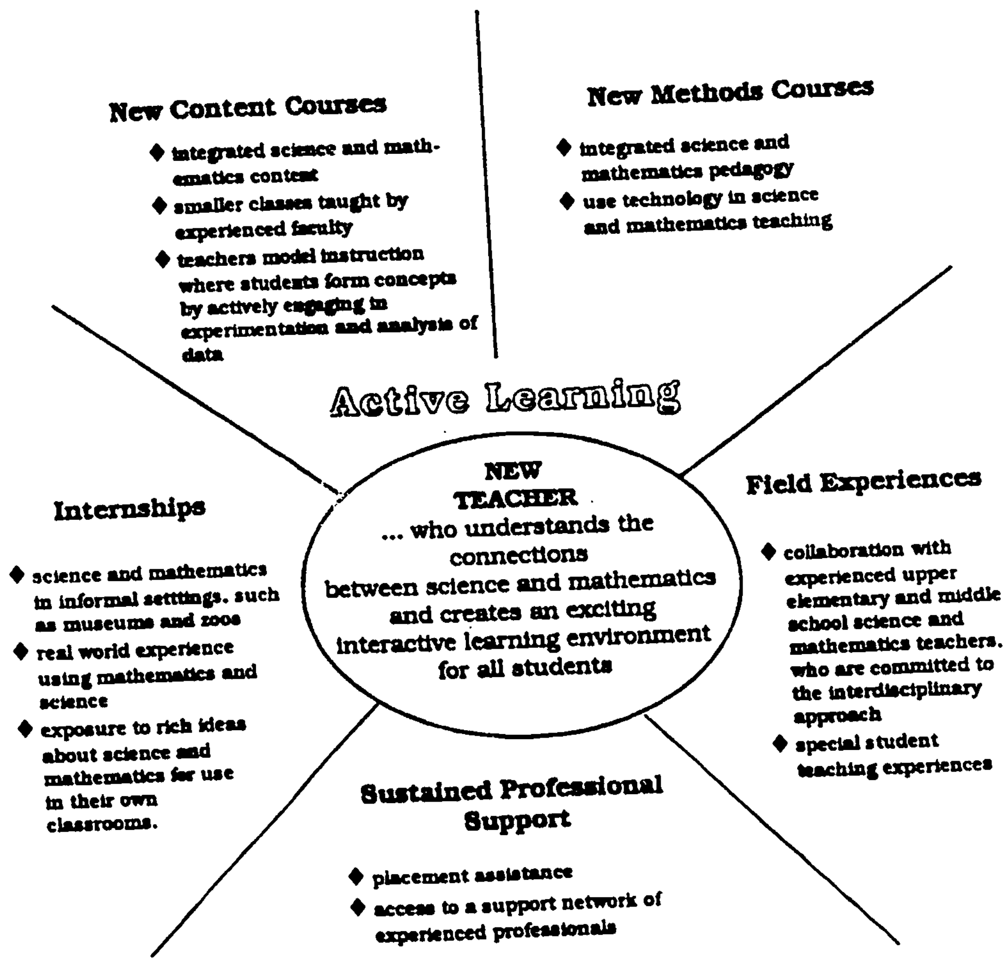
Maryland Collaborative for Teacher Preparation

The Maryland Collaborative for Teacher Preparation (MCTP), funded by a grant from the National Science Foundation (DUE#9255745), is endeavoring to design, develop, implement, and evaluate an innovative interdisciplinary program to prepare science and mathematics specialists for teaching in grades four through eight. This effort involves all of the eleven teaching and research institutions of the University of Maryland System in collaboration with Morgan State University, Baltimore City Community College, and the public school systems of Baltimore City, Baltimore County, and Prince George's County. Students who complete the program will be certified to teach in grades 1 - 8, but they will have course work and field experiences in mathematics and the sciences that far exceed the traditional requirements for elementary school teachers in those disciplines. Towson State University and the University of Maryland at College Park have been charged with developing complete programs. Now in our third year of funding, both campuses are well into the implementation phase. Other undergraduate institutions in the system are developing complete programs, arranging cooperative agreements with one or more of the lead campuses, or using elements of the program to enrich the mathematics and sciences offerings within existing elementary education programs. In addition, Baltimore City Community College has taken the lead in developing "feeder" programs at community colleges to enable students to transfer directly into a full MCTP program at one of the lead institutions.

The principle goal of the MCTP is to educate a new kind of teacher who has enthusiasm for learning, mathematics, and science and who will continue as an active learner, furthering his or her level of expertise in the disciplines and in teaching beyond the undergraduate level.

The program involves five main features (Figure 1): new content courses, new methods courses, internships, field experiences, and sustained professional support. Statewide collaboration of faculty and institutions has produced enough innovation within each of these features for several papers.

Figure 1. MCTP Program Overview



This report focuses on the development and implementation of introductory level science content courses at Towson State University. The specifics of courses vary a bit from campus to campus, but the basic content themes and teaching techniques are consistent throughout the project. In designing and teaching the content courses cooperating faculty were guided by two major principles:

1. prospective teachers should learn science and mathematics through instruction that models the best practice that they will be expected to employ in their own teaching, and

2. students must be given ample opportunity to discover and use the connections among the disciplines in developing understanding and skill in mathematics and sciences.

The MCTP program at TSU is a specialty track within the Elementary Education major. All elementary education students take their mathematics and science courses in the College of Natural and Mathematical Sciences (CONAMS). TSU students intending to teach science or mathematics in the middle and high school must complete a major in their chosen discipline. The historical contributions of CONAMS faculty to teacher preparation contributed to the ability of the MCTP to attract strongly discipline oriented faculty to the program. The MCTP program requires students to complete two semesters of introductory biological science, two semesters of introductory physical science, two semesters of introductory mathematics, one "calculus level" math course, and two semesters of upper level interdisciplinary science/math courses, for a total of 34 credits in mathematics and science.

Introductory Science Courses - Overview

Physical Science I

This is a "hands-on" course patterned after the work of Arnold Arons and others.

Students build concepts from laboratory experiences, integrate mathematical concepts with operational definitions of such phenomena as density, velocity, heat, etc. All labs include small group work and post-lab discussions. The class meets six hours/week for 4 credits.

Physical Science II

Fundamental concepts of atoms, molecules, energy, states of matter, and the processes involved in phase transitions are investigated through integration of chemistry and earth science. Concepts are developed from lab experiences, small group projects, and class discussions. The class meets five hours/week for 4 credits.

Bioscience I

This course integrates concepts of classical genetics, modern molecular genetics, evolution, and natural selection. It combines hands-on laboratory experiences, small group projects, and classroom discussion. The class meets five hours/week for 4 credits.

Bioscience II

This is an integrated biology/chemistry course that investigates the structure of the atom, molecular bonding, the relationship between molecular structure and properties, and the application of these principles to cellular metabolism in plants and animals. The course combines hands-on laboratory experiences, small group projects, and classroom discussion, and meets five hours/week for 4 credits.

The following discussion focuses on the specific content, pedagogy, and outcomes that were part of two units that typify the approaches used in all of the courses listed above.

Bioscience I

Content Objectives

Bioscience I explored classical genetics and the application of probability to the process of understanding the inheritance of traits. It also developed the concepts of the chromosomal basis of heredity and molecular genetics. These principles were then applied to the study of population genetics and evolution. Another major theme was the use of model-building to allow the students to appreciate the structure and function of DNA, RNA, and protein. This provided the students the opportunity to use experimental data to build a model of a DNA molecule and to appreciate the value of models in understanding the complex processes involved in gene expression. A second objective was the integration of the scientific method and mathematics into the students' daily activities through critical analysis of their experimental design and data. The students experimentally demonstrated that DNA carries the genetic information of an organism, and in so doing, they acquired hands-on experience with current techniques in biotechnology.

Pedagogical Considerations

Throughout the course, the over-riding objective was to prepare pre-service teachers to use a constructivist approach in their science teaching, an approach modeled after their own learning. At the beginning of the semester, students were assigned an article entitled *The Blue People of Troublesome Creek* (Trost, 1983) to engage their interest in the study of genetics and evolution. This article describes a small group of families in Kentucky that have a much higher incidence of blue skin coloration than is found in the rest of the human population. The molecular basis of this trait, the pattern of inheritance, and the evolutionary reasons for the high incidence of the trait are discussed in the paper. It was selected because:

1. it is an example of a genetic disorder without tragic implications.
2. all the major themes of the course and their inter-relationships are explored.

3. it is presented as a genetics detective story that begins with a physician observing one of the blue people and then investigating the cause of "blueness".

The article was accompanied by a set of questions designed to assess the students' prior knowledge and possible misconceptions, to determine what factual information they had derived from the article, and to challenge them to apply the concepts using problem-solving and critical thinking skills.

Through classroom discussion students had the opportunity to examine their prior knowledge. Student ideas and beliefs were assessed throughout the unit through their electronic-mail journal entries, classroom discussion, and cooperative model-building. The students were provided opportunities to invent and consider alternate beliefs about the molecular nature of the genetic information through classroom discussion and interpretation of historical experiments, model-building, experimentation, and data analysis. Students were encouraged to make connections between their classroom experience and the world around them. Throughout the course students were expected to communicate these associations both in class and in their journal entries.

Student ideas and hypotheses expressed in class were accorded respect by continually reinforcing the idea that any model has strengths and weaknesses. All student ideas were subject to discussion and were frequently modified as a result. This was not treated as a means of criticizing students, but rather as an effective sharing of ideas to establish and extend their understanding.

After the class had investigated Mendelian genetics and the chromosomal basis of inheritance, they were introduced to model-building. It was hoped that this experience would allow them to make connections between the structure and function of DNA, RNA, and protein. It was also our objective that students should be able to demonstrate experimentally that DNA is the molecule that carries the genetic information and to show that this genetic information is responsible for the characteristics of an organism.

In preparation for the unit, the 1928 experiment of Frederick Griffith was described (Griffith, 1928). Briefly, Griffith was studying the pathogenicity of *Streptococcus pneumoniae* using a mouse model system. He observed that when living, nonvirulent (rough) bacteria and dead, virulent (smooth) bacteria were mixed, living, virulent (smooth) bacteria resulted. These "transformed" bacteria killed the mice in Griffith's experiments. Students worked in groups to develop hypotheses to explain the experimental results. The strengths and weaknesses of each hypothesis were discussed. The class decided upon a hypothesis which stated that genetic information from the dead smooth cells must have entered the living rough bacteria, causing them to become smooth.

The experiments of Avery, McCarty, and MacLeod (Avery, *et al.*, 1944) were then described. From these historical data the class hypothesized that DNA was the molecule that transformed the phenotype of *S. pneumoniae* from rough to smooth. The students were then challenged to construct an understanding of the structure of DNA, the replication of DNA, the transcription of DNA into RNAs, and the translation of RNAs into the proteins that ultimately determine the phenotype. A molecular model kit, entitled "Information Flow in Biological Systems", was designed using ChemWindows software (Softshell International, Ltd. and Caret, et al., 1995). The "Information Flow in Biological Systems" exercise is available upon request. The experimental evidence available to Watson and Crick is presented in the packet, as well as models of the subunits required to construct a short DNA molecule. Students were given a copy of the kit and told to bring their DNA molecules to the next class.

The following quotation from a student journal revealed the student transformation that occurred as a result of the model building experience:

> I know it's only Tuesday, and this is unlike me, but I am so excited I just had to write you. At 8:30 p.m., Sarah came down to my room to do the DNA construction. We both had absolutely no idea of what to do with the paper cutouts. I mean, we had no clue. We were almost to the point of just giving up and saying we could not get it. We had three books out, though, each giving us a little different information, and we figured it out! I know this may not be a big deal to you, but it was an electrifying experience for both of us. It felt so good to go through it and know that we did it, with no one else's help. It was just incredible. I had to tell someone. See you tomorrow.

While students continued to work on the model kit out of class, we proceeded to carry out experiments in class to reinforce the idea that DNA carries the genetic information and that it is expressed through the production of a variety of proteins. Using the commercially available kit *Genotype to Phenotype* (Anderson, 1993), the students transformed *Escherichia coli* cells with two plasmid DNAs. One plasmid carried the gene for ampicillin resistance and the gene for the enzyme β-galactosidase. Cells transformed with this plasmid had the ability to grow in the presence of the antibiotic ampicillin and to produce blue colonies when grown on agar containing the substrate Xgal. The second plasmid also carried the gene for ampicillin resistance, but the β-galactosidase gene was inactivated. Cells transformed with this plasmid grew in the presence of ampicillin, but produced white colonies on agar containing Xgal. Cells in the negative control received no DNA and could not grow on agar containing ampicillin and Xgal.

The students were given three tubes labeled A, B, and C. They were told that one tube contained no plasmid DNA, one had a plasmid with the ampicillin resistance gene, and one contained a plasmid with both the ampicillin resistance and β-galactosidase genes. They worked in groups to plan and carry out the experiment. The results of the transformation experiment, along with data about the physical maps of the plasmids, were used to predict the restriction maps of the two plasmids used in the experiment. The students then prepared restriction enzyme digests of the DNA, separated the DNA fragments by agarose gel electrophoresis, photographed the gels, determined the sizes of the DNA fragments, and prepared restriction maps. Comparison of their predictions with the experimental restriction maps allowed the students to construct the relationship between the structure of each plasmid DNA and the phenotypes that each conferred on the cells. Each group presented its summary and conclusions to the class and each summary was discussed by the class. The final consensus was that the plasmid DNA introduced into the cells had "called for" the production of the enzymes that caused ampicillin resistance or p-galactosidase activity.

This presented an excellent point of departure for the remaining sections of the modelbuilding kit on information flow in biological systems. The students used models to carry out the processes of DNA replication, transcription, and translation. These activities allowed them to make the conceptual connection between the genotype of an organism and the biochemical processes that translate that genotype into the phenotype.

Physical Science II

Content Objectives

A number of major themes and objectives were addressed in this course. The students' factual base and reasoning skills were enhanced through exploration of the age of the earth, the chronology of major events in the evolution of our planet, and the implications of these events for modern society. A second goal was to integrate the scientific method into the students' daily lives through design and critical analysis of experiments that could extend their knowledge. Finally, the course was designed to help the students understand that, just as the universe is in a state of continuous change, so are our ways of investigating it. New technologies allow fresh ways of looking at old systems.

Pedagogical Considerations

Prior to beginning the course the students were assigned to read a short biography of Mme. Curie (Bertsch-McGrayne, 1993) to engage their interest in the subject and to introduce the study of the nucleus and radioactivity. This biography is particularly appropriate for the following reasons:

1. It describes very basic science. One can imagine the labor involved in purifying more than one ton of pitchblende under very primitive conditions.
2. It is a story of a female scientist doing work in a field that was dominated by men and, at the same time, nurturing a family.
3. It clearly demonstrates the human and political aspects of science.

After completing the biography, the students were required to read the chapter from the textbook (Trefil and Hazen, 1995) dealing with the material under study. This assignment was accompanied by a list of questions designed to assess the students prior knowledge and misconceptions, to determine what factual information they had derived from the biography and from the textbook reading, and to challenge them to use the information in problem solving and critical thinking.

At the beginning of this unit students were encouraged to discuss what they knew and what they felt about each topic. They often admitted very little knowledge. When questioned about the nucleus and radioactivity, they all expressed a genuine, and generally irrational, fear Their questions and uncertainties were used as targets for the ensuing unit. In this way, their prior knowledge (or lack thereof) became the basis for the unit.

Students' ideas and beliefs were monitored by involving them in the design of the experiments. Consequently, there was no way that they could hide their ideas and beliefs. In a conventional experiment, they could simply "fill in the numbers", turn in the report, and be graded solely on what is written on paper, not on what they genuinely understood.

Opportunities were provided for students to invent and consider alternate beliefs about how the world works. The students were encouraged to develop hypotheses, criticize each others' hypotheses, and then conduct experiments designed to support or reject the hypothesis. The belief that the experiment must be designed to respond to a question was a major theme of the course.

Students were provided opportunities to make connections between new ideas and previously held concepts. "Can zero radioactivity be achieved?" "Can you construct a model of radiation propagation that is consistent with your preconception and with your data?" These kinds of questions forced students to put their new knowledge into the framework of their own life experiences. Student ideas were accorded respect by reinforcing the idea that any model or hypothesis has strengths and weaknesses. Students only continue to actively participate if their comments, questions, ideas, and suggestions are respected. This is an essential component of any successful team-oriented adventure.

The supply of original ideas for hands-on, interactive laboratory-based experiences is certainly not without limits. However, it is possible to modify many currently available laboratory experiments to a constructivist-based approach. This is the path that we chose in designing a series of activities that were intended to enhance the student understanding of the major course topics. Most conventional laboratory experiments are recipe-driven with tables and graphs prearranged: all the students have to do is to supply the information in the appropriate space and they have generated an "instant" laboratory report. We used these experiments as a convenient starting point, keeping the major themes, but hiding much of the methodology and leaving design and procedural decisions, as much as possible, to the students.

As an example, the unit developed for the nucleus and radioactivity was designed to include and integrate the following major concepts: the scientific method and its practical application; nuclear structure and stability; the meaning of "background" radiation and its significance; half-life and its relationship to disposal and safety; types of radioactivity, alpha, beta, and gamma; safety of nuclear power plants and medical procedures; disposal of radioactive waste in relation to our earlier study of the earth; economics, politics, and science, their interrelationships, and their conflicts.

In the first part of the unit, students measured the levels of radioactivity as a function of type of source, distance from the source, type of shielding used, and the thickness of different types of shielding. Following these investigations, they were challenged to design an experiment to measure the half-life of an isotope. We chose iodine-125, $t_{1/2}$ = 60 days, out of necessity (it was the only reasonable isotope to which we had access). A shorter half-life substance would have been preferred, but iodine-125 had some advantages. The sampling protocol had to be carried out every class day for a month; thus, the students learned that all experiments are not finished in one day. The students became excited as they kept an "updated graph" showing the extrapolated data converging to a point. Finally, owing to the fact that the half-life of the isotope was greater than the measurement interval, the students observed, first-hand, the pitfalls of extrapolation. The students developed a "team report" and were responsible for all facets of measurement, data handling, calculation, conclusions and oral report.

Assessment

In both Biological Sciences I and Physical Sciences II, student electronic-mail journals proved to be a valuable way to assess student progress in constructing models of concepts. Students were asked to reflect on classroom activities and discussions and changes in their understanding of the ideas being studied. Authentic problem-solving exams were given in both courses. These reflected the experiences of the students in the class because exam questions focused on critical analysis of experimental data, experimental design, and problem solving by application of the principles learned in class.

Summary and Impressions

Our involvement with these courses has certainly changed our perception of classroom interaction and student learning. The limitations of traditionally structured lecture/laboratory courses have become obvious. Our desire to cover the material has been replaced by a desire that the students understand the material. Aspects of the constructivist approach have become an integral part of each of the majors courses that we teach.

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A Model For A Successful Elementary Science Inservice With Broad Implications For Replication (NSF)

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Overview

More than a decade has passed since federal funding for the improvement of K-12 science and mathematics education was substantially increased. A fluctuating re-allocation has occurred regularly since then, evidence of a modest awakening regarding the role science and mathematics must play if this nation is to remain a viable economic, political, and technological world partner. Public awareness and response to this need came late, and much remains to be done. The need to improve the preparation of our children and their teachers for the challenges of the twenty-first century remains great.

Pockets of significant improvement may be found, but elementary science is still viewed as a low priority and science instruction at the elementary level continues to be given little time or ignored completely. Most elementary teachers still do not have the broad-based investigative background that would prepare them for science teaching and do not feel qualified to teach science. Many have had minimal science coursework or only general methods courses rather than experiences specific to the content and inquiry based methodology of science teaching. In such a climate, teachers may not be motivated to teach science or to improve their effectiveness in science instruction. They may never learn to utilize inquiry, ask effective higher level questions, or integrate science with other subjects. Improving the overall status of elementary science instruction in the Cincinnati Public Schools was the major goal of the project described in this paper.

Numerous studies have shown that an activity oriented approach to elementary science promotes the development of both scientific literacy and the "basic skills" of reading, writing, and mathematics (Kotar, 1988; Kyle, 1988; Lloyd & Contreras, 1987; Mechling & Oliver, 1983; Shymansky, et al., 1982, 1983; Wellman, 1978). Students in hands-on elementary science programs have an opportunity to become actively involved with the processes of science as they observe, compare, classify, measure, collect and interpret data, organize information, and draw inferences or conclusions. Additionally, concrete physical experiences contribute to intellectual development as children learn to reason and make logical decisions. Under the supervision of a confident, well-prepared teacher, students of hands-on science attain a sound comprehension of science concepts and processes and develop positive attitudes toward science and science learning.

Effective elementary science programs require hands-on activities, but many teachers are unsure of the purpose of such activities, how to use them, or how to make them genuine learning experiences. Some research indicates that teachers are eager to remedy this situation. In a study of elementary teachers' science education research interests, the top areas of interest were: 1) hands-on experience; 2) science content of the curriculum; 3) cognitive development and learning styles; 4) problem solving; and 5) teaching strategies (Gabel, et al., 1986).

The Miami University Center for Mathematics and Science Education and the Cincinnati Public Schools have completed a five year project for the improvement of K-6 science instruction in the school district. Financial support came from the National Science Foundation Education and Human Resources Directorate ($845,000), the Ohio Board of Regents Eisenhower Program ($105,000), Miami University costsharing ($580,000) and from the Cincinnati Public Schools ($1,054,000). An Ohio Eisenhower Title 2 grant supported the first year of the project with a leadership development grant for 30 teachers (1990-91). The NSF grant added a component for curriculum development and funded an additional four years of teacher preparation for 290 selected teachers (1991-95). Four additional Eisenhower grants supported hands-on science activities conducted by informal science education facilities including Ohio's Center of Science and Industry, the Cincinnati Zoological and Botanical Garden, and the Cincinnati Museum of Natural History. Miami University contributed to direct project expenses and indirect expenses in the form of waivers of tuition and instructional fees. The Cincinnati Public Schools provided classroom materials and supplies, physical facilities, teacher inservice programs, and administrative support.

The project included an emphasis on minority and female students. Both have traditionally shown little interest in the natural sciences or in pursuing science careers. The district's 61 elementary schools have approximately 31,000 K-6 students and 1,300 teachers. Approximately

65% of the elementary students are from racial minority groups, largely African American. The selection process for each year included an emphasis on the selection of teachers from underserved groups and teachers of students from underserved groups. Additional consideration was given to any group of applicants who applied as a team from a single school.

Major features of this project included a hands-on, inquiry-based investigative emphasis to elementary science instruction; upgrading science content; a commitment to address the needs for effective science education of underrepresented and underserved groups; elementary science curriculum enhancement (taking advantage of recent and developing major curriculum projects); and elementary science leadership development. The following were specific objectives:

1. Establish a cadre of teacher leaders for the purpose of curriculum enhancement and inservice support.
2. Substantially enhance a new K-6 elementary science curriculum with investigative hands-on science activities.
3. Improve participant competence with respect to pertinent biological, physical, and earth science concepts.
4. Improve the attitudes of teachers toward science and science teaching.
5. Increase the confidence of Cincinnati elementary teachers so that they are eager to teach science with an investigative approach emphasizing science concepts, processes, and attitudes.
6. Establish regular inservice activities and activity sharing by participants and project staff.
7. Contribute substantially to a growing network of excellent elementary science teachers to provide communication, moral support, inservice support, and preservice support in southwest Ohio.
8. Foster program presentations for professional conferences.
9. Develop field-site locations for meaningful elementary science field experiences for preservice elementary education majors enrolled in science methods courses.
10. Develop model schools for elementary science instruction for effective student teaching locations.

First Year: Leadership Development

The first year of the project, 1990-91, was conducted by professors from Miami University's departments of Teacher Education and Zoology. The first year began with the selection of 31 elementary educators from the Cincinnati Public Schools, including 28 K-6 teachers, two supervisors, and one principal. They participated in a three week summer workshop which included an introduction to new and developing NSF sponsored curriculum projects, selected science concepts from biology, physical, and environmental science, curriculum enhancement, and hands-on methodology. They also completed an academic year follow-up which consisted of nine Saturday seminars, participation in selected science education conferences, leadership development activities, at least four substantial inservice activities by each participant, and regular classroom consulting by the project instructional staff in participant classrooms.

Second Through Fifth Years: Teacher Preparation

The second through fifth years of the project featured the selection of an additional 72-75 teachers into the project *each* year, three-week summer workshops, and academic year follow-up similar to the initial leadership development year.

The major difference between the leadership development year and subsequent project years was the degree to which various aspects of the project were emphasized. The first year had more emphasis on leadership and curriculum development. Science program adoption for all grades was in progress, and participants in the leadership development phase made up about half of the curriculum and adoption committees. The Project Director was invited to attend some deliberations of those committees. Subsequent years included more emphasis on the development of "hands-on, minds-on" strategies and more focus on activities and concepts in the elementary science curriculum that was adopted. Participant-led inservice and in-class consulting by university science education professors was an important element of all phases of the project. Since primary and upper grade teachers frequently have different needs, major project activities were conducted in grade level groups of 24-25 participants each. Summer workshops and academic year seminars were arranged in K-1, 2-3, and 4-6 teaching grade level groups.

The summer workshops and academic year seminars provided in-depth experiences with concepts and processes in the biological, physical, and earth sciences. As participants' familiarity with science concepts and processes increased, they became more comfortable with the subject matter and increasingly more confident in their abilities to lead their students and fellow teachers in scientific investigations. Each grade-level group summer workshop was led by an accomplished elementary teacher selected from the first year leadership project. Each workshop was team-taught with the assistance of three university professors from physical science, biological science, or science education. The university professors rotated, spending one week in each grade level workshop. Meticulous planning by the instructional staff was essential to assure the success of the project. Participants in this project are joining a growing core of elementary science teachers in southwestern Ohio who provide inservice for other teachers.

Results of Participant Testing

Each year of the project included pre, post, and post-post testing of cognitive and affective factors. The results for the fifth year, 1994-95, are reported in this paper. The pretests were administered on the first day of the three-week summer workshop. Posttests were given on the last day of that workshop 21 days later. Post-posttests were taken by participants near the end of the following academic year eight to ten months after the end of the summer workshop.

Cognitive Analysis

Knowledge of selected science concepts and science teaching practices were assessed using a 24 item multiple choice test prepared by the project director and project evaluator. Each item had five possible responses. Items included basic concepts from biology, electricity, earth science, and science education.

Total cognitive test scores were determined for each of the three groups and for the three periods (pre-workshop, post-workshop, and post-project year). The means and standard deviations for each period are reported in Table I. The dependent cognitive variable was analyzed using a two way repeated measures analysis of variance with grade grouping representing one factor (with three levels K-1, 2-3, and 4-6) and time of testing representing the repeated measures factor (with three levels pre, post, and post-post). The F-ratio associated with grade grouping was not significant, [F(2, 67)=2.63, p=NS.], indicating that there were no differences on the cognitive variable by grade level. The interaction between grade level and time of testing was not significant, [F(4, 134)=1.05, p=NS.], thereby indicating that any effects associated with the time of testing factor may be generalized to all levels of the grade level factor. The time of testing factor defined a significant F-ratio, [F(2, 4)=33.94, p>.001], thereby indicating that at least two of the time periods differed significantly (p<.001) on the cognitive variable. The cognitive means by time period were compared in a pair-wise manner using orthogonal contrasts. The posttest cognitive score was significantly greater than the pretest cognitive score, [F(1, 1)=61.69, p<.001)]. The post-posttest cognitive score was significantly greater than the pretest cognitive score, [F(1, 1)=36,98, p<.001)]. The difference between post and post-post cognitive scores was not significant, [F(1, 1)=3.11, p=NS.)].

Thus, the ANOVA results indicate that there was a significant (p<.001) workshop effect associated with the cognitive scores and this effect was maintained for eight months and is most likely "lasting" learning.

Table I
Fifth Year Cognitive Test, 1994-95, Means-Repeated Measures for X1 ... X3

Group	N	M	SD
pretest K-1	23	12.26	3.33
posttest K-1	23	14.00	3.12
post-posttest K-1	23	13.57	3.79
pretest 2-3	22	11.27	3.17
posttest 2-3	22	14.46	2.13
post-posttest 2-3	22	13.68	2.42
pretest 4-6	25	13.48	3.02
posttest 4-6	25	15.68	3.26
post-posttest 4-6	25	15.28	3.78

Table II
Fifth Year Cognitive Test, 1994-95, Two Factor ANOVA-Repeated Measures for X1 ... X3

Source	df	SS	MS	F	p
Group	2	124.9	62.5	2.63	.080
Subject (Group)	67	1592.3	23.8		
Test Period	2	216.4	108.2	33.9	.0001
Test Period*Group	4	13.35	3.34	1.07	.386
Test Period*Subject (Group)	134	427.1	3.2		

Affective Analysis

Attitudes toward science and science teaching were assessed using a modified version of the "Scientific Attitude Inventory" (Moore, 1973). The inventory consists of 70 statements to which subjects are asked to respond on a four point Likert scale from "strongly agree" to "strongly disagree." For use with this project, the inventory was shortened to 27 items by eliminating some "duplicate" items and items statistically shown not to contribute to differentiation between test periods for this project. On the response scanner form "strongly agree"=3 and "strongly disagree"=0. For about half the items the preferred response was "strongly agree." For the rest the preferred response was "strongly disagree." For statistical analysis the numerical value of the responses was "reflected," so that all preferred responses were read as the number three.

Within the 27 items on the attitude inventory, two main dependent affective variables were identified and analyzed. The first was identified as "attitude toward *philosophy* of science." Fourteen items were identified with this factor. The second was identified as "attitude toward the *knowledge* of science." Thirteen items were identified with this factor. Each dependent variable was analyzed using a two way repeated measures analysis of variance with grade grouping representing one factor (with three levels K-1, 2-3, and 4-6) and time of testing representing the repeated measures factor (with three levels pre, post, and post-post).

Affective Analysis: Attitude toward the Philosophy of Science

Attitude toward philosophy of science defined results quite similar to those associated with the cognitive variable as is reported in Table III and Table IV. The F-ratio associated with grade grouping was not significant, [$F(2, 66)=.05$, p=NS.], indicating that there were not differences on the attitude toward philosophy of science variable by grade level. The interaction between grade level and time of testing was not significant, [$F(4, 134)=1.61$, p=NS.], indicating that any effects associated with the time of testing factor may be generalized to all levels of the grade level factor. The time of testing factor defined a significant F-ratio, [$F(2, 4)=25.32$, $p>.001$], indicating that at least two of the time periods differed significantly ($p<.001$) on the attitude toward philosophy of science variable. These philosophy means by time period were compared in a pair-wise manner using orthogonal contrasts. The posttest philosophy attitude score was significantly more positive than the pretest philosophy attitude score, [F(1, 1)=26.73, p<.001)]. The post-posttest philosophy attitude score was also significantly more positive than the pretest philosophy attitude score, [F(1, 1)=46.47, p<.001)]. The difference between post and post-post philosophy attitude scores was not significant, [F(1, 1)=2.71, p=NS.)]. The ANOVA results indicate that there was a significant (p<.001) positive workshop effect associated with the attitude toward philosophy of science scores and this positive effect was maintained for eight months and is most likely a "lasting" effect.

Table III
Affective Analysis for Fifth Year Participants, Attitude toward the Philosophy of Science
Means-Repeated Measures for X1 ... X3

Group	N	M	SD
K-1 pre score	23	2.13	.34
K-1 post score	23	2.26	.31
K-1 post-post score	23	2.27	.29
2-3 pre score	22	2.08	.24
2-3 post score	22	2.26	.31
2-3 post-post score	22	2.38	.29
4-6 pre score	24	2.02	.34
4-6 post score	24	2.31	.34
4-6 post-post score	24	2.37	.36

Table IV
Affective Analysis for Fifth Year Participants, Attitude Toward the Philosophy of Science
Two Factor ANOVA-Repeated Measures for X1 ... X3

Source	df	SS	MS	F	p
Grade level	2	.02	.01	.05	.951
Subjects	66	12.98	.20		
Period	2	2.59	1.29	25.3	.0001
Period*Grade	4	.33	.082	1.61	.177
Period*Subject Group	132	6.75	.051		

Affective Analysis: Attitude Toward Knowledge of Science

Attitude toward knowledge of science defined results that were different from the other two analyses as is reported in Table V and Table VI. The F-ratio associated with grade grouping was not significant, [F(2, 66)=1.67, p=NS.], indicating that there were no differences on the attitude toward knowledge of science variable by grade level. The interaction between grade level and time of testing was not significant, [F(4, 132)=1.58, p=NS.], indicating that any effects associated with the time of testing factor may be generalized to all levels of the grade level factor. The time of testing factor defined a significant F-ratio, [F(2, 4)=9.58, p>.001], indicating that at least two of the time periods differed significantly (p<.001) on the attitude toward knowledge of science variable. These attitude toward knowledge means by time period were compared in a pair-wise manner using orthogonal contrasts. The posttest attitude toward knowledge score was significantly more positive than the pretest attitude toward knowledge score, [F(1, 1)=18.51, p=NS.)]. The difference between post and post-post attitude toward knowledge scores was significant, [F(1, 1)=8.15, p<.001.)]. The ANOVA results indicate that there was a significant (p<.001) positive workshop effect associated with the attitude toward knowledge of science scores but this positive effect was not maintained for eight months and is most likely not a "lasting" effect. Over the five years of the project, this was the only time a workshop effect was not maintained between the post and post-posttest.

Table V
Affective Analysis for Fifth Year Participants, Attitude toward the Knowledge of Science
Means-Repeated Measures for X1 ... X3

Group	N	M	SD
K-1 pre score	23	2.55	0.26
K-1 post score	23	2.81	0.14
K-1 post-post score	23	2.67	0.25
2-3 pre score	22	2.37	0.51
2-3 post score	22	2.68	0.47
2-3 post-post score	22	2.60	0.43
4-6 pre score	24	2.53	0.29
4-6 post score	24	2.68	0.22
4-6 post-post score	24	2.42	0.58

Table VI
Affective Analysis for Fifth Year Participants, Attitude Toward the Knowledge of Science
Two Factor ANOVA-Repeated Measures for X1 ... X3

Source	df	SS	MS	F	p
Grade level	2	.720	.360	1.67	.20
Subjects	66	14.2	.215		
Period	2	2.02	1.01	9.58	.0001
Period*Grade	4	.662	.166	1.58	.185
Period*Subject Group	132	13.88	.105		

Summary

Testing for each project year appear to confirm that nearly all project objectives related to the improvement of science understanding and attitudes toward science were met. For each of the five years, cognitive test scores for each group improved significantly from pretest to posttest or from pretest to post-posttest. In all cases, post-posttest scores have been significantly higher than pre-summer workshop scores. Affective testing for each year of the project indicate significant improvement of attitudes toward science knowledge, science teaching, and the philosophy of science over the course of the project. The design and implementation of this project appears to have contributed significantly to the cognitive gains of participants and to their attitudes toward science and science teaching. Casual observation suggests that affective scores improve in a manner similar to the improvement of cognitive scores.

Other objectives of the project have also been successfully met. Two Project Director visits each year to participant classrooms have confirmed that in-class expectations are generally being met. First year leadership participants helped to prepare the new district unified science curriculum and developed activities to enhance the curriculum. Participants in the first two years played a major role in the efforts to provide district-wide new science curriculum inservice for all elementary teachers. Participants in all five years have provided a wide array of inservice activities within and outside the district. All have provided at least four inservice activities within the district. Over half have provided inservice sessions for national, state, and local conventions and conferences. A growing network is linking participants of this project with participants in other southwestern Ohio hands-on science projects. They have opportunities to share ideas and provide moral support through regional conferences and newsletters.

One significant casual observation has been that participants had much less difficulty adapting to the procedures of hands-on science than to some basic generic teaching expectations. During summer workshops and academic year seminars, project faculty emphasized and regularly modeled how to get students involved at higher cognitive levels and how to use effective questioning skills. Still, many participants had difficulty demonstrating these skills in their own classrooms. In many cases there was little sign that participants ever learned skills such as planning, introducing and concluding a lesson for effective learning, and questioning techniques.

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STUDENT PERSPECTIVES ON LEARNING INQUIRY-ORIENTED SCIENCE

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Student Perspectives on Learning Inquiry-Oriented Science

The purpose of this study was to describe the relationship between teacher and student perceptions of inquiry-oriented teaching practice. In addition this study documented elementary student understanding of the nature of science as background for interpreting their statements about teaching. An extensive review of the literature on inquiry-oriented teaching revealed that studies generally concentrated on student behaviors and products and excluded descriptions of teaching practice that lead to those behaviors and products (Flick, 1995). While interest in inquiry-oriented teaching has been persistent for decades, the national science education standards (NRC, 1995) have the implicit assumption that inquiry-oriented teaching practice will be a part of every classroom that aspires to address the standards. The standards also explicitly state the goal of communicating the nature of the scientific enterprise as part of science education. An extensive review of the literature on teacher knowledge of the nature of science shows it to be a long standing goal of science education and yet one where teacher understanding is minimal (Lederman, 1992).

Integrated Science Concepts (ISC) is a four-year program designed to improve teacher knowledge of science, the nature of science, and recommended teaching practices. An evaluation component of ISC is to examine effects on students of teacher practice as influenced by project inservice sessions. Teaching behaviors that include more inquiry-oriented instruction must be tracked against student perceptions of these changes. If students don't perceive inquiry to be taking place or don't understand the purpose of this type of instruction, then its effectiveness is compromised. This study incorporated three data sources to derive a picture of inquiry-oriented teaching practice (a) video tape of teaching episodes, (b) survey data establishing the teacher's perspective of his/her own instructional practice, and (c) interviews with selected students from each of the teachers studied. Results indicated a consistency between student and teacher views of inquiry-oriented instructional goals and practices. The few discrepancies as well as broad areas of agreement between students and teachers reinforce guidelines already well articulated in the literature but suggest some modifications by grade level.

Subjects and Procedures

Three teachers from the first-year cohort of 16 teachers in the project were selected to participate in an examination of their teaching as influenced by the ISC project. Selection was based on evaluations of classroom video tapes, level of participation in project workshops, and willingness to cooperate in the complex logistics necessary to solicit parental and student informed consent to conduct video-taped interviews. As part of the cohort, these teachers filled out the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & White, 1994) and the Science Teacher Beliefs Instrument (STEBI) (Enochs & Riggs, 1990) at the end of the first year of inservice activities at the same time student data were collected. These teachers collaborated with the authors in the design of interview protocols used with members of their class whom they selected. The video-taped interviews were conducted during school time and lasted about 30 minutes. Simple classroom materials used during instruction prompted student thinking about science concepts. All interviews were conducted in classrooms unoccupied at the time of the interviews.

The pseudonyms of the teachers selected for this study were Mr. Lesh, 6th grade; Ms. Haver, 5th grade; and Ms. Braeburn, 4th grade. The teachers selected students for interviewing based on the criteria of providing a cross section of conceptual understanding of the science subject matter and an approximately equal distribution between males and females. To keep the research blind to the perceived achievement of the students, teachers provided an indication of student achievement after the interviews and analysis were completed. This provided an internal validation of the criterion of providing a range of student conceptual understanding among the subjects. Individual student transcripts were coded with three or four characters begin with the initial of their teacher, a unique student number, and M or F designating gender. Those students who teachers perceived to be high achievers in science are designated by an asterisk (*). The distribution of interviews across classrooms is shown below:

Table 1

Sample of Students Interviewed by Grade and Gender

	Boys	Girls	Totals
Lesh (6th)	3	4	7
Haver (5th)	5	4	9
Braeburn (4th)	6	5	11
Totals	14	13	27

The interviews were organized around topics designated by the teachers as being most appropriate for their relationship to the content of project inservice activities and of most interest to them in terms of feedback on their instruction. The teachers also discussed materials used during instruction from which props were selected for the interviews.

The interview protocol was designed to investigate three areas of student understanding considered significant in describing and evaluating classroom instruction from the perspective of students. These areas were (a) student knowledge in a topic selected by the teacher, (b) student understanding of the nature of science, and (c) student perceptions of specific teaching practices considered significant to the goals of ISC project. Interview protocols had to be tailor made for each of the three science topics, however, a standard set of questions were developed for probing perceptions of teaching practice and understandings of the nature of science. As an example, the protocol for Ms. Braeburn is described below followed by the standard protocols.

Example Interview Protocol

Ms. Braeburn selected her study of seasons and the relationship of earth and sun as the topic. She collaborated in establishing the following basis for the interview: (a) The seasons result from the uneven heating of the Earth's surface due to the tilt of the Earth's axis relative to its path around the sun, (b) The sun provides all the energy for our weather, and (c) Air that is warmer than the air around it will rise, or float, above the cooler air.

The classroom materials included a globe, flashlight, and tennis ball for discussing day/night, summer/winter, and global weather patterns. The interview protocol was:

- What causes the seasons?
- Why does it get cooler in the winter and warmer in the summer?
- How does the tilt affect our seasons?
- How do we get day and night?
- Why do we say that the sun creates our weather?
- Explain why this card stays on this upside-down glass of water. Why doesn't the water fall out?
- Why doesn't the water in the cup push the plastic cover and air out of the way and fall out?

Students were asked about the nature of science within the context of the teacher-selected topic and also within a context established by three sets of *National Geographic* pictures used in a uniform way with all students. While each picture was related to a story dealing with science content, the students were only asked to respond to the pictures as a stimulus for talking about the nature of science. The general line of questioning is listed below:

Introduction

General questions about how scientists learn about the teacher-selected topic of the interview to this point. This is used as a transition to specific questions probing their understanding of the nature of science.

Processes & Activities of Scientists

What do scientists do?

Fallibility of Scientists

Can they be wrong? Why?

Are there disagreements among scientists?

Why is this true, if they are looking at the same kind of information?

Validation and Proof in the Practice of Science

How would scientists resolve their differences?

Would it be possible for scientists to gather all the information necessary to learn everything there is to know about something? Would the scientists then be considered correct and no one would prove them wrong?

Respect for Scientists

Is it OK that scientists are wrong sometimes?

The last portion of each interview was devoted to questions concerning student perceptions of the teaching practices of the teacher. Questions were designed to focus student attention on key elements of classroom practice found in the CLES and STEBI. The interview protocol focusing on instruction is outlined below:

Introduction

What are some typical things that go on in your science class?

Relevance of Instruction

Is it OK to ask the teacher "why do we have to learn this?"

Teacher Actions

What does your teacher do that helps you learn science?

Expressing Ideas

Do you ever discuss your own ideas in class and tell the teacher what you are thinking?

What does the teacher do when you express your ideas?

Does this help you learn about the activity?

Peer Discussion

Do you ever talk to other students about science during science class?

Do you learn some things from other students when you talk to them during class?

Do you learn as much from other students as you do when you talk or listen to the teacher?

Anything else about science and science class that you want to talk about that we have not mentioned?

Analysis and Results

CLES and STEBI data were tabulated for all 16 teachers as a means of contrasting the teaching characteristics of the three teachers selected. Individual teachers varied within particular subscales, but there were no clear trends across the 16 teachers. The two elementary teachers were above one standard deviation from the mean on the CLES and the two STEBI scales while the one middle school teacher (Mr. Lesh) was very close to the mean on all three scales. In Mr. Lesh's view, students had less of a role in determining curriculum and instruction as compared to the perspectives of Mrs. Haver or Mrs. Braeburn. As will be shown from student interviews, students saw Mr. Lesh as having more of a direct role in leading the class.

The lower scores for Mr. Lesh on both scales of the STEBI can be attributed to responses that indicated he has less direct effect on what students learn than the elementary teachers expressed through their responses. For instance, on the following item, Mrs. Braeburn and Mrs. Haver answered "strongly agree" while Mr. Lesh marked "disagree:"

> When a student does better than usual in science, it is often because the teacher exerted a little extra effort.

For items on both scales that were worded in the negative, Mr. Lesh responded less extremely than the other two. For instance, Mr. Lesh disagreed while Mrs. Braeburn and Mrs. Haver strongly disagreed with the following statement:

Effectiveness in science teaching has little influence on the achievement of students with low motivation.

Discussions with these teachers concerning the content of the interviews and the nature of this project supports the view that Mr. Lesh sees his 6th grade students as having more responsibility for their learning than either Mrs. Haver (5th grade) or Mrs. Braeburn (4th grade).

Student interviews were transcribed and coded corresponding to the subsections of the interview protocol as shown above. For instance, that portion of the interview dealing with instruction was coded for four categories: (a) relevance of instruction, (b) teacher actions, (c) expressing ideas, and (d) peer discussion. The nature of science protocol was coded for, (a) processes of science, (b) fallibility of scientists, (c) validation and proof of scientific results, and (d) respect for scientists and the scientific endeavor.

Interview data concerning student knowledge of concepts taught verified that the students interviewed were sufficiently involved with the class to have experience upon which to base a description and judgment of teaching practices. Although these data are not reported here, in general the student knowledge of the concepts taught by each teacher varied according to teacher perceptions of their achievement. These data showed, for instance, that some of the 4th grade students were quite well versed on the nature of seasons by providing operational descriptions of the effects of tilt, orbit, and rotation on seasons. Other students showed only a facility with vocabulary and a knowledge of classroom activities associated with teaching that topic. The authors were satisfied that the teachers had indeed provided the cross section of students requested.

Also not reported here are the data pertaining to student understanding of the nature of science. The students expressed a remarkably consistent view of the nature of science that varied little with teacher-perceived achievement, grade level, or gender. Students generally described the activities of scientists as involving investigations into how things work, how the world works, and what things are made of. Their conversational knowledge of science processes was minimal. Regardless of grade students talked only in generic terms such as "classifying," "studying," and occasionally "hypothesizing." No mention was made of controlled experiments, specific steps in data analysis, or even using recently generated conclusions for building new investigations. However, students were very clear and consistent in stating that scientists could be wrong and that error was a natural consequence of inadequate technologies and limited time or knowledge. The fallibility of science was accepted by all students while at the same time they reasoned that other scientists would be able to come up with better information. While they agreed that better information was always forthcoming and that some of the information that science is reporting to them and their teacher may be wrong, the basis for errors was generally a lack of something such as technology, time, or number of scientists. For example, students believed that scientists could not be "super exact" about how a particular fish lives, because there are more fish than there are scientists to study them. Some students only slightly alluded to the idea that new ideas from scientists could lead to more and better information about the world.

The interview data are presented for each teacher. Comparisons are made between the each teacher's view as expressed through responses to the CLES and relevant student comments.

Student Perspectives of Mr. Lesh's Teaching

Statements that Mr. Lesh's students made during clinical interviews were generally consistent with responses he made on the CLES and observations via video tape of his classroom teaching. Lesh's students said that they typically "find out" about things in class. Finding out was operationalized as discussion with explaining and doing activities. The term "activity" mean a wide variety of things from "doing experiments" or "hands on stuff" to "watching a video." Notice the emphasis on classroom talk. Mr. Lesh's talk eventually emerges as a significant feature in student perceptions of his teaching.

L5M: Well, it's usually the hands on stuff like when you do experiments with him. Sometimes the reading, but it's easier to understand when you do experiments.

L6F: ...for instance, right now we're finding out how the earth is formed and stuff like that. We're just finding out, we're looking at other things. We're looking at videos and stuff like that, that explain like volcanoes and how they explode and stuff. We just study things. We look at them and we just talk about them and stuff.

L3F: We read out of (science books) sometimes, but most of the time we just talk...like at the beginning of the year we talked about and did activities on planets and stuff; the universe. We just talked and did activities.

Students said that during classroom talk there were opportunities to express their own ideas and engage in peer discussion. This took various forms that included discussion in small groups and speaking out in the whole class.

L5M: Oh ya, (students express their ideas) a lot. ...Mr. Lesh tries to help them explain. He tries to explain it to them, but usually we do something to explain what they ask. A lot of times when they ask, it's usually during an experiment that we're doing. Sometimes during greeting.

L3F: We have groups. There's groups and you work with them and you have your own paper, but you work with them. If you have a question or anything, you're supposed to ask whoever is in the group.

This was consistent with Mr. Lesh's views expressed on the CLES that students learn to communicate through discussion with other students and during class. Mr. Lesh restricted student "questioning" and "complaining" about instructional activities but "almost always" allowed students to discuss science ideas as a part of science class. The following is a paraphrasing of statements from labeled sections of the CLES using Mr. Lesh's responses:

Learning to speak out:

In the process of being in my class, they learn that it is almost always OK to ask "why do I have to learn this?" But it is only sometimes OK to question my teaching strategies or complain about activities that are confusing. While it is almost always OK for student to express their opinions, it is only sometimes OK for them complain about things that they think are preventing them from learning.

Learning to communicate:

Students almost always get a chance to talk to other students about solving problems, explaining their own ideas, and asking each other questions about what they think.

However, not as obvious from Mr. Lesh's perspective was his central role as the mediator of information and ideas in the classroom. Generating understandable explanations was, from the students' point of view, the most important thing he did in helping them learn science.

> L4M*: (Mr. Lesh) Explains stuff like gives us an easier explanation. ...like takes the explanation, the video that he gave us, and like made it so we can understand it like using smaller words or recreating their explanation to something we would understand.

> L6F: He explains it, he, well, Mr. Lesh makes it seem so easy... He makes it so that we understand it... It's the words he chooses and the way he lets us look at things.

L1F: Well, the teacher, he gives us films, and we take notes on what we hear. He learns things and then he tells them to us about how like maybe this was formed by volcanoes and that kind of thing, and he teaches us, and I think he does a very good job too.

L5M: Well, usually he'll take a break and talk about something we had just read about and tell us more about it that the book doesn't explain.

Mr. Lesh was central to the process of mediating ideas and processing information. Students felt that they learned from others in their class but they also stated that student attention was inconsistent and sometimes students did not listen to their peers. They looked to Mr. Lesh to create an atmosphere for sharing ideas and provide feedback on their thinking.

L1F: Ya, sometimes, but it's hardly ever that anybody has any (ideas to express) because they're here to learn, so they let the teacher teach.

L4M*: He says something about it like, "Very good," like he or she was right and he talks a little about what they said about. (Or) if they're wrong he says something that it kinda has something to do with the idea, but it's the right idea that they could have been thinking about but not what they were.

In one anecdote, a female student explained the relationship between using Mr. Lesh as a mediator of student thinking and students' own thinking. She was conscious of the value of his verbalized thought but was also aware that at least she was using that information to help her think on her own.

L6F: ...we don't use his mind, we use our own. We try to think of what happens like how things do things and we use our own minds. We don't just use his, it's like taking advantage of his mind 'cause he knows everything 'cause he's the teacher. It's kind of like we just, we think on our own. We just learn from our own minds and from each other.

Students were silent concerning their possible input with respect to the content of the class. While Mr. Lesh seemed to express the position that his students were to be, to a large extent, responsible for their own learning, his students did not directly express the view that they were contributing to their own learning. As we shall see, the elementary students were far more confident and outspoken about their role in their own learning. This result is contrary to the way Mr. Lesh expressed his position on the relevant section of the CLES:

Learning to learn:

Students sometimes help me plan what they are going to learn and which activities are best for them. While students often help decide how much time they spend on activities, they only sometimes help me assess their own learning.

Student Perspectives of Mrs. Haver's Teaching

Mrs. Haver's students found her class "fun so that we aren't bored." Student perceptions were focused on the materials they can "fiddle with." Learning science in her class was finding out what happens as a result of manipulating materials.

H7F: Well, she lets us fiddle with the stuff. And, let's us play with it and try to find out what kind of stuff the thing does... it like helps you, like, learn like what, how this stuff works and stuff. And, like what happens if something occurs. Like if you mix vinegar with baking soda or something.

H6F: Sometimes, most of the times, she hands out stuff and we try to make things. Like balloons and see how stuff and just fiddle around with it and see what you can make with it. Stuff like that.

H5M*: Well, what we usually do is that we usually have an experimenting free for all with some rules involved so that we don't short the whole school's power system or something. But, then we go and we talk about what we learn and what caused that and then we back to experimenting with our new knowledge to see.

Student statements support Mrs. Haver's views of her own teaching that imply students have a clear voice in the curriculum and instructional strategies. It was equally clear from the interviews that she selected the topics and provided specific materials. However, they were able to play a key role in deciding how materials were to be used and even how much time they spent on the topic. Paraphrasing from the CLES expresses Mrs. Haver's position:

Learning to learn:

Students often help me plan what they are going to learn and which activities are best for them. Students often help decide how much time they spend on activities and often help me assess their own learning.

One student described a classroom episode involving a discussion. While the plan was to spend only a half hour on the topic, the discussion stretched to 90 minutes. She talked as though the students would not let her stop the class for recess.

H4M*: Oh, well, we were talking about communities, I think, and we were talking about what makes a community. And we were going spend a half hour on this, and then we were going to have and hour 'til recess. We spent an hour and a half on it. So we got into it. Finally, one kid just put out the answer and we all accepted that.

Students said they regularly interacted with other students during Mrs. Haver's instruction as a way of learning science. A typical pattern involved students being asked for their ideas while Mrs. Haver wrote them on the board. Other students expressed agreement or disagreements with these ideas and a discussion followed.

H9M: She kind of goes with (our ideas) and talks to the class about it, and maybe see what they think about it and stuff like that. And, then we discuss it, and then we may (experiment) or we may not. ...and then each of us came up with that idea. And it's working.

H6F: Sometimes you have arguments. But, like they say some things are a community. And, they say "Naah, it has to be loving." or something. And, so, Mrs. Haver kind of writes up our questions and then we all talk about it and see which is right.

H4M*: Well, it always starts out with a question. And then a comment. And then we get into a discussion. It always happens when we do that. And only when Mrs. Haver stops us do we.

H5M*: Yeah. A lot of times I get ideas and sometimes I forget them. But, everybody gets to say their ideas, and, then, if everybody says "Yeah, yeah." then we kind of turn to a discussion about that. Or, if it's questionable, we maybe set up an experiment with it.

Sometimes discussions were stimulated in small group settings and students talked among their peers about science. Students generally associated these interactions with activities.

> H6F: Yeah. Sometimes when we get materials to play with and stuff, and figure out ways to do, we're in groups. And, yeah, we talk to each other about how to do it.

> H5M*: Yeah. A lot of times when we try an experiment, or something, before we do it, we talk about, like, sometimes I say, I use my knowledge that I already have and put that towards the experiment.

Peer discussions were an important way of learning science according to some students. When asked if they learned as much science from talking to peers as from Mrs. Haver, some felt that peers were an indispensable part of the instruction.

> H9M: ...But, when you're just talking to the teacher, it doesn't come out with the same idea. It kind of comes out better when you talk with your group and stuff, because then you guys can work together.

> H6F: Cause if you're alone with your teacher and just one class, or just you. Then you probably wouldn't learn as much because kids would bring up other ideas.

Mrs. Haver's responses to the CLES indicate a strong intention to let students communicate in class and with each other on a regular basis. She selected the option of "almost always" in the items relevant to communicating and speaking out.

Learning to speak out:

In the process of being in my class, they learn that it is often OK to ask "why do I have to learn this?" It is often OK to question my teaching strategies or complain about activities that are confusing. While it is almost always OK for student to express their opinions, it is only sometimes OK for them complain about things that they think are preventing them from learning.

Learning to communicate:

Students almost always get a chance to talk to other students about solving problems, about explaining their own ideas, and about asking each other questions about what they think.

Student Perspectives of Mrs. Braeburn's Teaching

Mrs. Braeburn's students have developed an alternative meaning for the term "science class." As a result of a teaching team developing an integrated curriculum, the students didn't identify with attending a class in science. Instead students saw themselves doing the activities normally associated with a science in time blocks reserved for integrated curriculum or in their math groups. One student separated his concept of science ("beakers and stuff") from what happened in school and said that "we don't have all that stuff." He then came to the startling conclusion that as a result "we do more hands on stuff."

> B11M: Well in our class I don't really think of it as a science class because it's like we don't have all the stuff, all the beakers and stuff. That's kind of why we don't call it a science class cause it's not really a science class. ...(It's) integrated curriculum. I think it's just different because we do more hands on stuff than I think you wouldn't do; chemistry, we don't do a whole lot of sitting down and listening to the teacher talk and talk and talk. We don't have the science stuff, but we do experiments like the thing with electricity and we did stuff with the weather, we did stuff with the ocean.

This perspective had an interesting effect on how students saw the role and fit of science in the curriculum. With no "class" being identified with "science" students were comfortable with science-like ideas being included wherever possible.

> B8M*: We really don't have a science class. You learn about science in any class that we have around here. We learn about air pressure, we do quite a few experiments. Like the thing we just did with the globe we did and things like that. We had some pop cans that we put into a bucket of water. A few sank and a few were still up on top.

> B2M: In our math group that's basically where we have most of our science. That and our integrative curriculum. She tries to bring in as much science as she can and it's all around things, it's not one particular thing. We try to make structures out of straws and see how high they can hold up, we're doing something on polymers right now and it's just lots of different things.

This more diffused or dispersed view of science learning was perhaps reinforced by the observation by several students that science was stuff brought from home or from outside the classroom either by the teacher or students. The sense of these interviews reiterated the point made in the pervious quote, "(Science is) all around things, it's not one particular thing."

> B1M*: Ya, we like take questions and we bring in stuff from home. She asks us questions like, she goes, "Does anybody have any questions," and we ask all our questions so we're all totally clear about it.

B6F: She brings in, like little things in, like today we were learning about trees and she brought in sticks for us to take the bark off and look at and so we can touch it and see how it feels. She talks about stuff and she takes pictures and we learn more about how we do research.

B7F: ...The teacher is up here and she brings in the big stacks of wood, she sets them on the tables and you take one of the microscopes and look inside them. She brings in stuff and she brought this stuff and she showed us stuff and oh god, it's so complicated.

Expressing ideas in class as well as discussion with peers was associated with activities and experiments similar to Mrs. Haver's students. Students describe the context of hands on activity as a time to say what they are thinking and to get feedback from the teacher. Whereas students found Mrs. Braeburn's feedback to be important, they also felt that considerable learning occurred by talking to other students.

B3M*: Usually she brings out an experiment and says, "What do you think will happen." People like give her as much information as you can on one idea.

B4F: If we have a science project and then we talk about what we think is gonna happen. ...She has us all raise our hands. If you say something that is really close or almost on the dot, she'll tell us and she'll tell us even more and give us little hints and it makes us think even more.

Students felt they learned a lot of science from other students. At times, they saw students as being the best source of information when Mrs. Braeburn did not know how to answer their questions. In a broader sense, students said that it was a good idea to have a variety of opinions because this would strengthen their own thinking.

> B2M: Ya, I think we learn more than it would be if she just told us what to do things and we didn't exactly talk. It gives us different ideas; different things to think about. If someone gives you a different opinion about things, it's much better than just going with your opinion and proven wrong and you not knowing why. I think it's about even (learn as much by talking to other students). She knows most of the facts, but we just have like little outcomes of it. We figure out well if that's right, maybe this could be right about a different thing. Doing that connects to another thing.

> B4F: Sometimes we do, not a lot. I usually don't. I like to keep my ideas in my head just in case it's a good idea. ...Ya, we learn a lot more. It's like what we do when we share and someone has a good idea. She tells us and we take that idea and we use it over and over again. It's pretty fun.

Students expressed the view Mrs. Braeburn's regularly sought student input which was consistent with her own view. Students expressed several ways that their ideas were heard and used in class. They went a bit further by saying that their discussions with each other about the tasks Mrs. Braeburn set for them were as important to their learning as discussions with her. A summary of Mrs. Braeburn's responses to relevant sections of the CLES express her position.

Learning to speak out:

In the process of being in my class, they learn that it is almost always OK to ask "why do I have to learn this?" It is almost always OK to question my teaching strategies or complain about activities that are confusing. It is almost always OK for students to express their opinions or complain about things that they think are preventing them from learning.

Learning to communicate:

Students almost always get a chance to talk to other students about solving problems, about explaining their own ideas, and about asking each other questions about what they think.

The students saw paper work as an integral part of science instruction. Far from being a burden, they saw it as constructive. Written work was a guide for what they were going to learn, were learning, and had learned. Further, the paper work was a vehicle for learning about organization.

> B10M: ...We study that for awhile and then we have papers that we have to do and stuff. We put it all into like our binders and stuff and then we give it to them (teacher team) and they grade us on how good we were organized and how good we did and stuff.

> B5F*: Sometimes we do papers and stuff to see if, to answer questions that we might have. At the beginning of the thing, we write down questions we have and stuff we don't know and stuff we do know and then we try to find out the stuff we don't know during the time we research it. That I think is kind of neat because it's hard to believe more stuff about plants or weather or whatever we're studying than when we came in.

> B9F: Ya, she gives us paper work and she gives us tests sometimes. Like she did it with plants and then like she gave us a test at the beginning of the year to show

what we know about it. Then at the end when we were finished learning about the stuff she would give us another test and see what new stuff we learned.

"Paper work" can be seen as Mrs. Braeburn's way of connecting students to the learning process that she designed. Her own view of instruction strongly emphasizes a student role in planning curriculum and instruction. A summary from the CLES expresses her position.

Learning to learn:

Students almost always help me plan what they are going to learn and often which activities are best for them. Students almost always help decide how much time they spend on activities, and often help me assess their own learning.

Conclusions

This study of the first of four cohorts revealed a consistency between teacher perceptions and student perceptions of inquiry-oriented instruction. Students valued teacher explanations, questioning, and solicitation of student ideas. In the case of two high achieving students, they detailed lengthy exchanges in class leading to inconclusive results about the science topic under discussion. This highlighted an uncertain state of knowledge that they felt was OK, and expressed belief that they would be interested in examining the ideas later. This was consistent with teacher intentions to solicit student ideas and to generate discussion among students about science concepts. However, there were differences between the one middle school teacher, Mr. Lesh, and the two elementary teachers with respect to the control of subject matter and the nature of instruction.

Mr. Lesh perceived himself as exerting tighter controls on student input on curriculum and instruction while Mrs. Haver, 5th grade, and Mrs. Braeburn, 4th grade, encouraged more dialogue about the structure and nature of classwork. Student interviews did not reveal this same distinction. For example, the middle school students, with one exception, did not comment on their ability to effect changes in curriculum or instruction. It appeared to be a non-issue. As one student said of the class, "they're here to learn, so they let the teacher teach." However, one student in Mr. Lesh's class did express discouragement while operating within the instructional guidelines and said that she had not found a way to express her frustration in class.

> L3F: We had to draw what we saw there. That's hard because in my rock there's dents and stuff like this and you can't draw that. The really talented people can, but I can't. ...we had to think (hypothesize) what it looked like and you can't really get much from a gray picture with just lines. So it was hard to do that. (What I wanted to do was) actually be able to look at it through the jeweler's loop or something without drawing it first.

She expressed hesitant agreement that she could express this problem in class and that Mr. Lesh would let her proceed in her own way. This was an isolated comment in an otherwise uniform endorsement of Mr. Lesh's teaching practice by the seven students interviewed.

Even though the students expressed a positive view of teaching practice that was consistent with Mr. Lesh, there were some discrepancies across grade levels. The 6th grade students cast their teacher in the role of mediator of information and ideas that was not implied in the CLES responses by Mr. Lesh. The 4th and 5th grade students did not make the same observations. While the middle school students were willing to "let the teacher teach," this subtle statement that students were not providing input into class structure and content was not perceived by Mr. Lesh. A logical extension of this view over the next few years of school would imply that students rationalize that they actually have <u>less</u> of a role in their own learning than they did in the elementary grades. This view directly contradicts Mr. Lesh's position that students at this age have <u>more</u> responsibility for their own learning. This contradiction between student and teacher perception of the nature of student involvement in the instructional process has direct implications for inquiry-oriented instruction and will be discussed below.

Students differed with respect to how often they questioned the relevance of instruction, but all agreed that questions of relevance would be greeted with respect and in some cases even encouraged by their teacher. There was consistency in the presence and perceived value of activities or hands-on instruction. Teacher actions were usually cast in terms of using an activity as a stimulus for discussion and questioning. Students reported being able to express their ideas in class although they did not take equal advantage of these opportunities. Within the 27 interviews there was no obvious relationship between gender or teacher-perceived, achievement level and student participation in classroom discourse. Students used and valued discussions with peers about science and generally agreed with the statement that they learned as much from each other as they did from the teacher.

Student thinking about the nature of science paralleled their experience in class where they were able to express their point of view and hear the ideas of others. Data not reported here showed that these students were able to discuss basic tenets about the nature of science. This convincing, though elementary, level of understanding of the nature of science provided background for student comments on the nature of inquiry-oriented instruction. For instance, students considered scientists and the knowledge they develop to be tentative and believed that it would change as more people studied the problem. Students did not, however, express much understanding of science processes nor did they say anything about the role of theory and hypothesis in directing the work of science. This selective knowledge about the nature of science probably affected their ability to perceive the broader intentions behind teaching practices designed to engage students in inquiry.

These results have implications for studying the nature of inquiry-oriented instruction at the upper elementary and middle levels. The participatory nature of instruction as stimulus for class discussion supported a view of the tentativeness of scientific knowledge and its dependence upon useful and accurate information about the environment. Although initial observations of these teachers did not imply that they had any special knowledge about the nature of science, their orientation to instruction suggested that they operated from an basis at least as sophisticated as their students and were able to convey that perspective through instruction. The shift away from direct participation in the nature and content of science class with the middle school teacher raises questions about the cause and extent of this shift in student perceptions of science instruction. The relationship between student and teacher changes dramatically by the 6th grade that may signal the way classroom instruction is interpreted by students.

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PRESERVICE TEACHERS' CHANGING ATTRIBUTIONS FOR ELEMENTARY STUDENTS SUCCESS OR FAILURE IN SCIENCE

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Attributional Theory of Achievement Motivation

Weiner's attributional theory of achievement motivation has been used extensively to investigate perceived factors leading to one's success or failure (Graham, 1991; Weiner, 1985, 1994). The fundamental assumption of attribution theory is that human beings are motivated to find out why an event occurred, especially one that was unexpected or not anticipated. According to Weiner, the process of finding out why an event occurred begins with a search of the perceived causes of the unexpected success or failure. An unexpected event could be attributed to any number of possible causal attributions, but Weiner and others (Graham, 1991; Weiner, 1985) have been able to identify several prominent causal attributions that occur frequently. The two most common causal attributions are ability and effort; other causal attributions may include task difficulty, luck, a teacher, or interest.

Weiner (1985, 1994) further classified causal attributions by the underlying dimensions common to all causal attributions. He developed a classification system based on three properties of causal attributions called *causal structures*. The three causal structures are: (a) *locus of causality*, (b) *stability*, and (c) *controllability*. Every causal attribution has a locus of causality. Locus of causality is the source of the attribution, which can be either internal or external to the individual. An internal locus of causality indicates that the source of the causal attribution is a characteristic of the individual. An external locus of causality is one that is external to the individual. An example of a causal attribution with an internal locus of causality is ability—ability is considered to be a characteristic of an individual. An example of a causal attribution with an external locus of causality is when a student attributes failure on an exam to a poor teacher. In this case, the perceived cause for the failure is external to the student.

The second causal structure, stability, is the length of duration of a causal attribution. Some causal attributions are perceived as being stable over time and others are perceived as being relatively unstable over time. Ability is usually considered a stable individual characteristic because it is perceived as being stable and invariant (i.e., fixed) for a particular task; but, some may consider ability as unstable if they perceive ability or intelligence as incremental. Typically, effort is viewed as an unstable characteristic because it can vary from task to task. At times, it also can be perceived as stable. An example in an achievement context is the student who perceives their ability to construct hypotheses in science as being stable over time and the amount of effort they exert in making observations in science to vary from time to time depending upon what they are observing.

Controllability, as the third causal dimension, describes the degree of control an individual has over a causal attribution. For example, effort and hard work are presumed to be under the control of the student, while ability is often not considered to be under the control of the student (ability on a task is perceived as being fixed and uncontrollable). Table 1 shows the relationship between the three causal structures and the two most prominent causal attributions, ability and effort (see Table 1). Each causal attribution consists of some combination of the three causal structures (i.e., locus of causality. stability, and control).

Table 1
Summary chart of the causal structures associated with the causal attributions of ability and effort

	Causal Attributions	
Causal Structures	Ability	Effort
Locus of Causality	Internal	Internal
Stability	Stable	Unstable
Control	Uncontrollable	Controllable

Note. From ‹eview of Attribution Theory in Achievement Contexts,' S. Graham, 1991, Educational Psychology Review, 3(1), p. 8.

The causal structures that are ascribed to a causal attribution can have a significant impact on the emotional and psychological outcome of an event (Weiner, 1994). For example, if a student attributes failure at a given task to low ability, then future expectations for success at the same or similar tasks will be lowered because ability has an internal locus of control, is stable, and is uncontrollable. The student perceives there is very little he or she can do to change future performances on the similar tasks. On the other hand, if a student attributes failure to a lack of effort (which has an internal locus of control, is unstable, but is controllable), then future success is under the direction of the student. Under effort-failure attributions, the student has the power to affect changes in the future; with ability-failure situations, the student may perceive herself or himself as powerless to affect changes in future performances. Future performance and motivation can be directly influenced by the causal attributions students make for unexpected events.

Beyond self-ascriptions of causal attributions, individuals may also infer causal attributions for another's success or failure (Graham, 1984; Juvonen & Weiner, 1993; Weiner, Graham, Stern, & Lawson, 1982). Weiner's (1985) hypothesis is that inferred causal attributions mediate the affective and emotional reaction individuals have toward others. For example, individuals may causally attribute someone else's failure to a lack of effort (a controllable causal structure) and become angry with the other individual; or, they may attribute failure to ability (an uncontrollable causal structure) and display pity or sympathy.

A major development to arise out of attributional research is the notion that causal factors and their underlying structures are perceived by individuals differently under differing contexts. Ability may be inferred as stable by one individual and unstable by another, and effort may be perceived as stable in one context and unstable in a differing context. As a result, investigators looking at causal factors for success and failure in new domains or contexts are encouraged to develop new attribution measurement instruments instead of relying upon instruments valid under differing conditions (Elig & Frieze, 1979; Russell, 1982). Elig and Frieze (1979) suggest the use of open-ended responses for success or failure attributions to establish a pattern of consistent attributions distinctive for a particular situation. Open-ended responses for measuring causal attributions avoid limiting subjects to predefined factors and avoid cueing to nonspontaneous causal factors. Open-ended responses are preferred for pretesting to develop a valid structured measure. The structured measure can then be used to elicit the causal dimensions inherent in the new domain, such as preservice elementary teachers' causal attributions for the success or failure of elementary students engaged in a learning task under the direction of an experienced classroom teacher.

One purpose of this study was to determine preservice teachers' perceived causal attributions for the success or failure of elementary students engaged in a hands-on science activity. Specifically the questions of interest were: What causal attributions do preservice teachers' make for the success or failure of elementary students after viewing a hands-on science activity in a real classroom? Another purpose was to investigate when preservice teachers change their attributions. Do they change after viewing the activity as it happened; after hearing student comments indicating failure; or, after group discussion?

A search of ERIC from the mid-1970's to 1994 did not reveal attributional studies examining the causal inferences preservice teachers' may make after viewing or witnessing a teacher lead a hands-on science lesson with elementary students. Given the modeling influence teachers have on the development of preservice teachers, it seemed prudent to investigate the common causal ascriptions preservice teachers give for student success or failure. An understanding of the causal structures may lead to improved teacher training.

Method

Participants

Subjects were 20 preservice undergraduate elementary education majors enrolled in an introductory educational psychology course at a midwestern university; 4 were male and 16 were female. Participation in the study was part of the regular instruction for the class and part of a required class project.

Materials

A 20-minute videodisc (Thompson, 1994) of a teacher conducting a hands-on science lesson to elementary students in a real classroom was used. The lesson was shown in edited form from start to finish. The elementary science teacher began the lesson by reviewing previous material, asked elementary students to define the concept for the present activity (electrical conductors), then led the elementary students through a guided discovery lesson investigating examples and non-examples of electrical conductors. The teacher finished by leading a class discussion of the results obtained by the students. The videodisc contained an audio track of the lesson as it happened and a separate audio track of elementary students' comments recorded shortly after the activity and two weeks later.

Procedure

After viewing the 20-minute videodisc, subjects were asked to indicate whether the elementary students had succeeded or failed at acquiring the concept of electrical conductors and to make open-ended causal attributions for their success or failure. The subjects were also asked to define an electrical conductor to ensure accurate assessment of the students' acquisition of the concept (see Appendix A).

After completing the first questionnaire, subjects listened to audio comments made by the elementary students during the lesson and 2 weeks after the lesson. The audio comments indicated that the students did not acquire the concept of electrical conductors. Most of the elementary students retained their original concept of a conductor as a man on a train. After listening to the comments, subjects were given a second questionnaire to indicate whether the elementary students had acquired the correct concept of electrical conductors and to make causal attributions for their success or failure (see Appendix B).

Following the second questionnaire, subjects engaged in small group discussion (4 to 5 per group) and a class discussion. The discussion was approximately 20 minutes in duration, free-flowing, student-directed, and focused on salient features of the lesson, namely classroom management and learning theory. Subjects were given the third open-ended questionnaire asking them to indicate success or failure for the students and to make causal attributions (see Appendix C).

Scoring

The data indicating success or failure on the questionnaires was quantitatively analyzed with the McNamar test for significance of a difference between two correlated proportions (Ferguson & Takane, 1989). The causal attributions were coded qualitatively by developing a multi-stage classification system elicited through patterns of causal attributions. Initially, two researchers independently developed a deductive list of attributions from the subjects open-ended responses. They compared lists and agreed upon a set of possible attributions. After arriving at a consensus on a list of attributions, two researchers independently reclassified the subjects' open-ended responses according to the list of possible attributions. Any differences were worked out until both researchers agreed on the classifications.

Results and Discussion

Indication of Success or Failure

As shown in Table 2, 19 subjects indicated the students succeeded at learning the concept of electrical conductors after viewing the videodisc for the first time and none indicated failure (see Table 2). One subject indicated both success and failure, and thus was eliminated from further analysis. After hearing the students' audio comments suggesting failure, 3 subjects

TABLE 2
Preservice Teachers' Indication of Student Success or Failure

Subject	Questionnaire #1	Questionnaire #2	Questionnaire #3
1	1	0	0
2	1	1	1
3	1	1	1
4	1	0	0
5	1	0 & 1	0
6	1	1	0
7	1	1	blank
8	1	1	0
9	1	1	0
10	1	1	0
11	1	1	0
12	0 & 1	0 & 1	0 & 1
13	1	1	1
14	1	1	1
15	1	1	1
16	1	1	1
17	1	1	1
18	1	1	1
19	1	0	0
20	1	1	1
Total	19 Succeeded 0 Failed	15 Succeeded 3 Failed	9 succeeded 9 Failed

Note. 1 = success, 0 = failure.

changed their perceptions of students' success to failure. Two subjects were omitted because they indicated success and failure. After the group discussion, 9 subjects indicated success and 9 indicated failure.

Results of the study demonstrated a significant change from the first viewing of the videodisc to the group discussion (z=2.84, $p < .01$). It appears that the audio comments by the students suggesting failure did not have a profound impact on the subjects' judgment of success or failure (z=1.74, $p < .10$). Only 3 changed their assessment and 15 held on to their initial judgment. There was a modest, yet significant (z=2.24, $p < .05$) change from the group discussion that followed the audio comments. It is hard to determine in the present study if it was the combination of the videodisc and the discussion that followed or the discussion alone that was responsible for the change in judgment and causal attributions. Surprisingly, only one-half of the subjects changed their judgment of success to failure by the third measurement.

Causal Attributions

The subjects made a total of 178 causal attributions for success and failure that were classified into student causal attributions, teacher attributions, task, environment, and other (see Table 3). Student causal attributions were further broken down into student engagement during the learning activity, prior knowledge, motivation, ability, knowledge of expectations, and student understanding.

TABLE 3
Summary of Success and Failure Attributions

Attributions	Questionnaire #1	#2	#3	Total
	Success			
Students	34	19	6	59
Teacher	44	23	16	83
Task	4	3	2	9
Environment		1		1
Other	2	6		8
Total success	84	52	24	160
	Failure			
Students			8	8
Teacher			8	8
Task				
Environment				
Other		2		2
Total failure			16	18
Total attributions	84	54	40	178

Teacher attributions were further classified into classroom management, instructional strategy, and personal characteristics of the teacher. Initially, the two independent coders agreed on 88% of the subject's responses when classifying them according to the derived list of possible attributions. The remaining differences were negotiated.

On the first questionnaire, preservice teachers attributed student success about equally between the students and the teacher. A shift occurred, however, as the number of students indicating success on subsequent questionnaires decreased. Those students who held on to their original indication of success attributed student success more to the teacher than to the students. Those preservice teachers' indicating failure were split equally between the students and the teacher.

The overall number of causal attributions decreased from 84 attributions on the first questionnaire to 40 on the third questionnaire. It may be that the preservice teachers were trying to hold on to their original belief as indications of failure mount, but were having difficulty supporting their original belief. It is also possible that the preservice teachers were becoming fatigued having to make three judgments of success or failure and the corresponding causal attributions in a short period of time.

As shown in Table 4, student success attributions were further classified into: student engagement in the learning activity, prior knowledge, motivation, ability, knowledge of expectations, and student understanding (see Table 4). It appeared the preservice teachers were generally making causal student attributions dependent upon the cognitive activity and behavior of the students. It is likely that some of the cognitive activity/lesson attributions may, in fact, be task-dependent attributions. Two examples of possible task-oriented attributions were that students engaged in hands-on activity and students engaged in trial and error. Some subjects attributed success to both the teacher and the students, suggesting preservice teachers perceive success or failure as being due to combination of several factors. There could also be interaction effects between multiple causal attributions.

Teacher attributions were classified into: classroom management, instructional strategies, and personal characteristics (see Table 5). The preservice teachers tended to attribute student success primarily to the teacher's instructional strategy. Initially, the teacher's ability to maintain classroom control and to prevent misbehavior (e.g., teacher had control of the room, and teacher was organized and had a set of procedures) were key attributions for success but were quickly dropped when it appeared the students may not be succeeding as had been expected. Personal teacher characteristics were noted in the first questionnaire as being a prominent force in student achievement, but were also abandoned in the second and third questionnaire. Apparently personal characteristics, such as the teacher gave support and was motivational, were not as salient as the teacher's instructional strategies.

Student causal attributions for failure focused on student ability and understanding (see Table 6). For example, subjects attributed student failure to such factors as the students persisted with misconceptions or prior conceptions and the students didn't grasp the concept. Only one subject attributed student failure to a non-cognitive student causal factor—namely, partners didn't work well together.

Teacher failure attributions were mostly instructional strategies with one subject indicating classroom management (see Table 6). Instructional strategies included such causal factors as the teacher not linking the current activity to the real-world and the teacher not calling on enough students.

Table 4
Student Success Attributions

Attributions	Questionnaire #1	#2	#3	Total
Engagement in learning activity	19	14	4	37
Prior knowledge	1			1
Motivation	7	1	1	9
Ability	5			5
Knowledge of expectations	2			2
Understanding		4	1	5

Table 5
Teacher Success Attributions

Attributions	Questionnaire #1	#2	#3	Total
Classroom management	10	1	2	13
Instructional strategy	20	19	10	49
Personal characteristics	14	3	4	21

Table 6
Student and Teacher Failure Attributions

Attributions	Questionnaire #1	#2	#3	Total
Student				
Engagement in learning activity			1	1
Prior knowledge				
Motivation				
Ability			2	2
Knowledge of expectations				
Understanding			5	5
Teacher				
Classroom management			1	1
Instructional strategy			7	7
Personal characteristics				

Overall, it appears that preservice teachers attribute student success and failure to both the students and the teacher. Causal student success factors differentiated into student engagement in the learning activity, prior knowledge, motivation, ability, knowledge of expectations, and student understanding. Student failure was predominantly attributed to student understanding and ability. Teacher success was dominated by instructional strategies and classroom management. Personal teacher characteristics, like enthusiasm and classroom management were quickly given up as it became apparent students were not learning the concept of electrical conductors. Teacher failure was primarily attributed to instructional strategy factors such as not linking the activity with real-world experiences or not calling on enough students.

Conclusion

The results of this study may shed light on the thought processes preservice teachers go through as they are confronted with changing perceptions of student success or failure. In particular, it is worth noting where inexperienced teachers focus their attention in situations of student success and failure. In the present study, preservice teachers tended to initially attribute student success during hands-on science activities to both the teacher and the students. But as the evidence accumulated suggesting student failure, preservice teachers held on to their notion of the teacher being responsible for student success and began to diminish their support for the students. Preservice teachers were as likely to attribute failure to the students as they were to the teacher. For example, before hearing the audio comments by the elementary students suggesting they did not learn the concept of electrical conductor, preservice teachers made 44 teacher attributions and 34 student attributions—the teacher appears to have a little more responsibility for student success. After the group discussion centering on the salient features of the lesson, preservice teachers made 16 teacher attributions for success and only 6 student attributions for success. Of those indicating failure on the last questionnaire, there were 8 student attributions for failure and 8 teacher attributions for failure.

It appears that inexperienced elementary science teachers tend to think of teachers as responsible for student success and students responsible for student failure. It was somewhat surprising to see preservice teachers "blame" students for their lack of success when teacher controllable attributions were primarily responsible for student failure. It would be worth pursuing in future research the dimensional structures of the attributions uncovered in the present study. Perhaps inexperienced, novice teachers have naive concepts about the amount of controllability and causality teachers have on instructional settings and learner outcomes. Preservice teachers need to be informed on what factors in student achievement are controllable from the teacher's perspective and what factors are not.

From this study, it should be possible to develop a valid measurement instrument designed to assess the preservice teacher's causal ascriptions to student success or failure. Ideally, a semantic differential scale similar to Russell's (1982) Causal Dimension Scale could elicit the causal dimensions underlying the causal attributions preservice teachers make. It may be possible to add to Weiner's attribution theory of achievement motivation if it is shown that the causal dimensions are in fact the locus of causality, stability, and controllability.

If preservice teachers attribute student failure to the teacher, specifically a controllable factor such as instructional strategy, then one could predict from attribution theory (Juvonen & Weiner, 1993) that preservice teachers may feel anger towards the teacher. Or, if preservice teachers attribute failure to the students, in particular to a lack of ability and understanding, then the preservice teachers may display sympathy towards the students. Perhaps teacher educators could strongly impact the shifting preservice teacher's attributions for observed student success or failure by inferring causal factors with affective cues. Given the proportionally high number of students in the present study that attributed failure to low student ability and a lack of understanding, it would be desirable to shift their causal attributions to controllable teacher factors such as classroom management and instructional strategy.

It would be fruitful to examine the pattern of changes that may exist between the novice, preservice teacher and the expert teacher's causal attributions for student success or failure in hands-on science activities. Questions to investigate include: (a) Do expert teachers notice controllable factors that novices miss?; (b) Do novices disproportionately attribute student failure to uncontrollable factors like student ability?; (c) Is there a typical progression that teachers go through to become experts?; and (e) How could teacher training programs effectively assist novice teachers in the transition to becoming experts?

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Appendix A

Questionnaire #1

Directions:

1. Please indicate your full name: ____

2. After watching the 20-minute videodisc scenario of the elementary school students engaging in a science activity would you say that the elementary school students succeeded or failed at learning the concept of electrical conductors?

   You must **circle** the answer that best describes your response:

   Succeeded　　　　　　　　　　Failed

3. **List** several things that you attribute their success or failure to:

4. Please **describe** what an electrical conductor is:

Appendix B

Questionnaire #2

Directions:

1. Please indicate your full name: ______________________________________

2. After listening to the audio and video clips of the elementary school students responding to the questions posed to them after completing the science activity would you say that the elementary school students succeeded or failed at learning the concept of electrical conductors?

   You must **circle** the answer that best describes your response:

   Succeeded　　　　　　　　Failed

3. **List** several things that you attribute their success or failure to:

4. Please **describe** what an electrical conductor is:

Appendix C

Questionnaire #3

Directions:

1. Please indicate your full name: ______________________________

2. After discussing the 20-minute videodisc scenario and the audio and video clips of the elementary school students engaging in a science activity would you say that the elementary school students succeeded or failed at learning the concept of electrical conductors?

   You must **circle** the answer that best describes your response:

   Succeeded Failed

3. **List** several things that you attribute their success or failure to:

4. Please **describe** what an electrical conductor is:

CONSTRUCTION AND VALIDATION OF A RUBRIC FOR SCORING CONCEPT MAPS

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Theoretical Background

Ausubel's meaningful learning and constructivist epistemology (Novak, 1990) provide the basis for concept mapping as espoused by Novak and Gowin (1984). According to Novak and Gowin, concept maps should illustrate a hierarchy of concepts where more specific and less inclusive concepts are linked together by valid and meaningful propositions and therefore are subsumed under the broader, more inclusive concepts. Examples of the concepts, therefore, are the most specific and least inclusive.

Concept mapping is useful as (a) an instructional tool (Martin, 1994; Mason, 1992), (b) an assessment procedure of processes and products (e.g., Malone & Dekkers, 1984; Roth & Bowen, 1993), and (c) a heuristic for developing science curriculum (e.g., Starr & Krajcik, 1990). Researchers (e.g., Cliburn, 1990; Heizne-Fry & Novak, 1990; Roth & Bowen, 1993; Roth & Roychoudhury, 1993) have touted concept mapping as a strategy for promoting meaningful learning. Roth and Roychoudhury concluded that concept mapping has some effect on achievement and a large positive effect on students' attitudes.

Concept mapping engages the learner in the construction of knowledge by linking subconcepts to more general, inclusive, and abstract concepts, thus bringing about meaningful learning. Concept mapping has, therefore, been accepted as a valid tool for assessing students' understanding of concepts. Researchers (Cliburn, 1990; Heizne-Fry & Novak, 1990; Markham, Mintzes, and Jones, 1994; Roth & Bowen, 1993; Roth & Roychoudhury, 1993) have defended concept mapping as a strategy for measuring meaningful learning, therefore establishing its construct validity.

In an attempt to establish concurrent validity of concept mapping as a research and evaluation tool in science education, Markham, Mintzes, and Jones (1994), using a sample of college students, compared concept mapping scores with scores obtained on card sorting task. They found that the concept maps of biology majors in comparison with non-majors included more branchings and more hierarchies, indicating greater concept differentiation and subsumption. The cross links, indicative of conceptual integration, and examples in the maps of the biology majors far surpassed those of non majors. Comparable results were found for the card sort, thus establishing the concurrent validity of concept mapping.

In scoring concept maps, Novak and Gowin (1984) recommended analytical scoring of the maps on four criteria: propositions ("1 point for each valid proposition"); hierarchy ("5 points for each valid level of the hierarchy"); cross links ("10 points for each cross link that is valid and significant and 2 points for each cross link that is valid but does not illustrate a synthesis between sets of related concepts or propositions"); and examples (1 point for "valid instances of the concept map"). In an earlier study, Cleare (1983) used a criterion similar to that described above but with slightly different point allocation. Later, Wallace and Mintzes (1990) added branching to the four criteria established by Novak and Gowin. In addition to the allocation of points recommended by Novak and Gowin, they recommended 1 point for each branch. Markham, Mintzes, and Jones (1994) suggested that the points awarded for branching should depend on the level at which it occurred. They assigned 1 point for branching at the first level and 3 points for branching at subsequent levels.

Schreiber and Abegg's scoring scheme (cited in Liu, 1994) included not just the propositions and the hierarchical structure of the map, but also included a measure of the ratio of the actual validity of the map components to the implied validity of the components. The total score was then computed using a mathematical equation with four different variables. This study, as well as the other studies reviewed above, used some form of an analytic scoring procedure. However, each study used a slightly different scoring scheme with different weightings for different attributes of the map. Even when using the same scoring scheme, scorers usually have to make judgments about the validity and accuracy or importance of the components being scored. As a result, scores obtained from the same concept map could vary from one scorer to another. Thus, as Liu suggested, when using these schemes it should be expected that interrater reliability may be low.

Rationale for Designing Rubric

Typically, an analytical scoring procedure, such as Novak's criterion map approach, is used to evaluate concept maps. This approach has been found useful in scoring maps in which specific concepts are expected or given and the assignment is more structured. However, when using the analytical scoring procedure for more open-ended assignments, variance in scores can present a problem. The variance in scores results because points are allocated for each occurrence of the attributes in the map. The scoring scheme used by Schreiber and Abegg may reduce this problem. However, the typical K-12 teacher would not use such a scheme because of its complexity. On the other hand, a rubric provides an analytic-holistic or more generalized procedure for scoring which K-12 teachers are more likely to use.

Development of the Rubric

A rubric with six attributes, originally identified as criteria by Novak & Gowin (1984) and Wallace and Mintzes (1990), was initially constructed. The theoretical underpinnings of those criteria are rooted in Ausubelian meaningful learning and constructivist epistemology as previously noted. Thus, the attributes represent different aspects of meaningful learning, specifically differentiation and integration of concepts. Hence construct validity is established.

The attributes in the original rubric are defined as follows:

1. Propositions establish meaningful relationships between concepts.
2. Hierarchy refers to the breaking down of the superordinate concept into valid levels, from most general to most specific.

3. The branches are the broadest concepts or subconcepts which flow from the superordinate concept.
4. Cross links show meaningful, valid, and significant integration of connections between subordinate concepts in the different branches.
5. Examples are the most specific differentiation of the subordinate concepts.
6. Degree of conceptualization indicates how well the superordinate concept and its connected subordinate concepts are understood. It also addresses naive or faulty conceptions.

The scale of the six attribute rubric ranged between 3 and 0 with 3 being most complete, valid, and significant to 0 indicating missing or invalid attributes. The scoring with this rubric did not allow for sufficient discrimination, i.e., ratings fell between the points on the scale. The scores did not appear to be very consistent and there was also a need for greater discrimination within the scale. Therefore, the rubric was expanded to a 4 to 0 scale.

In scoring a sample of concept maps in which the branches were assigned, it became apparent that the maps varied in the differentiation of the concepts within each branch. This variance led us to believe that the branching attribute was not sufficiently discriminating and that indeed the branching at the first level and subsequent levels, as identified by Markham et al. (1994), revealed different levels of conceptualization. As a result, we added a seventh attribute, differentiation of concepts, to the rubric. This attribute is defined as the elaboration of subconcepts or subordinates within each branch. The branching attribute in this instrument is the same as the first level of branching for which Markham et al. allocated one point. Branching at subsequent levels, to which they assigned three points, parallels the differentiation of concepts in our instrument. The revised rubric is presented in Appendix A.

Procedure for the Establishment of Interrater Reliability and Internal Consistency

The authors scored a sample of concept maps on beliefs about what should be taught in elementary science. The topic had been addressed in elementary science methods classes, and the subconcepts that should form the first level branches were given to the students. In addition, the students had assigned readings on the topic. Each student map was scored independently by the authors. Then the scores were compared. Differences in scores on the differentiation of concepts attribute were discussed further. These discussions led to fine tuning of the descriptors for the attributes in the rubric. The two raters then scored a sample of 10 maps independently using the revised rubric. The scores were entered on score sheets. Four more raters were then recruited to score the maps. Two of the raters were secondary science preservice teachers and the other two were elementary and middle school teachers. The same set of ten maps were scored independently by the four raters.

Next, the rubric was used to score a set of concept maps on diversity of living things. For this assignment, ten broad concepts were given to the students. However, they were instructed that they could include more than the ten concepts in their maps. The independent scoring procedure was repeated. The concept maps were then scored independently by four raters: the authors and the secondary science preservice teachers.

The data from the two sets of maps were analyzed separately. The scores assigned by the raters for the maps on beliefs about what should be taught in science were correlated to test for scorer reliability. The correlation between the scores for the seven attributes and the total score were determined using the Student SYSTAT Program. Pearson correlation matrix for all of the variables as well as the matrix of probabilities were obtained. The results recorded in Tables 1-9 were extracted from the matrices. The procedure was repeated using the scores for the maps on diversity of living things. The results recorded in Tables 10-18 were extracted from the matrices.

Results

The matrices of intercorrelations for scores on the ten maps assigned by the six raters are presented in Tables 1-8. Most of the correlation coefficients reported in Tables 1-6 and 8 were not statistically significant. However, with the exceptions of propositions and differentiation of concepts, there seems to be agreement in scoring of the maps by raters 1 and 2 (university professors). Also worth noting is the fact that several of the correlation coefficient for raters 3 and 4 (preservice secondary science teachers) were also significant. Except where noted above, most of the other correlation coefficients were not statistically significant. In fact, scores assigned by raters 5 and 6 (inservice elementary and middle school teachers) did not correlate significantly with those of other raters or with each others.

For the attribute examples (see Table 7), the correlation coefficients suggest agreement between raters 1 and 2 and raters 1 and 2 with all of the other raters. However, there is little or no agreement between raters 3, 4, 5, and 6.

Reported in Table 9 are the intercorrelations between the degree of conceptualization and the other attributes and the total score. In general, degree of conceptualization correlated significantly with the other attributes and total score. Although the correlation coefficients between degree of conceptualization and branches were not significant for raters 1 through 4 , they were significant at .01 or beyond for raters 5 and 6. The correlation coefficients for degree of conceptualization and cross links were low -.11 to .24 except for rater 6 which was .82.

The matrices of intercorrelations for scores on the diversity of life maps assigned by the four raters are presented in Tables 10-17. All correlation coefficients for the total scores (see Table 10) and cross links scores (see Table 15) were statistically significant. Except in the case of branches, the correlation coefficient for raters 1 and 2 were statistically significant (see Tables 10-17). Also, with the exception of total score and cross links, the correlation coefficient for raters 2 and 4 were not statistically significant (see Tables 10-17).

Reported in Table 18 are the intercorrelations between the degree of conceptualization and the other attributes and the total score. The intercorrelations for degree of conceptualization and other attributes for the four raters were statistically significant except for the attribute examples for rater 2 (see Table 18).

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Discussion

Of the six raters, the university professors (raters 1 and 2) had the most experience in both the use of and the evaluation of concept maps. Thus, finding agreement in their scores should be expected. The preservice secondary science teachers (raters 3 and 4) had previous experiences with concept mapping in their science methods course. They were provided with some instruction on the use of the rubric as a scoring technique for concept maps by one of the university professors. This accounts for the significant correlation coefficient for raters 3 and 4. Raters 5 and 6 (inservice elementary and middle school science teachers) had limited and different experiences with concept mapping. This may explain why their scores do not correlate significantly with the other raters and with each other. The inservice elementary teacher (rater 5) had experiences with schematic maps, but most of her experiences related to language webbing which does not have a hierarchical structure and does not require the use of propositions. Because of the low and even negative correlation coefficients of the scores for rater 5 with the scores of other raters, a question that surfaced was whether rater 5 had a true understanding of some of the attributes in the rubric, again suggesting that rater 5's experience with language webbing may have interfered with her understanding of the attributes in the rubric for scoring concept maps. Although raters 3, 4, 5, and 6 received the same information about the maps to be constructed, their backgrounds regarding the topic varied. It is believed, even with this variance in the background of the topic, with additional training in the scoring, as recommended by Cleare, a greater consistency in scoring would have been achieved because the meaning of the attributes would have been clearer.

Generally, the results reported in Table 9 tend to suggest internal consistency in the mapping attributes. The sufficiently high correlation coefficients suggest that indeed the attributes are related, but on the other hand they are defining different aspects of the map. In the areas of degree of conceptualization and branches and degree of conceptualization and cross links the correlation coefficients were low. Since the superordinate concepts for the branches were given in this assignment, the scores for branching should not be interpreted as the students' understanding of the concept. This explains the low and even negative intercorrelations between degree of conceptualization and branching. In the discussions among raters after the independent scoring of the maps, it became evident that there was variance in the interpretation of what constituted valid cross links. Specifically, some raters counted cross links that connected concepts within a branch as valid, whereas other raters counted only cross links which showed linkages between branches, the intent of the rubric scoring.

The intercorrelations of the scores on the diversity of life maps were in general statistically significant. Finding all correlation for the total scores and cross link scores statistically significant seems tc indicate a common understanding of the topic and a consistent interpretation of the attributes in the rubric. This result can also be attributed to the raters previous experience in using the rubric in the scoring of the first set of maps. No explanation can be given for the lack of significant correlation between the scores of raters 2 and 4. Internal consistency of the scores was found for the diversity maps. As opposed to the low or even negative correlations that were found for the degree of conceptualization and branches and the degree of conceptualization and cross links in the first set of maps, for the diversity maps significant correlations were found for the intercorrelations of these attributes, thus providing credence for these being essential attributes of the concept map. This further validates the identified attributes as essential criteria in the scoring rubric.

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Table 1

Beliefs About What Should be Taught in Science:

Correlation Matrix for Total Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.73*	.69*	.80**	.43	.51
Rater 2		1.00	.46	.50	.06	.63*
Rater 3			1.00	.85**	.37	.52
Rater 4				1.00	.16	.59
Rater 5					1.00	-.24
Rater 6						1.00

Note. Raters 1 and 2 are university professors; raters 3 and 4 are preservice secondary science majors; and raters 5 and 6 are inservice elementary and middle school teachers.

* $p < .05$.

** $p < .01$.

Table 2

Beliefs About What Should be Taught in Science:

Correlation Matrix for Proposition Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.35	.45	.33	.39	.09
Rater 2		1.00	.40	.45	.05	.61
Rater 3			1.00	.77**	.29	.09
Rater 4				1.00	-.05	.08
Rater 5					1.00	-.24
Rater 6						1.00

** $p < .01$.

Table 3

Beliefs About What Should be Taught in Science:

Correlation Matrix for Hierarchy Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.73*	.62	.40	.23	.27
Rater 2		1.00	.45	.16	-.32	.35
Rater 3			1.00	.76*	.14	.32
Rater 4				1.00	.00	.58
Rater 5					1.00	-.51
Rater 6						1.00

* $p < .05$.

Table 4

Beliefs About What Should be Taught in Science:

Correlation Matrix for Branch Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.76**	.13	-.25	-.07	.61
Rater 2		1.00	.18	.22	-.09	.36
Rater 3			1.00	.47	.04	-.19
Rater 4				1.00	-.07	-.66*
Rater 5					1.00	.03
Rater 6						1.00

* $p < .05$.

** $p < .01$.

Table 5.

Beliefs About What Should be Taught in Science:

Correlation Matrix for Differentiation of Concepts Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.55	.73*	.48	.50	.12
Rater 2		1.00	.52	.72*	.00	.33
Rater 3			1.00	.75*	.45	.68*
Rater 4				1.00	.42	.57
Rater 5					1.00	.16
Rater 6						1.00

* $p < .05$.

Table 6

Beliefs About What Should be Taught in Science:

Correlation Matrix for Cross Link Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.70*	.33	.86***	-.52	.59
Rater 2		1.00	.17	.50	-.30	.57
Rater 3			1.00	.55	.41	.21
Rater 4				1.00	-.33	.54
Rater 5					1.00	-.50
Rater 6						1.00

* $p < .05$.

*** $p < .001$.

Table 7

Beliefs About What Should be Taught in Science:

Correlation Matrix for Example Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.94***	.78**	.91***	.80**	.72*
Rater 2		1.00	.78**	.86**	.81**	.71*
Rater 3			1.00	.58	.61	.61
Rater 4				1.00	.79**	.57
Rater 5					1.00	.31
Rater 6						1.00

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 8

Beliefs About What Should be Taught in Science:

Correlation Matrix for Degree of Conceptualization Scores for Six Raters

	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
Rater 1	1.00	.80**	.49	.71*	.52	.45
Rater 2		1.00	.27	.54	.24	.52
Rater 3			1.00	.90***	.23	.55
Rater 4				1.00	.30	.76*
Rater 5					1.00	-.23
Rater 6						1.00

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 9

Beliefs About What Should be Taught in Science:

Correlation Between Degree of Conceptualization and Other Attributes for Each of Six Raters

	Rater 1	Rater 2	Rater 3	Rater4	Rater 5	Rater 6
Deg. of Con. and Prop.	.79**	.62	.51	.66*	.65*	.82**
Deg. of Con. and Hier.	.85**	.85**	.79**	.82**	.91***	.84**
Deg. of Con. and Bran.	-.29	.41	.24	-.50	.78**	.89***
Deg. of Con. and Diff.	.84**	.69*	.62	.89***	.45	.85**
Deg. of Con. and C. L.	.21	-.11	.24	.20	.17	.82**
Deg. of Con. and Ex.	.76*	.68*	.45	.69*	.66*	.94***
Deg. of Con. and Total	.95***	.92***	.88***	.89***	.92***	.97***

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 10

Diversity of Living Things: Correlation Matrix for Total Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.76**	.84***	.82***
Rater 2		1.00	.82***	.61*
Rater 3			1.00	.85***
Rater 4				1.00

Note. Raters 1 and 2 are university professors and raters 3 and 4 are preservice secondary science majors.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 11

Diversity of Living Things: Correlation Matrix for Proposition Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.62*	.54	.45
Rater 2		1.00	.88***	.47
Rater 3			1.00	.49
Rater 4				1.00

* $p < .05$.

*** $p < .001$.

Table12

Diversity of Living Things: Correlation Matrix for Hierarchy Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.58*	.73**	.60*
Rater 2		1.00	.48	.28
Rater 3			1.00	.68*
Rater 4				1.00

* $p < .05$.

** $p < .01$.

Table 13

Diversity of Living Things: Correlation Matrix for Branch Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.53	.31	.45
Rater 2		1.00	.29	.21
Rater 3			1.00	.82***
Rater 4				1.00

*** $p < .001$.

Table 14

Diversity of Living Things:

Correlation Matrix for Differentiation of Concepts Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.75**	.66*	.69**
Rater 2		1.00	.64*	.44
Rater 3			1.00	.55
Rater 4				1.00

* $p < .05$.

** $p < .01$.

Table 15

Diversity of Living Things: Correlation Matrix for Cross Link Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.79***	.78**	.75**
Rater 2		1.00	.74**	.59*
Rater 3			1.00	.80***
Rater 4				1.00

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 16

Diversity of Living Things: Correlation Matrix for Example Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.76**	.77**	.59*
Rater 2		1.00	.78**	.38
Rater 3			1.00	.58*
Rater 4				1.00

* $p < .05$.

** $p < .01$.

Table 17

Diversity of Living Things:

Correlation Matrix for Degree of Conceptualization Scores for Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Rater 1	1.00	.69**	.82***	.84***
Rater 2		1.00	.68*	.53
Rater 3			1.00	.80***
Rater 4				1.00

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 18

Diversity of Living Things:

Correlation Between Degree of Conceptualization and Other Attributes for Each of Four Raters

	Rater 1	Rater 2	Rater 3	Rater 4
Deg. of Con. and Propositions	.79***	.81***	.90***	.74**
Deg. of Con. and Hierarchy	.89**	.77**	.74**	.85***
Deg. of Con. and Branches	.71**	.76**	.87***	.77**
Deg. of Con. and Differentiation	.91***	.85***	.86***	.69**
Deg. of Con. and Crosslinks	.76**	.69**	.77**	.67*
Deg. of Con. and Examples	.67*	.54	.83***	.72**
Deg. of Con. and Total Score	.96***	.93***	.97***	.95***

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Appendix A

Rubric for Scoring Concept Maps

	4	3	2	1	0
Propositions	Complete, meaningful, and valid.	Most are meaningful and valid.	Some are meaningful and valid.	Incomplete, few are meaningful.	Missing or not meaningful.
Hierarchy	Superordinate & subordinate concepts are present and valid.	Most but not all are present and valid.	Some are present and valid.	Few are present and/or valid. Several subordinate concepts are missing.	Hierarchy is missing or invalid.
Branches	All are appropriate, meaningful, and valid.	Most are appropriate, meaningful, and valid.	Some are appropriate, meaningful, and valid.	Few are appropriate, meaningful, and valid	Missing, inappropriate or invalid.
Differentiation of concepts in each branch.	All valid subconcepts are present.	Most of the valid subconcepts are present.	Some of the valid subconcepts are present. Some subconcepts are invalid or trivial.	Few of the valid sub-concepts are present and/or most of the subconcepts are invalid or trivial.	Valid subconcepts are missing or subconcepts are invalid.
Cross links	All are valid and non-trivial. Strong evidence of higher level of thinking.	Most are valid and non-trivial. Some evidence of higher level thinking.	Some valid but trivial. Some evidence of higher level thinking	Most are invalid or trivial. Little evidence of higher level thinking.	Missing or invalid. No evidence of higher level thinking.
Examples	Complete set; valid, illustrative, and significant.	Incomplete set; but most are present and valid, illustrative, and significant.	Incomplete set; but some are present and valid, illustrative, and significant.	Incomplete set; few are present and valid, illustrative, or significant.	Missing or invalid.
Degree of conceptualization	Evidence of clear understanding of concept.	High degree but not complete understanding of concept.	Moderate degree of understanding of concept. Some naive or faulty conceptions.	Low degree of understanding of concept. Several naive or faulty conceptions.	Evidence of complete lack of understanding of concept.

CUSTOMIZING THE DRAW-A-SCIENTIST TEST TO ANALYZE THE EFFECT THAT TEACHERS HAVE ON THEIR STUDENTS' PERCEPTIONS AND ATTITUDES TOWARD SCIENCE

Juanita Jo Matkins, University of Virginia

The Integrated Physical Science for Elementary Teachers (IPSET) project (Matkins & Klein, 1994) was developed in 1992 as a cooperative effort of the University of Virginia Curry School of Education and Department of Physics, with NSF funding (NSF #TPE-9155262). The project was designed to provide training for teams of kindergarten through eighth grade teachers in the Central Virginia area. The IPSET project involved a group of teachers recruited from two city school systems and four county school systems. The effect of IPSET training on the 54 participating teachers was categorized into attitude changes, changes in content knowledge, leadership efforts, and classroom practices. By the end of the academic portion of the program, assessments had shown significant positive change in the teachers. Results of evaluations of IPSET teachers showed gain in both science content and in attitudes. All teachers showed gain in attitudes related to confidence toward teaching science and in the application of scientific processes.

As part of the IPSET training, instructors taught the IPSET teams two science content courses and one science methods course over about eighteen months. During this academic phase of the program, teachers were introduced to ideas about constructivist approaches to teaching elementary science. Regular discussion sessions were held investigating the applicability of the ideas of constructivism and practice sessions were structured so teachers could try out constructivist learning perspectives on several science phenomena. Thus, all participants in the IPSET program received substantial exposure to constructivism, the idea that persons construct their own knowledge of the world based upon their own experiences, questions, and thoughts.

Change in the students of these IPSET teachers needed to be considered in order to more completely assess the effectiveness of the IPSET program. A revision of the Chambers Draw-a-Scientist Test (1983), described by Symington and Spurling (1990), and renamed the "DAST-R" (Draw-a-Scientist Test-Revised) was used to answer the question: "Did attitudes toward science and scientists change in the students taught by the IPSET teachers?"

Literature Review

The Draw-a-Scientist Test (DAST) was originally developed by David W. Chambers (1983), using the research of the Draw-a-Man and Draw-a-Person tests (Goodenough, 1926; Harris, 1963; Goodenow, 1977). Chambers' purpose was to learn the person's image of a scientist. Chambers was responding to a study done by Mead and Metraux (1957), which showed the image high school students had of scientists. For his test, Chambers used the simple prompt, "Draw a scientist." Given this prompt, 4807 children in grades kindergarten through grade five were administered the DAST. Drawings were analyzed for indicators of the image children held of a scientist. Seven major indicator types emerged, e.g. lab coat, eyeglasses, and facial growth of hair. From these indicators, Chambers was able to show that views of scientists varied by age and grade level, and that children held stereotypical views of scientists. Children below second grade included a very low number of indicators or no indicators in their drawings. By second grade, the average number of indicators included in drawings had more than doubled, with indicator numbers reaching a peak in the highest grade studied, fifth grade. (The average number of indicators in fifth grade was 3.26.)

Other researchers have used the DAST to gauge various factors in students, including career goals (Warren, 1990), perceptions of scientists at the elementary through high school level (Schibeci & Sorensen, 1983; Flick, 1990), and perception of technology (Hill, 1991). In a study of differences in stereotypical views of science after a gender-equity intervention program (Huber & Burton, 1995), boys' posttest drawings showed greater movement away from stereotypes than girls' posttest drawings. Finson and Beaver (1994) developed a checklist to assess change in students, using the stereotypes noted in the Chambers' (1983) study.

The Draw-a-Scientist-Test revised prompt (DAST-R) was recommended and tested by David Symington and Heather Spurling (1990). They pointed out that students seemed to be drawing what they perceived to be the public stereotype of a scientist, and not necessarily their own perception of a scientist. To remedy this problem, Symington and Spurling tested the effect of a revised prompt, "Do a drawing which tells what you know about scientists and their work." They compared drawings done by children given both sets of prompts. The drawings showed enough differences that these researchers concluded their report with a recommendation that the DAST prompt be critically examined for what it actually was asking the students to draw.

Attitudes and Perception

What evidence was there that the way a teacher taught a subject effected a student's attitude toward the subject? In 1993, D.B. Rosenthal published a study that contrasted student attitudes toward scientists with teacher attitudes toward scientists. He found that teachers with a negative attitude toward science tended to show that attitude in their teaching, and their students tended to have a negative attitude toward science. Adults often possessed stereotypical views of science and scientists (Chambers, 1983). In several studies in the past three decades (Beardslee & O'Down, 1961; Smith & Erb, 1986; NSTA, 1992; NSTA, 1993; and Odell, Hewett, Bowman, & Boone, 1993) evidence indicated that negative stereotypes of science and scientists led to negative perceptions, which, in classrooms, led to negative attitudes toward science.

Constructivist approach effect on student perception

Chaillé and Britain (1991) found that young children who were provided with opportunities to construct their own learning became involved in scientific experimentation and problem solving. Gallas (1995), in *Talking Their Way Into Science* , observed that second, third, and fifth graders who had been taught from a constructivist framework thought about, talked about, and did science continuously. The qualities seen in children who were involved in doing science from a constructivist framework included creativity, imagination, curiosity, experimentation, problem solving, and enthusiasm for science. The constructivist approach to teaching affected students' attitudes in a positive manner.

The Study

This study involved the development of indicators and a scoring rubric for a revision of the Draw-A-Scientist test named the Draw-A-Scientist Test- Revised (DAST-R). Also examined were the results of administration of the test, which was used to measure attitude changes in students toward science and scientists.

Problem

The primary focus of this study was the use of the DAST-R to measure the effect of IPSET teacher influence on student attitudes toward science and scientists, but two other factors were included for analysis. These factors were the effect of gender and of grade level on attitudes toward science and scientists. Relationships between and among these factors were analyzed, as well. The following questions guided the research:

1. Did the IPSET program as implemented by IPSET teachers in their classrooms lead to a change in their students' attitudes toward science and scientists?
2. Did grade level have an effect on attitudes toward science and scientists?

3. Did gender have an effect on attitudes toward science and scientists?

4. Were there interactions between grade level, gender, and whether or not a student was in an IPSET teachers' class?

Variables

The three independent variables examined in this study were IPSET training, gender, and grade level range. Grade level range refers to a division of the subjects by: kindergarten through grade 1, grade 2 through grade 5, and grade 6 through grade 8. The dependent variable, attitude toward science and scientists, was defined as the way students viewed science. The IPSET teacher team which worked with the DAST-R determined that attitude included certain ideas about science. For example, one aspect the team considered important was whether or not students showed in their drawings that scientists enjoyed their work. Appendix A contains a more detailed description of the various indicators developed by the teacher-team.

Subjects

IPSET teachers provided drawings for this study, from approximately 1200 students, grades kindergarten through eighth grade. School types represented included city schools, suburban schools, and rural schools. Students who might have had an IPSET teacher during the previous year were eliminated from the study, as were students of members of the DAST-R research team.

Control Group

A control group was used for comparison to the students in science classrooms taught by IPSET-trained teachers. The control group consisted of 150 seventh grade students taught by a non-IPSET teacher. The teacher of the control group was an experienced middle school science teacher. Random selection practices were used with the control group, with 15 drawings each selected from males and females for a total of 30.

Administering the Draw-A-Scientist Test- Revised (DAST-R)

IPSET teachers administered the DAST-R to their students beginning with the 1993-1994 school year. In the summer of 1994, the second group of IPSET teachers (n=30) spent time in a group discussion period for analysis of the procedure for administration of the DAST-R to students. The IPSET teachers decided to give the test again in the next school year, both as a pretest (September or October) and as a posttest (May or June). They established protocols for directions beyond the prompt, and for transcribing student descriptions of the pictures in the case of kindergarten and first grade children.

Developing the Scoring Indicators

A small research team was recruited from the IPSET teachers to develop scoring protocols for the test. This team, the DAST-R research team, consisted of four IPSET teachers, the IPSET field supervisor, and the IPSET research assistant. The DAST-R research team decided that the indicators which emerged from the DAST (Chambers, 1983) were not sufficient for measuring the effect of the IPSET program. During several meetings in the fall and winter of 1994-95, the team met to discuss this problem and agreed that new indicators were needed. These new indicators would be based upon expectations of potential changes in students under the influence of IPSET teachers. The team developed a scoring protocol which consisted of indicators which the team expected to see in drawings from students of IPSET teachers, and of definitions of these indicators. The team practiced using the scoring protocol on a sample of the drawings, representing each grade level range. Each team member individually scored the drawings, and then the team met to discuss the scores. Discussion about scoring assumptions led to consensus about interpretations of the indicators. Statements were developed defining indicators and giving examples. The eleven indicators are:

1. Enjoyment or being engrossed in science.

2. Doing something with a socially useful purpose.
3. Consideration of safety.
4. One person is working with another.
5. Scientific activity
6. Inquiry
7. Measurement or data collection
8. Hypotheses
9. Repeated trials
10. Controlling variables
11. Discovery

A more complete description of the indicators, with examples, can be found in Appendix B of this document.

The Scoring Protocol

The scoring protocol was a checklist with the eleven indicators, covering areas of affect, activity, inquiry, and safety. It was designed so that scorers checked off indicators observed in a drawing. Checks would then be counted, and the total score for the drawing equaled the number of checks. The protocol was prepared with the assumption that student drawings would usually show several primary indicators, but would rarely, if ever, show all eleven. The drawing prompt was not intended to elicit a comprehensive picture of the student's attitude toward science and scientists, but to let students indicate some of the things they thought most scientists did.

Establishing Validity

Several persons with expertise in experimental design and science education were consulted to determine content validity of the scoring indicators and validity of the experimental design developed by the DAST-R research team. The DAST-R research team engaged in vigorous debate and discussion during the sessions focused on developing and defining the indicators. Indicators were named and defined only when the team had reached consensus as to the need for, and the meaning of, particular indicators.

Interpretation of the drawings was supported through interviews with students. The classroom teachers on the DAST-R research team had administered the pretest prior to the first team meeting, and had discussed a few of the drawings with the particular student artists after the administration. It was decided that teacher interviews of students were desirable, since that would provide the most accurate check for teacher assumptions about the drawings. Interviews were conducted with the students of the teachers on the DAST-R research team. The results of these interviews were used to confirm assumptions about the other student drawings.

Drawing selection and assurance of confidentiality

IPSET teachers administered the DAST-R in the fall of 1994. The students took the DAST-R again in late spring of 1995. Teachers were assigned numbers to assure anonymity, and students were assigned code numbers by the teachers, or their names were removed from the drawings before analysis took place. Drawings were classified by gender and grade level. Thirty student drawings were selected at random from each grade level range, K-1, 2-5, and 6-8, fifteen each from male and female students. In the control group, drawings were classified by gender, and then fifteen each were drawn from male and female students.

Ninety sets of pretest and posttest drawings were selected at random, thirty each from grades K-1, 2-5, and 6-8. Forty-five sets were drawings done by females and forty-five were drawings done by males, fifteen sets each gender from each grade level. The five raters who scored the drawings were members of the DAST-R team. The drawings were coded in such a way that the raters did not know which drawing was the pretest and which was the posttest. Any information about the identity of the teacher and the student on the drawings was covered before the raters obtained the drawings. Each rater scored a random selection of sixteen sets of drawings, for the purpose of experimental results (5 raters x 16 sets of drawings= 90 sets of drawings). As shown in Table 1, the raters also scored six drawings (three male, three female), the same drawings for every rater, for testing inter-rater reliability. A correlation score was calculated from these scores to show whether there was sufficient consistency among assessors.

Table 1

Distribution of Drawings for Scoring by Raters

	Assessor				
Grade level	A1	A2	A3	A4	A5
	Sample for analysis of treatment effect (sets[a])				
K-1	5	5	6	5	5
2-5	5	6	5	5	6
6-8	6	5	5	6	5
	Sample for inter-rater reliability				
K-1	2	2	2	2	2
2-5	2	2	2	2	2
6-8	2	2	2	2	2

Note. Each assessor scored a total of 38 drawings (16 treatment effect sets and 6 inter-rater reliability, 32 + 6 = 38).

[a]A set of drawings consisted of pretest and posttest drawings from the same student.

Each set of drawings was selected so each rater had a subset from each grade level. Distribution of grade level ranges by rater for the main sample and the sample intended for inter-rater reliability are shown in Table 1. Eight sets of drawings for each rater came from male students and eight sets came from females, in the sample drawn for analysis of treatment effect. Grade distribution by gender was at random, since rater bias by gender was not expected to interact with grade level. In the drawings used for inter-rater reliability, there were three drawn by males and three by females. Control group drawings were coded, randomized, shuffled, and scored in the same manner as the treatment group.

Experimental Design

The design for this study was a repeated measures, three-factor mixed design: 2x3x2. The factors were the level of the test (pretest or posttest), the grade level range (K-1, 2-5, or 6-8), and gender (female or male). An analysis of variance was used to determine the probability that variance was due to chance. An alpha level of .05 probability was chosen as the level of significance for the purposes of this study.

Results

There was a highly significant change from the pretest to the posttest performance on the DAST-R of the students in the classrooms of the IPSET teachers ($F_{1,84}=11.24$, $p < 0.001$). Effect of gender on the responses of the IPSET-taught students was significant ($F_{1,84}=5.06$, $p = 0.027$). Grade level range in the treatment group was another significant factor ($F_{2,84}=13.42$, $p < 0.001$). There were no significant interaction relationships found between any of the factors.

For those factors where a significant difference was found, the mean scores show the direction of the variance and the standard deviation of the scores shows the consistency of the variance. The treatment group pretest scores had a mean of

2.14, and the posttests had a mean of 2.61. The standard deviation range was 1.19 (pretest) to 1.21 (posttest). In the control group, the mean pretest score was 1.97, and the posttest mean score was 2.50. The standard deviation for the control group pretest to posttest scores was 1.07 to 1.55.

Females in the IPSET-trained group had a mean score of 2.53, with a standard deviation of 1.24. Males scored an average of 2.22, with a standard deviation of 1.18. Grade level mean differences were: K-1, 1.87 (standard deviation: 0.99); grades 2-5, 2.30 (standard deviation: 0.94); and grades 6-8 had a mean of 2.97 (standard deviation of 1.40).

Results for the control group showed no significant effect pretest to posttest ($F_{1,28}=3.26$, $p = 0.08$). Also, there were no significant effects for gender ($F_{1,28}=0.462$, $p = 0.50$) and no significant interactions in the control group.

Conclusions

The results of this study show that students of teachers trained in the IPSET program drew more factors indicating positive attitudes toward science. Though maturation could have played a part in this change, the difference in scores of the treatment group and the control group indicate that the IPSET training of the teachers in the treatment group was an important component in the positive change seen in those students' drawings. Since the indicators were developed to reflect positive attitudes toward science, and these scores show that more positive factors were included in the posttest drawings, then IPSET training contributed to the development of positive attitudes toward science in students. Females scored higher than males in the treatment group, indicating that females benefited especially from the IPSET/constructivist approach. The significant effect of grade level range was found to correspond with the Chambers (1983) study, where K-1 level children had a poorly developed concept of science. An interesting aspect of analysis of the grade level factor is in the large standard deviation in the grades 6-8 scores, indicating a greater variability in attitude toward science at that grade level range. This could be due to the developmental patterns of adolescence, but it could also be the result of more years of science classes with teachers trained in different ways.

An important result of this study is the Draw-a-Scientist Test-Revised (DAST-R) was shown to be a useful instrument for analysis of attitudes about science. The ease of administration and the additional guidance of the scoring indicators and rubric developed by the DAST-R teacher research team combined to provide an accessible tool for evaluation of the effect of science instruction.

Longitudinal study is needed on the effects measured by these indicators, to determine if attitude changes are stable across time. The eleven indicators used for scoring the DAST-R represent different aspects of scientific attitude and attitude toward science. Additional analysis of student drawings for representation of the individual indicators could tell exactly where gains were made. Gender and grade level factors should be considered when this analysis is accomplished.

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Appendix A

Scoring the Draw-a-Scientist Test - Revised

"Make a drawing of a scientist or scientists that tells what you know about scientists and their work."

____
Student's # or name

____
Your name, #, or initials

See the "Scoring the Draw a Scientist Test - Revised" sheet for more detailed explanations and examples.

Optional interview to be used with Draw-a-Scientist Test- Revised: Ask: Tell me about your picture. What does it show?
Check indicators if the student tells about them while discussing the drawing. If an interview is not done, check if these are observed in the drawings. The important thing about the question or questions asked is that they NOT lead the student to say things which otherwise would not have been volunteered. The initial probe, "Tell me about your picture. What does it show?", may be followed by other probes such as: Tell me about this part of your picture? or What does this show? or What is this? Try not to ask questions which imply a specific type of response, such as : Is the scientist smiling? or What is the scientist doing?

Remember: Students are not expected to have included all the indicators in their drawings.

Indicators:

The scientist is happy. _____

The scientist has a socially useful purpose. _____

Safety is considered. _____

People are working together. _____

There is evidence of :

Activity (while doing science) _____

Scientific inquiry _____

Processes:

Measurement/collecting or recording data _____

Hypothesizing or predicting _____

Repeated trials _____

Controlling variables _____

Conclusions or discovery _____

Appendix A

Scoring the Draw-a-Scientist Test - Revised

"Make a drawing of a scientist or scientists that tells what you know about scientists and their work."

____
Student's # or name

____
Your name, #, or initials

See the "Scoring the Draw a Scientist Test - Revised" sheet for more detailed explanations and examples.

Optional interview to be used with Draw-a-Scientist Test- Revised: Ask: *Tell me about your picture. What does it show?* Check indicators if the student tells about them while discussing the drawing. The important thing about the question or questions asked is that they NOT lead the student to say things which otherwise would not have been volunteered. The initial probe, *"Tell me about your picture. What does it show?"*, may be followed by other probes such as: *Tell me about this part of your picture?* or *What does this show?* or *What is this?* Try not to ask questions which imply a specific type of response, such as : *Is the scientist smiling?* or *What is the scientist doing?* Remember: Students are not expected to have included all the indicators in their drawings. If an interview is not done, check if these are observed in the drawings.

Indicators:

The scientist is happy. _____

The scientist has a socially useful purpose. _____

Safety is considered. _____

People are working together. _____

There is evidence of :

- Activity (while doing science) _____
- Scientific inquiry _____

Processes:

- Measurement/collecting or recording data _____
- Hypothesizing or predicting _____
- Repeated trials _____
- Controlling variables _____

Conclusions or discovery _____

TOTAL # CHECKED _______________

Appendix B

Scoring the Draw a Scientist Test- Revised

This is to be used with the DAST scoring rubric and is meant as an explanation for the different components.

1. The scientist appears to be enjoying the work. The scientist is NOT scowling or frowning. The scientist can, however, seem focused and engaged in the work. Smiling is not necessary.

2. The work has a socially useful purpose. The scientist appears to be doing good for the world. Examples could include a cure for the common cold, or some other illness. Also, someone could be working to save the whales or dealing positively with some other modern life situation like pollution or acid rain.

3. Safety is considered. In the room or environment in which the scientist is working there may be goggles, lab coats, safety slogans, eye wash stations, fire extinguishers, etc. present. This is not to be confused with lab coats on scientists where there is no implied safety reason for wearing the lab coat (as in a drawing of the stereotypical "mad scientist").

4. The scientist is working together with another scientist. There will be more than one person in the picture, and the people are working together.

5. Science activity is present. A chemical change is in evidence, or plants could be growing. The scientist could have something in her/his hand, there could be bubbling beakers, etc. The idea is that science involves doing and changing things.

6. Scientific inquiry implies that the student scientist is making observations, or questioning (what if . . ?). The presence of books or computers indicates inquiry if there is evidence that they are being used.

7. Measurement/Data collection may be shown by the picture if clipboards, graphs, or notebooks are in evidence. Also, the labware (thermometer, a ruler, a beaker, measuring cups) needs to show the measurements lines to indicate measurement.

8. For hypothesizing or predicting, there will be evidence in the picture such as a 'thought bubble' showing the scientist wondering "I think it will . . . .".

9. Repeated trials will be counted if the scientist is drawn in a situation where there is a presumption of trying again for verification.

10. If the scientist in the picture is controlling for variables, then the picture will show that conditions have been manipulated purposefully for experimentation.

11. The drawing shows discovery when there is evidence of discovery of a new solution and an "I've got it!", or an "A-Ha!" type reaction on the part of the scientist.

Some parts of the student drawing may receive two or more checks if they fit into different categories. For example, "Look, men, we've found the cure for the common cold. We've done it!" (#2, #4, & #11 seem appropriate.)

AN ANALYSIS OF ELEMENTARY EDUCATION MAJORS' PROGRESS WITH VEE DIAGRAMMING

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Research Questions

In this paper, we describe how the vee diagram was used in elementary science methods courses. We used student-centered investigations to provide the context to test the assumption that the vee diagram was a tool to help prospective teachers with their construction and implementation of investigations. The following questions focused the study:

1. Do the prospective teachers show improvement in their use of vee diagrams while designing and implementing investigations?
2. Do the prospective teachers show a reduction in anxiety toward doing investigations, as a result of using vee diagrams while designing and implementing investigations?
3. What patterns are revealed through analysis of pretest and posttest vee diagrams?

Subjects and Instrumentation

Students

Students participating in this study were enrolled in one of three sections of a elementary/middle school science methods course (3 credits). Students in science methods represent one of three programs leading to licensure: 1) pre-school, kindergarten, and elementary school, (preK-6); 2) elementary school, (grades 1-6); and 3) elementary and middle school, (grades 1-9). Just over half of the students were either 1-6 or 1-9 majors. As is typical, the students in these methods courses were female, from rural or suburban schools, and White. Most male students were elementary/middle school majors (1-9 majors).

Prior to enrollment, students completed two years of general studies and a nine semester credit Pre-Professional Program including an eight day urban field experience. Most students completed the mandatory eight semester credit hours of science including a five semester credit laboratory science course and a three semester credit non-laboratory science course. These courses must be either physical science or life science. Few students choose to complete the 24 credit general science minor that can be elected.

None of the students had previous experience with constructing investigations or vee diagramming. Students at the beginning of one methods course were asked to respond to questions about their previous science experiences. The following statements from that open-ended survey are representative:

> "In middle school my teacher taught science through lectures and movies. I really didn't learn much about science during these years."

> "I have not really learned a lot about science during my college years. I've had one biology class where all of the exams were open book."

> "[In college] Lectures and lab. Both were interesting, but the lab really caught my attention and was easily remembered, where in lectures there was a lot of memorization."

Anxiety

Zuckerman's instrument (1960) was used to document students' anxiety towards constructing and implementing investigations. Jegede, Alaiyemola, & Okebukola (1990) used this instrument and found gender specific trends (among males) between anxiety reduction and achievement. The instrument has twenty-one adjectives reflective of anxiety embedded in a field of sixty adjectives. Scores lie on a scale of 0-21, 0 indicates no anxiety and 21 indicates high anxiety. A more complete discussion of Zuckerman's anxiety instrument was provided by Jegede et al. (1990).

Vee Diagram

The vee diagram instrument was designed for students to construct responses to capture their investigative operations. This instrument includes a simple description of vee diagrams, a blank vee diagram, graph paper, narrative data, and tabular data. The narrative and tabular data consist of information about Whooping Cranes (Stoker, Agsteribbe, Windsor, & Andrews, 1972). The narrative portion provides a brief description of the Whooping Cranes' migratory pattern, nesting and feeding habits. The tabular set provides data students might modify to answer questions they pose. For example, students can convert snowfall into rainfall then combine rainfall with snowfall. Variables include year of migrating adults, number of migrating adults, number of nests, eggs laid, eggs hatched and precipitation. The graph paper is provided to support students while they search for relationships.

The rubric for scoring vee diagrams provided by Novak & Gowin (1984, p. 71-2) was modified. Table 1 shows the modified scoring scheme with a total possible 18 points. Students were asked to apply the concept of variables in their Focus Question and Principles & Concepts. The Transformations section emphasized skills associated with graphing (McKenzie & Padilla, 1986). Students were not asked to include the following sections of Novak & Gowin's vee diagram: World View, Philosophy, Theory, and Value Claims.

Table 1
Vee Diagram Scoring Rubric Adapted From Novak & Gowin (1984)

Component of Vee	Criterion
Focus Question	
0	No focus question is present
1	A question is present, but does not suggest variables
2	A focus question is present, but either the dependent or independent variable(s) is/are not suggested by the question
3	A clear focus question is present with specific suggestion of both independent and dependent variables
Principles & Concepts	
0	No conceptual side is present
1	A few concepts are identified, but without principle(s)
2	A few concepts are identified and a principle present, but it is the knowledge claim sought in the investigation
3	Concepts that are relevant to the investigation and principle(s) are present
4	Concepts are operationalized and principle(s) is/are present
Objects/Events	
0	No objects or event s are identified
1	The objects or events are identified, but are/is inconsistent with the focus question
2	The objects or events are identified and are/is consistent with the focus question
Records	
0	No records identified
1	Records are identified, but are inconsistent with the focus question or the major event
2	Records are identified, and are consistent with the focus question or the major event
Transformations	
0	No transformations are present
1	Processing of raw data (arithmetic manipulations) or graphing is present but is inconsistent with the focus question
2	Processing of raw data (arithmetic manipulations) or graphing is present and is consistent with the focus question, but the graphing is done incorrectly
3	Processing of raw data (arithmetic manipulations) or graphing is present and is consistent with the focus question, and the graphing is done correctly
Knowledge Claims	
0	No knowledge claim is present
1	Claim is unrelated to the left-hand side of the Vee or the focus question OR there is simply a statement of data without a generalization present
2	Knowledge claim includes a generalization that is inconsistent with the records and transformations OR claim is not clearly derived from records and transformations
3	Knowledge claim includes the concepts from the focus question and is derived from the records and transformations
4	Same as above, but the knowledge claim leads to a new focus question

Procedures

The study involved three sections of science methods courses taught by two different science educators. In the descriptions that follow, the two method sections are referred two as Group 1 (taught by one investigator) and the third section as Group 2 (taught by the other investigator).

Group 1

Students in the first two sections ($n = 51$) completed approximately 10 investigations using vee diagrams. As the semesters progressed, the strategy was to shift from investigations initiated by the instructor to those constructed by the students. Butts' (1966) model of inquiry was used to engage students in investigating. Butts suggested that students search information, process data, discover ideas, verify ideas, and transfer ideas as a "cyclic operation" (p. 6). Early in the semester, students were provided data (in tabular form) from which they searched for relationships, or asked a question (e.g., What factors might affect . . .) from which students generated a list of ideas to investigate. Students used science resource books to generate investigations later in the semester.

Early in the semesters, students were introduced to the following ideas: 1) variables (dependent, independent, and controlled), 2) determining ways to control, measure and manipulate variables, and 3) constructing graphs using the variables they tested. Students were then introduced to vee diagramming. Questions that students asked were used to explain the components of the vee using ideas from Tobin & Capie (1980). Table 2 shows how the integrated process skills were related to selected components of the vee diagram. Most instructional time was used to discuss students' ideas for measuring and manipulating both the dependent and independent variables (Concepts) of the investigation.

Table 2
A Comparison Selected Components of the Vee Diagram and the Integrated Process Skills

Selected Components of the Vee Diagram (Novak & Gowin, 1984)	Integrative Process Skills (Tobin & Capie, 1982)
Focus Question	
Principles (Conceptual)	Identify variables that may affect the dependent variable
Concepts (Conceptual)	Identify appropriate procedures for measuring or manipulating the independent variable
	Identify appropriate procedures for holding identified variables constant
	Identify appropriate methods of measuring the dependent variable
Objects/Events	Identify the dependent variable
	Identify the variable to be manipulated
	Identify the variables to be held constant
Records	Identify data that support an hypothesis
Transformations (Methodological)	Use an appropriate scale for graphical representation of data,
	Present quantitative data graphically,
Knowledge Claims (Methodological)	Use data to construct or modify an hypothesis

<u>Group 2</u>

Students ($n = 27$) in this section completed seven investigations and vee diagrams. The first investigation was a demonstration used to introduce two major themes: 1) the process of restructuring "activities" such as those found in popular science resource books as investigations, and 2) vee diagramming as a tool for deriving meaning from the investigation. In this investigation, the instructor established the context (linear inertia) and dependent variable while the students determined the independent variable and its forms, the focus question, method of data collection, data transformation, and knowledge claims.

Following this initial introduction, students located an activity and redesigned it as an investigation, located appropriate materials and equipment, and "taught" their activity to three other members of the class. Each "teacher" was to have his/her "students" construct vee diagrams for the investigation. The "teacher" then graded the vee diagrams from his/her "students." Because the students were organized in groups of four, each class member constructed three different vee diagrams, one for each of three investigations.

As part of the prospective teachers' construction of a unit plan related to some science content area, they were to design and implement investigations and construct associated vee diagrams related the following aspects:

1. Practice of inservice teachers when they teach science, especially in the content area of the unit,
2. Two areas relevant to understanding the interaction between children and science, particularly that which is tied to the unit topic area: content knowledge, attitude toward learning science, motor skills, and thought patterns.

These investigations were to result in three vee diagrams, one related to the investigation of inservice teachers and two related to grasping an understanding of children in each of two relevant domains.

Results

Comparison of Students' Vee Diagram Mean Scores

Elementary methods students pre-vee mean scores and their respective post-vee scores were analyzed to determine whether students showed improvement in their use of vee diagrams while designing and implementing investigations. Because Group mean scores showed no statistical difference, students' scores were combined.

A total of 78 mean scores were compared using a *t* test for Correlated Samples (See Table 3). The mean score of the pre-vee was 6.2 ($SD = 4.1$) and the mean score of the post-vee was 11.9 ($SD = 2.7$), thus indicating a mean gain of 5.7 ($p < .05$). Preservice elementary/middle students in all three sections showed significant improvement in constructing vee diagrams.

Table 3
A Comparison of Students' Pre-vee and Post-vee Mean Scores

Test	*N*	*M*	*SD*	*t*
Pre-vee	78	6.2	4.1	
Post-vee	78	11.9	2.7	10.99*

*$p < .05$

Comparison of Students' Anxiety toward Investigating

The mean scores of students' who completed both the pre- and post- vee diagram tasks were used in this comparison. Because students pre-anxiety and post-anxiety mean scores showed no statistical difference, both Groups' scores were combined. This comparison answered the question: Do the prospective teachers show a reduction in anxiety toward doing investigations, as a result of using vee diagrams while designing and implementing investigations?

Zuckerman's anxiety instrument (Zuckerman, 1960) was used in pretest and posttest fashion to compare 78 preservice elementary/middle school students' anxiety towards investigating. Table 4 shows the comparison between pre-anxiety and post-anxiety mean scores. The pre-anxiety mean score was 13 ($SD = 3.3$) and the post-anxiety mean score was 9.7 ($SD = 1.9$) with a mean difference of 3.3. The *t* value was 8.39 ($p < .05$). The methods class treatments significantly shifted students anxiety in a positive direction (0 - low anxiety). However, no significant correlation was found between investigation anxiety change and vee diagramming change scores ($r = .06$, $p = .22$).

Table 4
A Comparison of Students' Pre-anxiety and Post-anxiety Mean Scores

Test	*N*	*M*	*SD*	*t*
Pretest	78	13.0	3.3	
Posttest	78	9.7	1.9	8.39*

$^*p < .05$

Analysis of the Components of Students' Vee Diagrams

At the beginning of the semesters many students chose not to attempt the Whooping Crane task. The rubric previously discussed was used to reveal strengths and weaknesses in students' investigative skills. Table 5 shows the components of the vee emphasized in the courses and the distribution of students' scores. While the Possible Score shows the score for the criterion of each component, the Percent (Pre-Vee & Post-Vee) shows the proportion of students ($N = 78$) receiving the score.

From pre to post, students showed improvement in constructing all components of the vee diagram. The students achieved the greatest improvement in their focus questions, objects/events and records. On the post-vee, the students received the maximum score for the following:

1. developing a clear focus question with specific suggestion of both independent and dependent variables (72%, Possible Score = 3),
2. identifying records consistent with the focus question or major event (83%, Possible Score = 2), and
3. identifying objects/events consistent with the focus question (73%, Possible Score = 2).

Table 5
Scores on Vee Components (N = 78)

Component	Possible Score	Percent Pre-Vee	Percent Post-Vee
Focus Question	0	19	0
	1	32	15
	2	26	13
	3	23	72
Records	0	70	14
	1	3	3
	2	27	83
Objects/Events	0	80	9
	1	8	18
	2	12	73
Knowledge Claims	0	35	1
	1	19	14
	2	27	55
	3	19	28
	4	0	2
Transformations	0	41	5
	1	26	14
	2	22	46
	3	11	35
Principles/Concepts	0	26	10
	1	24	26
	2	32	48
	3	17	13
	4	1	3

Students had more difficulty improving their knowledge claims, transformations and principles/concepts. The greatest percentage of students (35%) did not construct knowledge claims (Possible Score = 0) on their pre-vees. On the post-vee, most students' knowledge claims (55%) included inconsistent generalizations or their claims were not clearly derived from the data (Possible Score = 2). However, 28% of the students constructed post-vee knowledge claims appropriately derived from the records and transformations (Possible Score = 3). In comparison, only 19% of the students constructed knowledge claims appropriately.(Possible Score = 3) on the pre-vee.

Students showed a positive shift in constructing their transformations. While 41% of the students did not construct graphs in their pre-vees (Possible Score = 0), 35% of the students correctly combined data, and correctly made graphs consistent with their focus question (Possible Score = 3) on their post-vees. However, on the post-vees, the greatest proportion of students (46%) correctly processed data (e.g., combined rainfall and snowfall), but their graphs were incorrectly constructed (Possible Score = 2). Two common difficulties emerged from analysis of the students' graphs. Students often placed the independent variable on the y-axis or incorrectly labeled their graphs. Other students tried to show relationships between too many variables. Often times, they made scatter plots in chronological order (x-axis = Year), then plotted number of eggs hatched and precipitation on the y-axis. A clearer approach might have compared precipitation with the number of eggs hatched, by rearranging the data according to the quantity of precipitation.

Students had the most difficulty in constructing their principles/ concepts, with respectively 32% (pre) and 49% (post) of the students identifying concepts and principles sought in the knowledge claim (Possible Score = 2). Few students, on the post-vee, developed non-redundant principles/concepts (13%, Possible Score = 3) and only 3% went one step further by operationalizing the concepts (Possible Score = 4).

Conclusions

When science methods courses emphasize investigations and the processes involved in "doing science," prospective elementary/middle level teachers generally show a significant reduction in anxiety about using investigations in the classroom. In terms of the sections of the vee diagram, the prospective teachers tended to move to maximum scores on the more concrete levels of the vee diagram, objects/events and records, as well as the focus question. The conceptual side of the vee diagram and the more abstract portions of the methodological side of the vee diagram showed the least change. Students continued to show problems in the following more creative aspects of investigating:

- In the principles and concepts, students identified concepts and principles sought in the knowledge claim.
- In the transformations, students need to take the risk and restructure the data in such a way that it clearly answers the focus question.

The often heard rhetoric of "hands-on, minds-on" science is lacking tools to make that connection possible. The vee diagram is just such a tool. In this study, the elementary/middle level methods students showed improvement in the use of this tool and in the willingness to engage in investigations, but they also had difficulty with the "minds-on" portion of the investigation. The challenge is captured by the following statement by Hodson (1992)

> . . . doing science is not just theory-driven, it is *experience driven*, and . . . a major element in a scientist's ability to do science successfully is the steady accumulation of the tacit knowledge that eventually constitutes conoisseurship. It follows that the development of children's tacit knowledge, through experience of holistic investigations, should be a major priority in science education (p. 136).

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THE EFFECT OF TRADITIONAL CLASSROOM ASSESSMENT ON SCIENCE LEARNING AND UNDERSTANDING OF THE PROCESSES OF SCIENCE

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The issues of grading and reporting on student learning have perplexed educators for the better part of the century (Guskey, 1994). In recent years, assessment of student learning has become a topic of great emphasis in the educational literature. Many previously unfamiliar terms, such as practical assessment, authentic assessment, alternative assessment, portfolios, and journaling have become a part of the established vocabulary in educational publications. The implication of the newly emerged emphasis on alternative methods of assessment also has a significant effect on what is taught and how it is taught. According to Rakow (1992), curriculum as used in the schools is driven by assessment. Mitchell (1992) addressed the distinction between assessment and testing. Assessment is an activity that can take many forms, can extend over time, and aims to capture the quality of a student's work. A test is a single-occasion, unidimensional, timed exercise, usually in a multiple-choice or short-answer form.

The influence of testing on student performance has been a subject of research for many years. Recently, the possible negative effects of traditional testing have caused the development of new alternative methods of assessment, and traditional assessment has been pushed aside. However, traditional tests do have advantages over other forms of assessment. They are less time consuming than most other forms of assessment, even when they include higher level thinking items. It is also relatively easy to validate and determine internal consistency for traditional multiple choice tests. Past studies, including Gaynor and Millham (1976), found that students who took weekly quizzes earned higher scores on final examinations than did those who took only midterm exams. Other studies indicate that higher scores by students who are frequently tested may be attributed to the students' test wiseness and teachers who "teach to the test" (Nungester & Duchastel, 1982).

Although alternative forms of assessment are currently popular, traditional assessment (quizzes and tests) should not necessarily be eliminated by other types of assessment. "Traditional tests are valid for testing students' factual knowledge" (Brown & Shavelson, 1994, p.87). Most tests use an objective format, such as multiple-choice questions. Multiple-choice tests have some advantages, including a "lower probability of correct guesses than ordinary true-false tests do; they can be used to measure many levels of learning; they allow for extensive sampling of material, and they are easy to administer and grade" (Johnson, 1989, p.57).

Although there may be exceptions in subject areas that students find especially difficult, today's students are accustomed to taking tests and have essentially become good test takers. "Students of today have become very test-wise, so it is imperative that questions be written in a manner that does not give away the correct answers" (Johnson, 1989, p.57). Since students who are accustomed to taking tests have become good test takers, test scores can go up without a commensurate gain in achievement (Shepard, 1989). One negative effect testing may have on learning is test anxiety. The results of one study on test anxiety implied that tests were a source of emotional discomfort for students (Kellaghan, Madaus & Airasian, 1982).

One of the questions minimally addressed in the literature is the effect, if any, of traditional classroom assessment on learning. It is possible that testing in and of itself may have a negative effect on learning. This is mainly because of the way students memorize information for tests (Schilling & Schilling, 1994), but also because of the large amount of time spent in testing students as opposed to learning new information. Tests tend to directly influence the behavior of students and teachers.

Testing and learning are not the same thing, and if the focus is on learning, rather than testing, then students' opportunities to learn are enhanced (Berliner, 1988). Gosenpud and Miesing (1992) reported that motivation and interest have the largest effect on student performance. The class situation and emphasis on assessment in turn affects what motivates students, or influences what they find interesting or relevant. If testing plays such as important role for the students, how might the absence of traditional testing impact student learning?

Purposes of the Study

The purpose of this study was to determine the relationship between the presence of traditional classroom assessment (tests and quizzes) and achievement of students in elementary science methods courses at East Carolina University in Greenville, North Carolina. The null hypotheses were:

(1) There will be no difference in achievement, as measured by the Test of Integrated Process Skills (TIPS), between students who have taken part in elementary science methods classes that include tests and quizzes as part of the evaluation process and students in classes that do not include tests and quizzes.

(2) There will be no difference in achievement, as measured by the Science Test for Elementary Methods (STEM), between students who have taken part in elementary science methods classes that include tests and quizzes as part of the evaluation process and students in classes that do not include tests and quizzes.

A further objective of this study was to determine if student perceptions about their particular class situation (testing or nontesting) have an effect on how they respond or feel toward the class or the subject being covered. For example, if the testing situation makes a student feel especially uncomfortable because of the subject matter involved, they might respond negatively toward learning science. Students have varying class participation, note taking skills, and science backgrounds that also affect how they respond to traditional assessment in the science classroom. Open-ended survey questions were used to gather information about the different perceptions that students may have towards the testing or non-testing classroom situation. The elementary science methods course instructor also completed a questionnaire to give a different perception of the same class context.

Design of the Study

A pretest-posttest nonequivalent group design was utilized for this quasi-experimental study in order to determine the relationship between the presence of traditional classroom assessment (tests and quizzes) and science achievement of students in elementary science methods courses at East Carolina University in Greenville, North Carolina. The independent variable was the presence or absence of traditional testing (tests and quizzes) in the science classroom. Dependent variables were scores from the achievement instruments utilized. The data for this study were gathered during the spring, summer, and fall of 1994, with each session including a testing and a nontesting group. The same instructor was responsible for teaching all of the sections involved.

The 99 subjects included in the study were students enrolled in elementary science methods courses at East Carolina University during the spring, summer, and fall semesters of 1994. Participation in the study was completely voluntary, and an informed consent form was utilized. All of the subjects in the classes involved volunteered, even though no incentives were offered for doing so. The classes of students in this study were selected at random to be in the testing group or the nontesting group.

Procedures

This study included six sections of students enrolled in elementary science methods courses. The first treatment condition consisted of three classes of students that did not include tests and quizzes as part of the evaluation process, but instead were evaluated based on projects and class presentations. The second treatment condition (utilized as a comparison group) included three classes of students that did include traditional tests and quizzes as part of the evaluation process.

Students in both the tested and nontested conditions were given two pretests; the Test of Integrated Process Skills (Dillashaw & Okey, 1980) and the Science Test for Elementary Methods (Watson, 1995). These instruments were administered on the first day of classes for each semester, and the students understood that scores from the test would not be part of their grades. The same instruments were administered a second time as posttests during the last day of each semester.

Two fairly traditional multiple-choice instruments were selected for use in this study because these types of tests are still the predominant testing method in science classrooms (Frederiksen, 1984). Students were allowed 75 minutes for taking each test, although most finished within 45 minutes. A 10-item survey was administered at the end of each semester to all students. A similar questionnaire was also completed by the instructor.

Instrumentation

The Test of Integrated Process Skills (TIPS) is a 36-item multiple-choice instrument that was administered to the student sample population as a pretest and posttest. The process skills selected for the TIPS are those associated with planning and conducting experiments and interpreting results from investigations. They include formulating hypotheses, operationally defining, controlling and manipulating data, and interpreting data. Internal consistency of the test (Cronbach's α) was determined to be 0.89 (Dillashaw & Okey, 1980). Internal consistency for the TIPS for the sample of students utilized for this study was 0.81 using Kuder-Richardson's formula 20.

The Science Test for Elementary Methods (STEM) was developed as a pretest for elementary science methods classes. It includes primarily recall and application items, with a few simple problem solving questions. Emphasis for the STEM is on the nature of science and the basic science process skills. The instrument was validated using a technique developed by Hambleton and associates (Martuza, 1977). Each validator was provided with a written procedure to use in the validation process. They were given general test specifications, and were asked to rate questions on a 1-4 point scale, with 4 being the highest. Any question with a rating of less than three was eliminated. Internal consistency of the instrument was determined to be 0.82 using Kuder-Richardson's formula 20. It should be noted that the STEM was developed as a simple classroom evaluation instrument to assess the topics covered in the particlular science methods classes involved in this study.

A 10-question survey was also administered to students in the sample population. The survey was developed with the guidance of several experts in the field of education, and was validated using a procedure similar to that described for the STEM (above). Three of the 10 questions were Likert-scale type questions. The remaining questions were open-ended items. The last three questions of the survey were written specifically for the particular group that was completing the questions (testing or nontesting). A few questions on the survey asked the students to describe their class participation, note taking skills, and study methods. Four questions were included in the survey that dealt with students' perceptions about the assessment method and class situation. A 10-item questionnaire was also given to the instructor of the elementary science methods course. The questions paralleled those in the student survey. The purpose of the instructor survey was to determine the instructor's view of the learning environment.

Data Analysis Procedures

An Analysis of Covariance (ANCOVA) design was utilized for this study. The independent variable was the presence or absence of traditional testing in the science classroom. The dependent variables were the scores on the two achievement tests in science. The pretest scores for this study were treated as covariates. Responses to survey questions were categorized accordingly with each sample group, testing and nontesting. The answers were coded for quantifiable data during analysis. The responses to the questionnaire were compiled to determine the relationship between the class situation and what students determine as relevant.

Findings

All of the test scores were categorized into testing or nontesting groups. Overall means and standard deviations for the TIPS and STEM tests are shown in Tables 1 and 2, respectively.

Table 1

Means and Standard Deviations for the TIPS pre and post scores

Treatment		Pretest		Posttest	
	n	Mean	S D	Mean	S D
Nontesting Group	41	25.90	3.76	28.81	3.90
Testing Group	54	27.43	3.77	30.41	3.42

Table 2

Means and Standard Deviations for the STEM pre and post scores

Treatment		Pretest		Posttest	
	n	Mean	S D	Mean	S D
Nontesting Group	41	24.93	4.88	31.05	3.33
Testing Group	58	25.59	5.25	33.85	3.39

The scores for both tests were subjected to an Analysis of Covariance (ANCOVA). Results of the ANCOVA are shown in Tables 3 and 4. Results of the analysis of the TIPS scores for the two treatment groups indicated no significant difference (p=0.107) between the testing and nontesting groups. Results of the analysis on the STEM scores also showed no significant difference (p=0.056) between the testing and nontesting groups. Therefore, both null hypotheses were retained.

Table 3

Analysis of Covariance Summary for TIPS scores

Source	df	Mean Square	F-value	p
Testing	1	0.92	5.20	0.107
Covariate	1	0.90	5.06	0.110
Error	3	0.18		

Table 4

Analysis of Covariance Summary for STEM scores

Source	df	Mean Square	F-value	p
Testing	1	15.39	9.22	0.056
Covariate	1	2.09	1.25	0.345
Error	3	1.67		

Questionnaire Findings

A questionnaire was administered to students in both the testing and nontesting groups in an attempt to determine the effects of the treatments on factors that play a role in the learning or understanding of science. Information was also gathered pertaining to the students' study habits, note taking skills, and class participation in the two groups. Responses were tallied according to the frequency that appeared on the surveys within each treatment group. The total number of each response for each question was then subjected to chi-square analysis. Results of four of the ten questions indicated significant differences between the testing and nontesting groups. The four significant items dealt with whether students took notes, the quality of the notes, utilization of those notes, and overall perception of the particular class situation. Results of several other questions revealed meaningful, although not statistically significant, differences.

Students were asked whether or not they took notes in class. The purpose of this question was to see if notes were valued as a study source for testing, for assisting in projects, or for future reference. The difference was found to be significant (x^2= 4.95, p= 0.025) with the testing group taking more notes than the nontesting group. The students were also asked if they felt if they needed to take good notes depending on which class situation they were in. The difference in answers between the two groups was significant (x^2= 6.04, p= .0136) with the testing group taking more notes because they were being tested. The students were asked how often they looked over their notes that were taken in class. The responses received for both the testing and nontesting were: Never, once a week, everyday, only at test time, or only when completing a project. The difference in answers between the two groups proved to be highly significant (x^2= 24.40, $p < 0.001$) with the testing group only using notes during test time and the nontesting group using notes for future reference and for completion of projects. Students were also asked if their attitude would have been different if their class situation was changed. For instance, how would their perception towards the class differ if they were in the testing rather than nontesting group. Student responses included no difference, higher test anxiety if tested, or lower test anxiety if not tested. The nontesting group indicated that they would have had a great deal of test anxiety if they were in a testing situation. The testing group indicated that if their situation had been nontesting they either would have had no change in attitude or their test anxiety would have been greatly reduced. The difference in the responses was found to be significant (x^2= 4.91, p= 0.025). The ten questions and the percentages of each response were as follows:

1. Did you take notes in this class (testing or nontesting)?

	Testing	Nontesting
Yes	79%	53%
No	21%	47%

2. Did you feel as if you needed to take good notes since you were (or were not) being tested on the class material?

	Testing	Nontesting
Yes	85%	64%
No	15%	36%

3. If you took notes in this class, how often did you look at them? (Never, once a week, or every day)

	Testing	Nontesting
Never	3%	19%
Once/Week	35%	35%
Everyday	18%	23%
Only for Test	44%	2%
Only for Projects	0%	21%

4. If the class situation had changed (to testing or nontesting), would your perception of the class have differed?

	Testing	Nontesting
Test Anxiety Difference	42%	71%
No Difference	58%	29%

5. Which did you put more time and effort into: assigned projects or studying for tests?

	Testing	Nontesting
Projects	88%	87%
Equal	9%	13%
Tests	3%	0%

6. Explain your reasons for above responses.

	Testing	Nontesting
Major part of grade	18%	40%
Projects take time	51%	12%
Projects are fun	14%	12%
Equal time to both	17%	36%

7. If you experienced any negative feelings about this class situation (testing or nontesting) explain why.

	Testing	Nontesting
Groupwork not efficient	7%	3%
Desire to learn different implementations	0%	3%
Slow pace	93%	94%

8. What enabled you to learn in your class situation?

	Testing	Nontesting
Repeated material	20%	5%
Test anxiety	6%	0%
Hands-on experience	50%	55%
Low stress environment	8%	9%
Activities	16%	31%

9. On a scale from 1 to 5 with 5 being the highest, how would you rate your participation in other classes?

	Testing	Nontesting
1	13%	9%
2	3%	19%
3	26%	41%
4	23%	10%
5	35%	21%

10. Explain your reasons for the above responses.

	Testing	Nontesting
All lecture format	47%	63%
Shyness/not strong in science	11%	14%
Other factors	42%	23%

There were several trends in data for the open-ended items included in the questionnaire that could account for how the students interpreted what was occurring in the context of the class. Students in both the testing and nontesting groups had similar responses when asked what they thought the instructor intended for them to learn. For instance, different presentations of lessons, science process skills, methods for teaching science (especially with hands on activities), and lessons about the scientific method were the most common student responses. The instructor's opinion of what he intended for the student's to learn was:

> *I intended for the students to learn the 'basics' of science and how to teach science to students.*

The students' interpretation of what they thought the instructor intended for them to learn was found in the responses to the questionnaire. Following are a few of the most common quotes about what they thought the instructor intended for them to learn:

> *The basics of science and the process skills necessary to learn science.*
>
> *It was his intent to teach how to teach and develop the process skills.*
>
> *How to teach elementary science effectively.*
>
> *Science Process Skills!!!!! And activities to use in the classroom.*
>
> *The basic scientific concepts, incorporated in the scientific method, that will enable us to effectively teach elementary science.*

The everyday routine of the class did not seem to pose any major concerns for the students. The majority of the students in both treatment groups reported that they were very comfortable and at ease in their science methods class. Students maintained the that hands-on activities, low stress levels, and relevant class material made learning easier and more effective. Nontesting group students replied that lack of test anxiety and emphasis on hands-on activities made the class very meaningful. Testing students said that hands-on activities and the class atmosphere made the class more conducive to learning.

What seemed important to each student played a role in how and why they participated in activities, whether or not they took notes during discussions, and what was relevant for them. The reasons a student has for being on task may be complex and unique for each individual, but it can be assumed that if students are "on task", it is because of their own interest in the subject, the relevance they see in the topic, or that they are motivated by something else, including grades. Relevance affects the reasons a student has for being on task. The instructor had an opinion about whether testing creates a barrier for students to learn science:

> *Some students are greatly motivated by testing. Others are greatly restrained in the amount and quality of information that they are able to learn by the testing and memorization process itself.*

Most students in this study had been accustomed throughout their education to having tests and grades as part of their class format. If grades are what is important to students, then what happens when grades from tests are removed? It is likely that students shift their interest to other things that are graded. Students in the testing group were asked which they put more time and effort into, studying for tests or assigned projects. Basically, the testing group put more time into projects because this helped them prepare for the tests, and also because there were more project grades than test grades. Some of the responses were as follows:

T (Testing students)

> *Projects, because they were more time consuming.*
>
> *Assigned projects because they were more fun and I learned more by doing.*
>
> *The projects. I enjoyed them more and I feel like they will help me more later in life. The projects that we did in class helped us study for the tests.*

Students in the nontesting group were asked if they put more time and effort into their projects since they had no tests. The responses by students in the nontesting group show how their shift in interests was primarily concerned with grades.

NT (Nontesting students)

> Yes (more effort into projects), *I knew my assignments were my only grade, so I made sure I put the necessary time into them.*

> Yes (more effort into projects), *because I knew that these projects would be counted for my final grade.*

> Yes (more effort into projects), *because they were basically the final grade! The Grade is the Reward!*

Although the majority of students in both groups said that they spent more time on and put more effort into projects, the reasons they indicated for doing so centered around grades. The tested students wanted to do well not only for a good project grade, but because doing projects helped them study for the tests. Nontested students reported that they put more effort into projects because that was the basis for their grade. Their shift of interest, in the absence of tests, showed a great interest in grades and the understanding that projects were the only source for grades.

Another way to interpret what students find important is to determine whether or not they take notes on the material covered in class and if they use the notes. The students were asked "Do you take notes in class and if you do, how often do you look over them?" The nontested students were more concerned about using notes for their projects and for future, long-term references.

NT (Nontesting students)

> *I plan to keep these notes and use them in the future.*

> *I took notes even though there were no tests. I still wanted to have the information in case I needed it for later.*

> *Yes I take notes in my class notebook. When I have the chance, I will rewrite them all in ink and add them to my file of notebooks for future reference.*

I looked at my notes when I needed them to refer back to them for a hands-on project.

The most common response about notes from the tested students shows how they were more concerned with test grades.

T (Testing students)

Yes, I took notes. I looked at them only right before the test.

I read my notes about twice a week and more during testing time.

I look at my notes once a week when not near a test and everyday as tests get closer.

The instructor noticed a difference in the amount of note taking in the two groups of students.

At first (during the first part of each semester), it seemed that the classes that were not being evaluated in the 'traditional' manner were actually more intent on taking notes. Toward the end of each semester, the group that was being evaluated 'traditionally' surpassed the non-traditional group in note taking.

When comparing the reasons for taking notes, the nontested group seemed more concerned about having good notes for doing well in projects as well as for long-term references. The tested group was only concerned with having notes to use during test time.

The differences that existed between the overall attitude of the testing and nontesting groups were evident in the following quotes. Students in the testing treatment felt that if they had not had tests they would have had less anxiety. Obviously, grades were very important for these students, and they dominated what they found to be relevant.

Maybe not as stressful as other classes, but I always get stressed out around test time.

T (Testing students)

> *I would be less stressed out (if there were no tests). I think too much pressure is put on you when being tested because if you misunderstand a question but you know the information it affects your grade. I think your participation and performance should show your ability enough to be graded on.*
>
> *If the situation was not testing, I would not have studied for anything.*

The nontested students were very quick to say that they would have had a great deal of anxiety if they had been in the testing treatment.

NT (Nontesting students)

> *I felt like I had more control over what I made in the class. Tests sometime don't show our full abilities. Also ,some people stress over tests and this causes them to do bad.*
>
> *There was less stress and it was more fun. When you are not stressed, you are open to learn more because you are not worried about what you are going to make on the test.*
>
> *I would have not felt different because the assignments (projects) were our assessments.*

Conclusions

The conclusions derived from the experimental portion of this study are based on the TIPS and STEM pretest-posttest score analysis using ANCOVA. They are as follows:

(1) No significant difference existed between the science achievement of elementary science methods students in testing situations and those not in testing situations as measured by the Test of Integrated Process Skills (TIPS) (p=0.107).

(2) No significant difference existed between the science achievement of elementary science methods students in testing situations and those not in testing situations as measured by the Science Test for Elementary Methods (STEM) (p=0.056). Thus, both null hypotheses were retained.

Results from the student questionnaire developed for this study were examined to determine changes in student perceptions within each class situation. A common pattern observed within this study was the shifting of interests to what is graded, as students tend to value what is graded (Wilson, 1994). When students were taken out of the 'traditional' testing situation, they shifted their interest to what was graded. In this instance, projects and presentations were valued in place of tests. Results of the student questionnaire indicate four significant differences in the responses of two groups: whether students took notes, the quality of the notes, utilization of those notes, and student perceptions about their particular class situation. The students in the two groups seemed to be motivated for different reasons.

Newman (1989) stated that educators can motivate students to achieve if they fulfill students' needs for competence, extrinsic rewards, and intrinsic interests. Students in the testing group were concerned with doing well on the tests, so they took more notes than the nontested students, and only used them to study for the tests. The overall perspective of testing students also indicated that they had much higher levels of test anxiety to deal with on a day to day basis. The nontesting students took notes, but they were concerned with using the notes in the future or for projects (which were now the basis for their grade). Nontesting students indicated that they felt comfortable and learned more freely, perhaps due to the lack of test anxiety.

As students shift their interests within the context of the class, the 'relevance' of class activities and requirements becomes important. Students who view class material as relevant will be more likely to study for long-term retention, to take notes during class, and to participate in activities. Students can interpret relevance in terms of how they study in two ways. First, many students find what is to be graded relevant, so they memorize information for tests. Other students find the information itself important, not simply because they are being tested on the material, but because they want to retain the information for future use.

Implications

There are many factors other than simple test scores that indicate the quality of a learning situation. Most of the students involved in this study were accustomed to the 'traditional' testing format in a science class. Rote memorization of science facts`along with grades dominate the 'traditional' format. Students find the factual knowledge in the science class to be relevant because ultimately that knowledge is assessed. Wilson (1994) explained that students tend to value only what is graded. If this is the case, then if testing is removed from a class situation, students will shift their interests or what they see as relevant to something else that is graded.

Bergen (1993) explained that good assessment possesses several qualities, one of which is integration of learning and assessing. Foster and Heiting (1994) share the idea that assessment must be embedded within the everyday science activity. They further suggest that the traditional emphasis on memorization in science assessment has created lingering false assumptions about the purpose of assessment, which indicates that assessment should bring closure to learning and focus on specific science terminology rather than on processes or general ideas. According to the results of this study, testing does not need to occur in order for learning to take place, or for students to feel safe in their 'traditional' learning environment. This finding implies that traditional assessment is not necessarily to bring closure to learning. Nontested students did not have traditional assessment embedded in their class situation, and the learning was a continuous process not a closed activity.

The students involved in this study demonstrated ways and reasons to adapt to changing learning situations through their responses to the questionnaires. Students in the nontesting treatment had two main responses: (1) They were more comfortable because of reduced test anxiety, and (2) They were somewhat uncomfortable because they did not have their test grade to determine how well they were doing in comparison with classmates, so instead they placed emphasis on other activities that were graded. One can imply from the results of this study that testing is not necessarily an important factor in learning. Even without emphasis on test scores, nontesting group responses to the survey item: "How much, on a scale from 1 to 5, with 5 being the highest, do you think you learned in this class?" were not significantly different from responses of the testing group. The indication is that nontesting group students felt that they learned as much as testing group students. Hands-on lessons, relevant class material, and group activities all contributed to their learning. One difference in responses of the two groups was the mention of lower test anxiety by the nontested group, which contributed to the ease of learning for these students. They explained that low test anxiety promoted freedom for creativity and learning for learning's sake, and that they felt that they learned a great deal. "Grades are not essential to the instructional process: teachers can teach without them and students can and do learn without them"(Frisbie and Waltman, 1992, p. 37). Testing and learning are not the same thing, and if you focus on learning, rather than testing, then students' opportunities to learn are enhanced (Berliner, 1988).

Findings of the present study indicate that there is little difference in student learning when in tested or nontested situations. Should teachers who tend to test daily or weekly continue to do so? Is testing necessary? Yes, testing is necessary to a certain degree. Test grades are a simple way to satisfy society's, parents' and administrators' need to know the level of student achievement. On the other hand, other students say they feel more comfortable without tests due to reduced test anxiety. If the presence of testing does not affect student performance, then valuable classtime should not be spent testing. Again, to satisfy the need for grades, the favored assessment method should be embedded within the classroom activities, and should not take time away from more productive learning situations.

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PRE-SERVICE TEACHERS EXPLORE TRADITIONAL ECOLOGICAL KNOWLEDGE IN A SCIENCE METHODS CLASS

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During the 1980s and early 1990s, science educators created an emphasis in science education which could be summed up as making science education more society oriented and more learner centered. This legitimizes and includes the different cultures' and social groups' interests and values in matters of local concern and international issues. Addressing real-life situations demands that we address matters related to environment, sustainability, peace, justice, and equality, and that we consider a range of perspectives. Thus, one of the goals of science education is to to provide students with the knowledge and skills necessary for developing a broader perspective on world issues.

One approach for developing a broader and more global perspective is to infuse examples of the considerable contributions made by long-resident cultures to the field of scientific inquiry into pre-service science education programs. Long-resident cultures have, in the course of time, developed knowledge and wisdom strategies which have enabled them to sustain environment, resources, and populations. Acknowledging the contributions of multicultural science (especially that of long resident oral culture peoples) is a necessary step in enabling students to recognize and learn from groups outside the dominant culture who have made important contributions in the fields of medicine, agriculture, geology, biology, ecology, habitat and resource management, and community-environment relationships. Multicultural science education must begin with the exploration of local issues, environments, technologies, and methods for sustaining the environment; and proceed to national and global issues; and provide an active learning environment that encourages questioning and decision making.

Over the past 30 years, there has been increasing appreciation among working scientists for the contributions of science traditions in other cultures. Biologists, ecologists, geologists, climatologists (among others), have been developing strategies and accumulating an extensive literature identified as TEK: Traditional Ecological Knowledge (Berkes, 1988, 1993; Inglis, 1993). At the same time, educators, particularly specialists in Multi-cultural and First Nations Education have long called for the contributions of other cultures to be properly integrated into all subject areas (Lee, 1982; Leith & Sientz, 1984; Pepper & Henry, 1986; Whyte, 1986). New terms have become part of this research such as traditional ecological knowledge (TEK), multicultural environmental education (Running Grass, 1994) and multicultural science education (Atwater, 1991; Akinhead, 1993; Hobson, 1993; Atwater & Riley, 1994; Stanley & Brickhouse, 1994).

The authors realize that many colleges and universities have yet to address the issue of multicultural science education in even the broadest context. It is hoped that the ideas expressed in this essay for incorporating traditional science into school curricula will clarify some of the steps that need to be taken in this direction. However, since many schools have not yet developed a formal multicultural science policy, the responsibility to design and implement multicultural science programs now falls heavily on the shoulders of university professors and pre-service teachers. Thus, there is a strong need for both the pre-and in-service training of teachers in the theory and methods of multicultural science education.

We begin this essay by providing a rationale for a shift in direction in science education and resource development, one which respects the concerns and perspectives of long-resident oral peoples. In an effort to support wider consideration of the lessons to be learned from traditional peoples, we discuss the nature of traditional science, including aspects of this body of knowledge which are referred to as TEK and traditional wisdom. We offer many examples from Canada and around the world of traditional peoples' contributions to science, environmental understanding, and long-term sustainable societies. Efforts by teachers to promote a broader multicultural view of science education will be reviewed, including what needs to be done to change teacher education programs and curriculum models in science education programs.

The Need for a Cultural Perspective Towards Science Education

Making science education more society oriented and more learner centered promotes questions of interest and value between cultures and social groups related to issues of local concern, international issues, and so called "third-world" issues. Addressing real life situations demands that we address matters related to science, sciene-technology and society issues, and long-term sustainability. Most Ministry of Education documents across Canada mandate that making science education more learner centered means takeing into account *all* learners.

Concern with enhancing self-image and feelings of self-worth--(a key strategy in creating a climate of success in school)--raises fundamental multicultural issues. Even a cursory glance at data relating educational attainment with ethnicity reveals that children of ethnic minorities (Maori children in New Zealand, First Nations children in North America, Aboriginal children in Australia, those of Afro-Caribbean descents in Britain, Afro-Americans, and Inuit and Meti in the United States and Canada), fail to achieve these expected goals (Eggleston, 1986), and as a consequence fail to achieve in secondary school science and in post-secondary science (Atwater, 1986, 1994; Hodson, 1993).

How can children of ethnic minorities identify with global concerns, or even national concerns; when they seldom, if ever, learn about their own contributions to knowledge, their own beliefs about the world, their history, or their values? According to Wetzel (1992), many First Nations children cannot focus on national and global issues because they are the continuing victims of an oppression that has gone on for over a hundred years. In Canada and the United States, most of the literature on aboriginal education has focused on the failure of the formal education system to serve the needs of Native Indian, Metis and Inuit students (Hodson, 1993; Whyte, 1986). Public schools have received considerable criticism for practices and policies which inhibit the student's achievement and success in academic endeavors, and which stymie the expected academic, moral and social development of the indigenous population (Haukoos & LeBeau, 1992; Pepper & Henry, 1986; Whyte, 1986).

To develop a truly multicultural perspective to education, one must recognize the need that exists for this perspective in science education. There is a tendency in western society for ideas and research--indeed almost any statement that is presented in a scientific way--to be accepted as true (Siram-Blatchford, 1987, 1990). As a consequence, school science can be misused by groups of people to promote their own interests. The case is well put by the School Science Curriculum Review (1985) and cited by Hodson (1993):

> Science or "pseudo science" has been used to justify racism and the oppression of minority groups at home and of conquered people abroad. Pupils should be aware of this misuse of science and at the same time be able to understand the basic sameness of the human race and the different ways in which groups have adapted to their environment. (p. 696)

According to Hodson (1993), one has only to critically analyze most science textbooks to realize that the implicit message is that the only science is western science.

Among the several causal factors, according to Hodson (1993), are the following:

1. Science curriculum content is often exclusively western in orientation;
2. Many curriculum materials are covertly racist, just as many are still covertly sexist;
3. Teaching and learning methods are sometimes inappropriate to the cultural traditions of minorities;
4. The image of the scientist as the controller, manipulator, and exploiter of the environment is in conflict with the cultural values of some children.

According to science education researchers (Atwater, 1986, 1991, 1994; Whyte (1986), factors inhibiting the progress of ethnic minority students, including Indian, Inuit, Metis, and Afro-American, in Canadian and US schools include the following:

1. Ethnic minority students are frequently absent from science and math classes.
2. English is not spoken in many minority homes, or if it is spoken, it is as a second language. Communication problems can be both verbal and nonverbal.

3. School personnel and curricula are frequently characterized by attributes such as aggressiveness and working for personal advantage, which run counter to the value placed by many cultures on cooperation, and group well being.
4. There is continued insensitivity to minority cultures and communities which results in withdrawal from school, parent apathy, and community alienation.
6. Teachers of ethnic decent who can serve as positive role models are not available.
7. Federal, provincial, and local authorities have the tendency to exclude minority parents and community members from decision making and planning regarding their children's education.

These findings indicate that acceptance of a multi-cultural view of science education is not presently widespread in schools. The findings describe a system of education in which students are expected to be passive, to adhere strictly to a western view of science, and to accept information that is presented without question. Such techniques not only go against what is presently known about effective teaching, but also discourage students from seeking to understand science concepts.

In a number of areas considerable efforts have been directed and undertaken to address some of the barriers and problems noted and to develop quality educational experiences for First Nations students, and to do justice to their rich history and culture. Although such efforts are commendable, they usually are not adequately researched at either end, that is, their development is frequently not research based, nor are their outcomes studied systematically enough to permit firm conclusions about what does and does not help First Nations children experience success (Atwater & Riley, 1993; Whyte, 1986). Because responsibility for developing culturally appropriate curricula has largely been left to social studies and multi-cultural teachers, the development of inadequate researched programs and the development of appropriate teaching and learning strategies for science teachers remains pressing.

The key to effective strategies seems to be contained in the multitude of variables surrounding the issues of communication within the classroom setting. The problem lies not with the child, but with the inability of educational systems to design learning settings which are right for the children--in which children feel comfortable and secure enough to participate. The intention of this essay is to identify a number of problems and strategies for infusing traditional science topics into mainstream science curricula.

Multicultural Science Education

Although multicultural science education is a new term, it has been described as a "construct," a "process," and an "educational reform movement" with the goal of providing equitable opportunities for culturally diverse student populations to learn quality science in schools and universities (Atwater, 1991). The National Science Teachers Association (NSTA) has created a standing committee called the Committee on Multicultural Science Education whose charge is to provide general recommendations in the area. The committee has defined as one of its goals to ensure that "culturally diverse children . . . have access to quality science education experiences that enhance success and provide the knowledge and opportunities required for them to become successful participants in our democratic society" (NSTA, 1992).

Hodson (1993) states: "multicultural science education can mean many things to many people. Relative emphasis will need to vary from country to country, region to region, and even from school to school and class to class" (p. 688). Hence, awareness of cultural diversity in science education seems to be the cruz of multicultural science educdation. Ogawa (1995), argues that while "multiculturalism" can be a powerful and significant tool to reflect on science education and to improve classroom practice, a "multiscience" perspective on science education affords richer implications for reflection and practice:

> While cultural diversity claims that culture should be viewed in a relativistic perspectice, why is science itself never viewed in such a relativistic perspective? Science is always treated as absolutely singular. We should remind ourselves that the word 'multicultural' means 'of many cultures.' Its simplest implication to science education is 'of many sciences' which can be denoted as 'multisciences.' (p. 584)

Yamada (1970), a historian of Oriental science, as quoted in Ogawa (1995), writes:

> I think that the concept of science is valid only either when it is used in the narrowest sense, as the meaning of the modern science, or when used in the broadest sense, as the meaning that 'every society and culture has its own science, and its function is sustaining its mother society and culture.' And I would like to use the concept 'science,' in the latter usage. (p. 585) [Translated from the Japanese original by Ogawa]

The authors of this essay agree with Ogawa and Yamada, that every culture has its own science and we shall refer to the science in a certain culture as its "indigenous science" or here by its "traditional science."

Children's Prior Beliefs and Cognitive Commitments

Students bring ideas based on prior experience to the classroom, and these ideas or beliefs effect the ways they respond to and interpret instruction in science. The notion that students approach the world with some degree of mental organization, not a blank mind, is not new (Ausubel, 1963; Driver & Erickson, 1983; Schon, 1987; Von Glaserfield, 1987, 1989). Not only have researchers been able to identify and describe a range of intuitive views for specific phenomena, but they have also established that such views can be remarkably persistent.

A scond line of investigation into children's learning in science emphasizes that children of different cultural backgrounds frequently interpret science concepts differently than the standard scientific view, and that teachers need to begin instruction with the prior knowledge that children bring to the classroom (Hewson & Hewson, 1981; Hewson & Hamlyn, 1983; Driver, 1987, 1989; Novak, 1985). Although little research has focused on the beliefs and explanations of children from different cultural groups, some major differences between aboriginal and the Euro-American children have been documented. For example, children of aboriginal cultures such as the Maori in New Zealand, the Afro-Caribbean, Afro-American, Native American and the Inuit may have very different beliefs about the concepts of time, life cycle, growth, death, taxonomy, food chain, energy, evolution, tidal cycle, weather, causation, and resource management (George & Glasgow 1988, 1989; Gough, 1992; Jegede & Okebukola, 1991; Snively, 1986, 1990). Thus, when teachers talk of science education assisting children to understand the world, they need to be clear about whether they mean the world of the child, or the world of the dominant culture (Atwater & Riley, 1993).

An example of research undertaken with this perspective is Snively's study on children of both traditional Native Indian background and children of Anglo-European background, and their conceptions of marine science concepts:

> Students have experienced and thought about the world, they enter learning situations with a complex cluster of ideas, beliefs, values and emotions, ...and it is the potential match between these existing cognitive commitments and the new information which determines how the student will respond to the instructional inputs. (Snively, 1986)

What is Science?

As is well known, there are numerous versions of what science is, and of what counts as being scientific (Woolgar, 1988). Science is generally described as knowledge obtained through observation and experience. We can also define science as an attempt by people to search out, describe, and explain patterns of events within their natural universe (Yore, 1981). According to Brownowski (1977), humans everywhere practice science and art--we know and we create. The Latin root, *scientia* means knowledge in the broadest possible sense. Omniscience means simply knowing everything. Societies everywhere have different ways of interpreting the world around them, and how a people perceive their world is called a world view.

Science is more and more conceived to be a method of thinking rather than a collection of thoughts. Sir Peter Medawar, the Nobel Laureate, tells us, "Science is really the art of the experimentable." Jacob Brownowski, as quoted by Doyle (1985), further said, "Science is experiment, science is trying things. It is trying all possible alternatives in turn, intelligently and systematically, and throwing away what won't work and accepting what will." Sometimes the fruits of technology or "applied science" may be indicated.

Western or Modern Science

Although the word "science" has been in use since the time of Imperial Rome, the word has evolved dramatically over the last one hundred years. Terms such as "modern science," "standard science," "western science," "conventional science" and "official science" have been is use only since the beginning of the twentieth century. For some, modern science began with Greek atomism; for others it began towards the end of the nineteenth century when scientists started to grapple with abstract theoretical propositions--for example evolution, natural selection, and kinetic-molecular theory. What confidence could one have in theoretical statements built from or based on unobservable data? Care was taken to develop formal rules outlining how theoretical statements can be derived from observational statements. The intent was to create a set of rules to guide the practice of theory justification (Duschl, 1993). Many current scientists agree that the so-called scientific method does not represent the thought processes of working scientists" and "may leave students with an inaccurate picture of how science and scientists work" (Doyle, 1985).

Also, western science is often thought to proceed in a "linear" fashion, that it moves ahead step-by-step, with each advance depending on the previous one. Although scientists do "advance on the shoulders of their predecessors", a more exact comparison according to Doyle (1985), "would be to the construction of a jig-saw puzzle (science often starts from the middle and expanding outward--for example, the application of a new chemical methods or the invention of the microscope, which accelerates and changes the direction of scientific activity in starling ways." Also, western science may refer to officially sanctioned knowledge--which can be thought of as inquiry and investigation that government and courts are prepared to support, acknowledge and utilize.

Traditional Science

Traditional science interprets how the world works from particular cultural perspectives. Traditional science, or ethnoscience, has been described as "the study of systems of knowledge developed by a given culture to classify the objects, activities, and events of its universe"

(Hardesty (1977). Expressions of science thinking are abundant throughout traditional agriculture, astronomy, ecology, and medical practices. In additon, processes of science which include rational observation of natural events, classification, and problem solving are woven into all aspects of traditional culture (Cajete, 1986).

The science of long-resident peoples differs considerably from group to group depending on the locale, and is knowledge built up through generations of living in close contact with the land. It is both remembered sensory information built upon repeated observation and inquiry, and more formal information that is usually transmitted orally in story form, where abstract principles are encapsulated in metaphor (Bowers, 1993a, 1993b; Cruikshank, 1981, 1991; Nelson, 1983). Examples of traditional science may be accessed through living elders and specialists of various kinds, or found in anthropology, ethnology, ethnobiology, ethnogeography, history, politics, mythology, and literature.

A fundamental principle taught by Aboriginal elders is that subject matter is to be examined and interpreted contextually. For example, identification and examination of a particular plant and its fruits, is almost incidental to stories and demonstrations of its use as a food source, its ceremonial uses, its complex preparation process, the traditional accounts of its use in purification rituals, its kin affiliations, and so on (Christie, 1991). This social context is in marked contrast with Western science where "environmental" influences are considered confounding, and scientists often do their most serious work in the laboratory. Traditional science tends to be holistic, viewing the world as an interconnected whole. Humans are not regarded as more important than nature. Thus, "traditional science is moral, as opposed to supposedly value-free" (Berkes, 1993).

Traditional science, like western empiricism, is based upon observations and experiences; and addresses a wide range topics, as outlined by Corsiglia and Snively (1995):

- preparation and design of clothing, shelter, food, and tools;
- traditional medicine, counselling, and psychology;
- aboriginal classification systems of natural and social environments;
- aboriginal taxonomy within the plant and animal Kingdoms;
- traditional knowledge of plants and animals (uses, life cycles, migrations, inter-relationships;
- ecological knowledge of habitats, food sources, and the interrelationships

between environments and life forms;
- traditional perspective on traditional harvesting;
- technology applied to hunting, fishing, root-digging, harvesting basket materials, tanning hides, etc;
- knowledge of weather, seasonal changes, lake, and river changes;
- knowledge of geology, volcanic activity, and glacial activities;
- knowledge of ocean currents, tides, distribution of organisms, and food relationships;
- knowledge of metallurgy, copper technology;
- wilderness survival, living off the land;
- conceptions of preservation, conservation, and sustainable development. (p.27)

Acceptance of the validity of these insights by courts, government officials, scientists, and First Nations advocates shows recent appreciation that TEK provides useful, highly reliable, and cost-effective information about plant and animal species as well as relationships amongst species, habitats, and human-environment relationships (Berkes & Mackenzie, 1978; Andrews, 1988; Berkes, 1988, 1993; Inglis, 1993; Williams & Baines, 1993). The outcome of this abstracting of lessons or pieces of wisdom is an emphasis on results, not procedures and authorship.

Metaphor and stories are often used to create highly compressed oral wisdom and even make it entertaining. Oral narratives may explore historical events such as the coming of the first outsiders, encroachment on traditional lands, or changes in animal populations due to over-use. Narratives provide information about changes in the migration routes of caribou as a result of new land use activities; changes in the population of salmon or crabs; changes in the size, vitality, longevity, and even the viscera of animal populations. Oral narratives often provide biologists with important long-term observations describing changes in plant and animal populations which can be correlated with over-fishing and pollution (Cruikshank, 1981, 1991; Kuhnlein & Turner, 1991).

Important traditional science observations may be encoded in highly compressed metaphor which can be decoded in relation to specific circumstances upon appropriate reflection or contemplation. The ubiquitous "trickster" stories have been described as sufficient to guide a person who has become lost in finding all the necessities required to sustain life. Edwin Scurvy once explained to Cruikshank (1991):

> If I ever get stuck in the bush, I wouldn't have any trouble. I'd just remember what Asuya did when he was traveling around and I'd know what to do. You

> follow that story and it tells you everything you need to know. That's how they used to teach us when we were kids. (p.13)

Since traditional people tend to spend generations learning about life in one place, traditional science often may not resemble the more mobile and dramatic western science that was developed in intimate association with the rise of Western global expansionism. Experimentation and innovation may take place at a more measured pace than in western science. In her observations of Athapaskan and Tlingit languages in the Yukon and Northwest Territories, Julie Cruikshank (1991) notes:

> Observations are made over a lifetime. Hunting peoples carefully study animal and plant life cycles, topography, seasonal changes and mineral resources. Elders speaking about landscape, climate and ecological changes are usually basing their observations on a lifetime of experience. In contrast, because much scientific research in the north is university-based, it is organized around short summer field seasons. The long-term observations included in oral accounts provide important perspectives on the questions scientists are studying. (p.18)

Among the NisGa'a of northern British Columbia, for example, one rarely responds to a request for information or opinion quickly—it is more respectful to consider such requests for a number of days before making a carefully considered response. Mistakes cannot be tolerated when footsteps take one where swift water rushes beneath river ice. Trial and error may not be cost-effective in a stable community where one must live with correct or incorrect solutions. Where a community is resident and stable, solutions to problems can be carefully preserved, refined, and re-applied. When circumstances dramatically change, communities move, or individuals are lost or under pressure, the rate of inquiry must be accelerated.

Contributions of Traditional Science

Traditional peoples' contributions have been incorporated in modern applied sciences such as medicine, architecture, engineering, pharmacology, agronomy, animal husbandry, fish and wildlife management, nautical design, plant breeding, and military and political science (Ford, 1979; Weatherford, 1988, 1991). Meso -American mathematicians and astronomers used base 20 numeracy to calculate calendars more accurately than those used by Europeans at the time of contact, even after the Gregorian correction (Kidwell, 1991; Leon-Portilla, 1980). In the

Americas, traditional scientiests developed the long-staple cotton that now clothes the world and also developed some 290 varieties of potatoes. They also developed innumerable varieties of grain, oilseed, squash, hot peppers, as well corn, squash, and beans. They introduced the use of rubber and platinum metallurgy (Weatherford, 1988, 1991), as well as the hull design of large cotton sails and the hull design of clipper ship and its modern America's Cup descendants (Duff, 1991). Native Americans developed highly articulated and effective approaches to grassland management (Roe, 1991) and salmon production (Stewart, 1977). Traditional native American healers discovered and used quinine, aspirin, ipecac (a drug still used in traumatic medicine to expell stomach contents), as well as some 500 other important drugs (Weatherford, 1988, 1991). In modern times these disciplined observers and innovative thinkers might well have earned several Nobel Prizes. Most people do not realize that they are benefiting from the labors of aboriginal scientists and doctors almost every time they dress, dine, travel, or visit their physicians. Suggestions that traditional peoples cannot practice "science" turn upon narrow and restrictive definitions, old justifications of harsh expansionism, or insufficient factual data.

The Wisdom Aspect of Traditional Science

In addition to making significant scientific and technological discoveries, traditional cultures focus on applying useful discoveries to human needs. Generally, the wisdom aspect of traditional science is so much a part of traditional people's underlying conceptual systems that it is broadly diffused throughout the culture. Traditional wisdom, a virtually untapped treasury of concepts related to *respect* and *restraint*, provides community and individuals with well articulated "controls" designed to limit the application of powerful traditional science and technology in an inter-related world. Traditional wisdom usually begins with an understanding that spiritual essence infuses and defines all forms, and that all life-forms must be respected as conscious, intrinsically valuable, and inter-dependent. Respecting an animal means honoring its spirit and using every part of an animal's body. In practical terms, traditional wisdom extends the caring relationships associated with "family" life to communities and even to the environment. It is wrong to exploit anyone or any other life forms—we are all relations. The deep interest our children feel in animals, plants, water, and earth should be trusted and encouraged. All creatures can be our teachers and while humans may readily affect other life forms, humans need not see themselves as particularly superior life forms. In fact, among the Nisga'a "Wolves and bears may be considered superior life forms because they do not need to talk to communicate" (personal communication with Harold Wright).

Stewart (1977) refers to the place of the salmon in the lives of Northwest Coast Native Americans, in the ways in which salmon are literal embodiments of the wisdom of the locale, incorporating a moral understanding of self, community, earth, and the interrelationships among them. As one example, when the first silver salmon (coho) were caught by trolling, the fisherman's wife met her husband's canoe at the beach and said a prayer of welcome to the fish. When the roasted fish were laid on new mats spread before the people, the one of the highest rank then prayed to the food before it was eaten:

> Of friends! thank you that we meet alive.
> We have lived until this time when you come this year.
> Now we pray you, Supernatural Ones, to protect us from danger,
> that nothing evil may happen to us when we eat you,
> Supernatural Ones!
> For that is the reason why you came here,
> that we may catch you for food.
> We know only your bodies are dead here,
> but your souls come to watch over us
> when we are going to eat
> what you have given us to eat now.
> Indeed! (Stewart, 1977, p. 165)

Such an understanding of the salmon is similar to that of the Koyukon of Alaska, whose moral system governs human behavior towards nature. In *Make Prayers to the Raven*, Richard Nelson (1983) describes the pervasive elements of nature in the Koyukon people's traditional spiritual beliefs. The proper role of humankind is to serve a dominant nature, in contrast to a western tradition of humankind dominating nature. The proper forms of human conduct are set forth in an elaborate code of rules; deference is shown for everything in the environment, through gestures of etiquette and by avoiding waste or excessive use. Humanity, nature, and the supernatural are not separated, but are united in an interactive cosmos. Humans should be careful and respectful before encroaching upon any harmonious relationships. Harmony can be preserved through respect, justice, and diligence. Wealth achieved without the respect for sustaining harmony simply indicates negative disturbances—neuroses like greed and selfishness. The territories, resources, and interests of others are to be respected.

Examples of traditional wisdom as summarized by Corsiglia and Snively (1995), include the following:

- animals viewed as social beings with thoughts and feelings; treated with respect; animal souls survive and are reborn;
- humans and nature are inseparably linked with other life forms in a universe pervaded by consciousness;
- if one were lost in the woods or coming to a new place one could survive by remembering and imitating our animal teachers–the Bear Mother or Raven;
- all natural and supernatural objects have power to harm or help humans;
- understanding that spiritual essence persists while forms change;
- all humans return to face their mistakes through the process of re-birth;
- the truth of situations will always become known, death may be less fearful than shame. (Corsiglia & Snively, p. 30)

Traditional science can be thought of as the coming together of the technical aspects of traditional knowledge and the values, philosophies, or ethical aspects of traditional wisdom.

<u>Strengths and Limitations Associated With Oral Narrative Traditions</u>

Whether attempting to develop science programs for pre-service teachers or currucula for schools, or conduct research, it is important to consider the strengths and limitations of oral tradition as evidence for scientific contributions and past history. Despite growing support for traditional science, some scientists operating within Western empiricism are reluctant to accept oral narratives and metaphors as a source of scientific knowledge for at least two reasons. One, oral cultures use information storage and retrieval systems which are substantively different from those employed in cultures that use permanant record-keeping (Johnson, 1992) and two, traditional narratives integrate scientific information with spiritual, mythological, fictional, elements.

Oral tradition has been defined succinctly as "oral testimony transmitted verbally from one generation to the next or more" (Vansina, 1971). Anthropologist, Cruikshank (1981) describes Native oral narrative traditions as a distinct intellectual way of knowing (epistemology), and lists several strengths as a data source. Among those that are of interest to science educators are the following:

Integration of historical events: Anthropologists have documented the tendency of long-resident, oral culture peoples to incorporate historical events into traditional narratives. In the Yukon, for example, traditional narratives incorporate Native perspectives on the Klondike gold rush, the arrival of the first whites and well-known historical figures. In fact, the narrative style seems quite responsive to incorporating new materials using a traditional formula (McClellan, 1970). In the same way, accounts of natural catastrophes which are inherent to northern geologists, glaciologists, archeologists, and climatologists often become part of oral tradition (Cruikshank, 1981).

Oral tradition as technology: Traditional narratives may contain highly technical information. Anthropologist Robin Riddington (n.d.), suggests that oral tradition is a critical adaptive strategy for hunters and gatherers particularly in harsh environments. He argues that the conceptual ability to recreate, through language, a situation for someone else who has not experienced it directly is a highly adaptive technology carried in the mind, rather than in the hand. Detailed descriptions of how to make a caribou snare, how to make a snowshoe, how to trap specific animals, or find the way back home are all embedded in stories. Accurate transmission from generation to generation becomes critical for group survival, therefore each generation is careful to get the critical aspects accurate.

Duration of observation: Oral traditions may provide detailed observations of natural phenomena made over a lifetime (or several life times), and in all seasons, scientists, by contrast, are often limited to short field trips during summers.

Absence of documentary sources: In an area where most written documents date from the beginning of this century, oral tradition is a significant source of historical information. With such a shallow historical base for their observations, northern scholars may well dispute the validity of evidence in oral narrative, but "they cannot afford to ignore it."

On the other hand, Cruikshank (1991) lists some significant limitations of oral narratives as a source of evidence for those working in a western science framework. Among those that are of interest to science educators, Cruikshank identifies the following:

Cultural context: Traditions passed on orally begin with very different premises from western science and cannot readily be interpreted out of context. Usually a scientist interested in a particular phenomenon will both pose a question and answer it within a western frame of reference leading to misinterpretation of a story.

Literary style and symbolism: Each culture has a special literary style which cannot be ignored in the analysis of narrative. Like all literature, oral narratives may seek to transform rather than accurately reflect life, and this poses problems for the scientist or historian seeking to isolate historical or scientific data.

Time and space perspective: A serious limitation for scientists is the extrapolation of linear time from oral narrative based on cyclical time. Most oral traditions do not contain even an internal sequence of time and would be undatable and unusable if other supporting evidence were not available.

Quantitative data: Native resident peoples of northwestern Canada do not handle quantitative data in the same manner as western science. This can be most bewildering to a western listener and limits the possibility that a scientist can date or quantify scientific phenomena on the basis of Native traditions.

In summary, Cruikshank (1991) concludes that "oral tradition tends to be timeless rather than chronological, and refer to situations rather than events". Oral tradition has "a specificity of its own which puts limitations on its use". Hence, "a single tradition cannot be used by itself, but only in combination with other sources, in comparative ways".

Although cultural perspectives may make it inconvenient or difficult to incorporate traditional science examples into a western scientific framework, science researchers and students can none-the-less learn from the narrative stories of Native Americans. Their languages, myths, and rituals generally articulate culturally and ecologically located conceptions of self and a sense of the connections which bind their communities together and to the land. Their mythologies—such as their moral stories of ancestral beings--are closely tied to place, and therefore, are not easily exportable in the same way that western science could be exported (Bowers, 1993b; Gough, 1992).

Traditional Ecological Knowledge

Traditional ecological knowledge (TEK) represents experiences acquired over thousands of years of direct human contact with the environment. Although the term TEK came into widespread use in the 1980's, the practice of TEK is ancient (Berkes, 1993). Pioneering work by ecologists such as Conklin (1957) and others documented that traditional peoples such as Philippine horticulturists often possessed exceptionally detailed knowledge of local plants and animals and their natural history, recognizing in one case 1,600 plant species. Other kinds of indigenous environmental knowledge were acknowledged by scientific experts. For example, ecologist Pruitt has been using Inuit (Eskimo) terminology for types of snow for decades, "not in any attempt to be erudite, but to aid in the precision in our speech and thoughts" because when dealing with ice phenomena and types of snow "There are no precise English words" (Pruitt, 1978).

Increased appreciation for ethnoscience, ancient and contemporary, paved the way for the acceptability of the validity of traditional knowledge in a variety of fields. Various works showed that many indigenous groups in diverse geographical areas from the Arctic to the Amazon (for example, Posey, 1985) have had their own systems of managing resources. Thus, the feasibility of applying traditional ecological knowledge to contemporary resource management problems in various parts of the world was gradually recognized (Johannes, 1989; Johnson, 1992; Berkes, 1993; Inglis, 1993; Williams & Baines, 1993).

Fikret Berkes (1993) provides an overview of TEK theory and scholarship in his comprehensive article, " Traditional Ecological Knowledge in Perspective". Besides discussing the significance of TEK and comparing it with western science he provides the following working definition:

> TEK is a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. Further, TEK is an attribute of societies; by and large, these are non-industrial or less technologically advanced societies, many of them indigenous or tribal. (Berkes, 1993, p. 3)

The debate between western science and advocates of traditional science, is admirably summarized and clarified by Eugene Hunn (1993):

> Most educated people today--except for those trained in sociocultural anthropology or related disciplines--believe that traditional cultures are unscientific because they are based on magical beliefs and/or because they lack the benefit of the western scientific method of empirical observation and experiment. Ironically, many sociocultural anthropologists also believe that the traditional cultures are unscientific. This follows from the anthropological dictum that every culture has a unique world view. Thus, modern science, as a product of western culture, represent but one cultural perspective, different from but no better than any other. The first group believes that Science (with a capital "S") is a recent invention of European culture. The second group professes that there can be no Science (with a capital "S") because there is no Reality (with a capital "R"), only unique cultural definitions of reality. Neither perspective leaves room for TEK and modern science to join forces to the end of achieving an understanding of reality superior to both." (p. 16)

As we have seen, a problem of integration is that of the refusal of many scientists to recognize traditional ecological knowledge as science because of its spiritual base, which they regard as superstitious and fatalistic. What they often fail to recognize is that spiritual explanations often incorporate important ecology, conservation, and sustainable development strategies (Johnson, 1992). In reference to traditional ecological knowledge, Johnson and Ruttan (1991) point out the following:

> Spiritual explanations often conceal functional ecological concerns and conservation strategies. Further, the spiritual aspect does not necessarily detract from the aboriginal harvester's ability to make appropriate decisions about the wise use of resources. It merely indicates that the system exists within an entirely different cultural experience and set of values, one that paints no more and no less valid a picture of reality than the one that provides its own (western) fame of reference. (cited in Johnson, 1992, p. 13)

Johnson (1992) further asserts that "the spiritual acquisition and explanation of TEK is a fundamental component and must be promoted if the knowledge system is to survive" (p. 13).

Contributions of TEK

TEK scholarship is concerned with the ecological and environmental knowledge of long-resident, usually oral-culture societies. The list below is adapted from the International Union of Circumpolar Nations program on Traditional Knowledge for Conservation (IUCN, 1986) and reprinted in Inglis (1992). Some of the contributions of traditional ecological knowledge are listed below:

- provides new biological and ecological insights. New scientific knowledge can be derived from perceptive investigations of traditional environmental knowledge systems (Johannes, 1981, 1993).
- provides effective shortcuts for researchers investigating the local resource base. Local knowledge may make it possible to survey and map in a few days what would otherwise take months, for example, soil types, plant and animal species, migration pathways and aggregations sites (Howes, 1980; Johannes, 1993).
- locates rare and endangered species for researchers dentifying sensitive areas such as aesthetic qualities or species diversity (Johannes, 1993).
- is relevant for contemporary natural resource management, as in such areas as wetlands (Gadgil & Berkes, 1991).
- helps define protected areas and for conservation education. Protected areas may be set aside to allow resident communities to continue their traditional lifestyles, with the benefits of conservation. (Gadgil, in press).
- provides time-tested in-depth knowledge of the local area which results in more accurate environmental assessment and impact statements. People who depend on local resources for their livelihood are often able to access the true costs and benefits of development better than any evaluator from the outside (Johannes, 1993). Also, involvement of the local people in the

planning process improves the chance of success of development (Warren et al. 1993).

TEK provides useful, highly reliable, and cost-effective information about plant and animal species as well as about relationships between species and habitat, and humans and the environment (Andrews, 1988; Berkes, 1988, 1993; Berkes & Mackenzie, 1978; Inglis, 1993; Williams & Baines, 1993).

TEK is of interest to First Nations people with whom it originates, and is also being used by courts and government officials, as well as scientists. The Brundtland Commission report, *Our Common Future (World Commission on Environment and Development*, 1987), drew our attention to the contributions of indigenous knowledge. The recogniton of TEK globally is explicitly addressed in international agreements resulting from the "Earth Summit" at Rio de Janeiro in June, 1992; including the *Convention on Biological Diversity, Agenda 21*, and *Guiding Principles on Forests*. [1] In British Columbia, the report of the scientific panel for sustainable forest practices First Nations' Perspectives Relating to *Forest Practices Standars in Clayoquot Sound* (British Columbia, 1995), emphasizes TEK and the importance of including indigenous people and their knowledge in planning and managing their tradtitional territories.

Convergence of Oral and Scientific Traditions in Canada

In a comparison of Native oral traditions in the Yukon and Northwest Territories with western scientific research, anthropologist Cruikshank (1981, 1991) concludes that traditional societies can contribute in unique ways to scientific knowledge. For example, Cruikshank cites a geographer who has interpreted Inuit testimonies recorded in journals of early Arctic travelers as reflecting their understanding of earthquake activity and isostatic rebound (Spink, 1969). A geophysicist is recording traditions associated with sea ice on the north Alaska coast; another hopes to record oral traditions about volcanic eruptions at Mount Wrangell (Benson, 1978,

[1] These documents, outputs of UNCED '92, or Earth Summit" at Rio de Janeiro in June 1992 are reviewed in detail in the pending Scientific Panel document *A Vision and its Context: Global Context for Forest Practices in Clayoquot Sound*.

personal communication). A dendroclimatologist from Columbia University attempting to reconstruct past climates in Northern Canada is interested in Yukon traditions about an extremely cold summer during the last century (Cruikshank, 1981).

An almost universal oral tradition describes the Deluge, a great flood which covered the earth and from which only a handful of survivors escaped (Thompson, 1932). Glaciologists argue that traditions recorded in the Yukon are helping to reconstruct events surrounding the emptying of glacier-dammed lakes which followed the last glaciation (Clarke, n.d.; personal communication). Vitaliano (1973) suggests that Deluge traditions may be related to the thousands of small lakes that were impounded temporarily by tongues of ice. When ice dams impounding such lakes suddenly failed, the resulting floods could have wiped out Indian villages downstream (1973).

Oral accounts involving flora and fauna convey precise observations about animal-plant life passed from generation to generation as well as linguistic classifications used by native speakers (Cruikshank, 1981, 1991; Hunn, 1933; Kuhnlein & Turner, 1991). For example, biologists and linguists have collaborated to record Cree names and classifications for fish species. This work has particular immediacy because some fish species have elevated levels of mercury and it is impossible to issue warning without knowing the names and classifications Cree speakers use for the fish (Berkes & MacKenzie, 1978).

Plans to build a natural gas pipeline from Prudhoe Bay, Alaska through Canada to the United States initiated research to determine the displacement history of traditional peoples along proposed pipeline routes. The Denali fault, a major intercontinental crustal break, is the focus of much attention. Conceivably, Indian traditions about intensity and duration of earthquakes could make a contribution to scientific data (Stevens & Milne, 1974; Clague, 1979). Such data can be compared to data about earthquake lore elsewhere in the world, including examples of how Japanese seismologists integrated information from ancient traditions into their research (Vitaliano, 1973).

Worldwide Traditional Knowledge and its Relevance to Sustainable Development

Growing worldwide acceptance among scientists and international aid agencies of TEK is reflected in a network of national and regional Indigenous Knowledge Resource Centers, so far embracing Europe, North and South America, Africa, the Philippines, Mexico, and Indonesia (Warren, 1991; Healey, 1993).

In some of Africa's most ecologically fragile and marginalized regions, knowledge of the local ecosystem simply means survival. Famine caused by drought, deforestation, desertification or topsoil erosion, and declining productivity are some circumstances which may have encouraged or necessitated the acceptance of innovation. Among the traditional management practices which encompass the individual and community wisdom and skills of African indigenous peoples TEK scientists list the following: indigenous soil taxonomies; soil fertility; agronomic practices such as terracing, contour banding, fallowing, organic fertilizer application, crop-rotation and multi-cropping; indigenous soil and water conservation; and anti-desertification practices (Atteh, 1989; Lalonde, 1993).

Although traditional pest control systems were once widely used in tropical countries, their use has been severely disturbed by the introduction of modern agro-chemicals. This dependence on expensive modern pesticides poses a potential threat to the health of traditional farmers and is often poisonous to the local ecosystem (Heeds, 1991). The earliest known mention of a poisonous plant having bio-pesticide properties is*Azadirachta indica*, or Indian lilac, recorded in the Indian Rig Veda 2000 B.C. (Hoddy, 1991). Throughout India and Africa, traditional farmers long observed the immunity of its leaves to desert locust attack. It works as a repellent and antifeedant to many chewing and sucking insects in the larva or adult stages (Emsley, 1991; Heeds, 1991). Recent analysis of the neem extract determined the plant to contain 20 active ingredients which makes it difficult for any insect pest to develop a resistance to them all (Hoddy, 1991). Currently, TEK researchers are working with farmers in India and Africa to develop a neem spray made from the seeds of the fruit, while over a dozen campaigns in industrialized countries are working on commercial neem products that are as stable and effective as naturally occurring neem (Emsley, 1991).

Towards a Multicultural View of Science Education

Despite much discussion, a complete understanding of a multicultural approach to science education has yet to be elucidated. In this era of advancement in our understanding of prior knowledge and science education instruction, new approaches to learning are being introduced. This section makes specific recommendations to reform school science programs for both Native students and indeed all learners, and describes challenges to universities and possibilities for reforming science methods instruction for pre-service teachers.

Reforming the Science Curriculum

As pointed out, the school curriculum in Canada and the United States performs the function of distributing and legitimizing the definitions of reality shared by the dominant society. For the student, the curriculum both reinforces experiences and provides the vocabulary for thinking and communicating about it. Reform for science curriculum in a manner that would serve as an instrument of liberation rather than control would occur at several levels. It would involve attempting to achieve greater accuracy in how societal and cultural conditions are represented in curriculum materials. It would insure accuracy in representing the nature of science, scientific progress, technology, the contributions of traditional science and wisdom, and the contributions and limitations of western science. It would involve presenting the complexity, contradictions, and actual prospects that are necessary for reflection. At times, this would lead to presenting more than one theory for explaining the phenomena under discussion.

Science textbooks need to provide well chosen examples of the contributions of traditional science, to the fact that traditional science and wisdom enabled Native people to live in environments over long periods of time. Similarly, examples from the history of western science can be used to illustrate how the purposes, theories and methodologies of Western science have changed. Science textbooks and teaching materials need to provide examples of the limitations of western science (as well as the limitations of traditional science), and opportunities for the student to examine the part of the culture under consideration in terms of futuristic considerations. These omissions result in a distorted, romanticized view of western science, and it leaves the student without the necessary concepts and vocabulary for thinking about the complexities and contradictions that characterize the nature of science, science-technology-society issues, and science literacy.

The acceptance of traditional science leads to a very different set of curriculum proposals with significant implications for mainstream students. Students would experience ecologial interdependence along with a concern for long-term sustainability as important educational themes.

Approaches to Gathering Traditional Local Science Knowledge

Sometimes, collecting information on traditional knowledge is fairly simple, such as when information is readily available in a book or film, or when an elder is able to assist as a resource person. It can be more complicated when the information concerns specific local knowledge or when the knowledge has been lost, distorted, or is culturally sensitive. Gathering traditional knowledge takes time, creativity and effort. Primary teachers will need to identify their own materials and resource persons, but at the intermediate and secondary level, teachers can engage the students in the information collecting process. The following are possible sources of information:

- interviews
- resource people from the local community
- biographies of elders
- fieldtrips
- books, legends, taped stories
- maps, photographs, sketches, time lines
- films, documentaries, National Film Board of Canada
- historical archives, musems
- tribal Band Offices
- Ministries of Education (Aboriginal Programs)

- TEK researchers (biologists, geologists, climatologists, ethnobotonists, etc.)
- government agencies, Fisheries and Oceans Canada, Parks Canada staff

Comparing Official and Tradtional Science Perspectives

One way for teachers to begin a unit on multicultural science is to have the class brainstorm what they know about western science and traditional science, as well as questions they have about the two perspectives. Together, the teacher and students should brainstorm topics of interest, such as knowledge of life cycles, medicinal herbs, weather, seasonal changes to the environment, or migration roots. From the set of topics, the class should identify one topic of interest and then brainstorm a set of related questions. For example, students might identify caribou migration as a topic of choice, then brainstorm questions: What do we know about caribou migration roots? Why do caribou migrate? What roots do they take? How was the environment and how it is changing? How are humans changing migration roots? The class could be divided into two groups, one group to assume the role of modern scientist researching the contributions made by western science to our knowledge of changing migration roots; and the other group to assume the role of traditional science practitioners researching the knowledge contributions made by traditional science. The groups can then brainstorm information sources and specific tasks, and begin the data collection process. As students complete their assignments, the teacher can ask each group to list the explanations and interpretations generated by their perspective, and present their findings to the class. In small groups, students could make comparisons, explore similarities and differences as well as advantages and disadvantages, and consider practical applications for combining the two.

Students can also analyze how both perspectives use observation and inquiry to obtain knowledge. Critical-thinking involves students' ability to detect bias in information obtained, to identify underlying assumptions, and in general, to develop a shared definition of the two perspectives. Although the two perspectives interpret the world differently, students should see that the two often overlap and can reinforce one another. Discussion should stress similarities rather than differences, and areas where traditional knowledge helps fill the gap where knowledge in western science is lacking, and vice versa. Teaching multicultural science education includes identifying local examples of traditional science, attempting to discover traditional terminological classification systems, and exploring practical possibilities for combining the traditional and western frameworks in science education.

Science Education in a Multicultural Setting

When teaching multicultural students, teachers could develop lessons around what students experience and talk about in their community. Teachers can allow for participation and a sense of how a common environment is viewed from both a traditional science perspective and a western science perspective, or a combination of perspectives. This will help alleviate alienation which is common to those who cannot participate fully in what has become the typical science classroom. When teaching students of long-resident oral cultures, or in a community of mixed ethnicity, the following considerations adapted from Snively (1995), must occur:

1. No textbook can comprise a viable science program for culturally different students. Textbooks should be reviewed with the purpose of removing all offensive and racially stereotyped content. A variety of materials and resources should be used.

2. Oral traditions must be respected and viewed by teachers as a distinctive intellectual tradition, not simply as myths and legends. The oral narratives and heritage of long-resident cultures should become part of the school science experience.

3. The similarities and differences, and the strengths and limitations of the different traditions should be articulated and explored during instruction.

4. We should adapt our use of written and spoken language to avoid disadvantage to those with language difficulties. We should pay attention to the language of science education, and provide more opportunities for students to use language to explore and develop understandings; the use of analogies, models and metaphors.

5. The history of colonization and how language has been used to legitimate economic and cultural imperialism should be acknowledged.

6. We should acknowledge that issues of history, morality, justice, equality, freedom and even spirituality are inseparable from the proper discussion of science and technology.

7. Instruction should compare traditional categories for plants, animals, habitats, systems and relationships with scientific analogies of the same phenomena.

8. Gather and discuss data to show that there are many interpretations of the same phenomena; e.g., different cultural notions of the concept of heat, snow, Phylum, life cycle.

9. Instruction should provide a high percentage of unstructured play activities and "discovery" and "inquiry" learning that provides for the intake of sensory experiences and experiential learning.

10. Field trips should be organized to local areas to study where traditional peoples used resources for harvesting and meeting daily needs: e.g., soap weed, medicinal herbs.

11. Instruction should identify local approaches for achieving sustainability, and remember that it is the aggregate of local problems worldwide that define a global problem.

12. References should be made to current events and to present day home and community, real life situations and relevant contemporary issues.

13. We should design curriculum materials and lessons that use exemplars from a variety of cultures and countries, so providing a 'multicultural view' of science and technology.

14. We should design activities that help students recognize the likelihood of continual change, conflict, ambiguity, and increasing interdependence.

15. Students should be given opportunities to identify and articulate their own ideas and beliefs with others in small group situations.

16. Teaching strategies should emphasize solving science and technology problems, environmental problems, resource management and sustainable societies problems. All children (Native, Inuit, Meti, Afro-American, East Indian, etc.) can help build a sustainable society. Acknowledging traditional science can empower oral culture children and others with traditional knowledge and wisdom. This will increase the meaningfulness of school and be consistent with traditional beliefs in working for the good of the whole group and community rather than the individuals. (Snively, p. 65-66)

The fact that students bring to the classroom ideas based on prior experience, and that children of different cultural backgrounds frequently interpret science concepts differently than the standard scientific view, suggests that teachers need to begin the exploration of multicultural science instruction with the prior knowledge that children bring to the classroom. Thus, pre-service and in-service teachers need workshops on how to probe for and incorporate the prior beliefs of ethnic minority children, and talk about the possibility of multiple perspectives and traditions in science.

A Five-step process for exploring multicultural science outlined, as described by Snively (1995), provides a general framework for exploring the two perspectives (western science and traditional science), while thinking about one concept or topic of interest.

Step 1: Choose a Science Concept or Topic of Interest

e.g., wilderness survival, migration roots, conservation, sustainability, medicine, geology

Step 2: Identify Personal Knowledge

- discuss the importance of respecting the beliefs of others
- identify personal ideas, beliefs, opinions
- articulate and compare their own beliefs with others in small groups
- brainstorm questions they have about the concept or topic

Step 3: Research the Various Perspectives

- research the western science perspective
- research the local traditional science perspective
- research the perspective of different traditional peoples
- organize/process the information
- identify similarities anddifferences of the two perspectives
- identify strengths and limitations of the two perspectives
- ensure that explanations for both perspectives are presented

Step 4: Reflect and Decide

- consider the consequences of each perspective
- consider the concept or issue from a synthesis of the two perspectives
- consider the consequences of a synthesis
- consider the possibility of multiple perspectives
- ensure that students compare their previous views with the two perspectives
- consensus building

Step 5: Evaluate

- evaluate the decision making process
- evaluate effects of personal (and/or group) actions
- evaluate possibilities in terms of futuristic considerations
- how did this process make me feel?

Such an approach can begin in large groups with one teacher. Once a topic is chosen for exploration, the class could be divided into small group for data collection and for small group discussions.

In addition to making science education more sensitive and appropriate to the needs of First Nations children, it is imperative that First Nations peoples' considerable contributions to science be elucidated for mainstream students (Bowers, 1993a, 1993b; Snively, 1995). The introduction of aboriginal examples adds interest and excitement to the science classroom. All students need to identify and debate the strengths and limitations of different approaches in order to explore how others experience the world, and to broaden their understanding of the nature of science. A critical approach to teaching science can be used to help confront and eliminate racism, ignoran e, stereotyping, prejudice and feelings of alienation. All students need to be encouraged to examine their own taken-for-granted assumptions and to distinguish between those that reflect perfectly natural and appropriate cultural preferences and those that are rooted in misinformation or an unwillingness to allow for the existence of alternative perspectives.

In multicultural classrooms it should be fairly easy for sensitive teachers to gather data and use resource persons of different cultural groups to explore the different attitudes and beliefs about the environment. Discussions of differences in the ways in which societies view plants and animals and develop resources, and the reasons why they do so, establishes a base for discussions of environment, appropriate technology, and sustainable societies. As well, science education must emphasize the relationships between sciences and technology and the culture, values and decision-making processes of the society within which we operate. As "outsiders" trying to make sense of a society continually being shaped and reshaped by science and technology, students need more from science instruction than an ever increasing quantity of scientific facts and concepts. Science education must help all students understand what science really is--what its powers are, what its limitations are, and more important what it can become. The focus should not be on getting children of ethnic minorities to *accept* the scientifically accepted notion of the concept, but on helping children of all cultures to *understand* western science concepts, explore the differences and similarities between their own beliefs and western science concepts, to explore combining the two approaches to knowlede, and be successful in school.

The Education of Pre-service Teachers

To develop a multicultural perspective, one must first recognize the need that exists for this perspective even in science education. Science professors and university administrators must acknowledge that it is a process that should be modeled by faculty and students as we move toward short- and long-term goals. Multicultural science education should be considered an essential part of every science methods course. This education includes an understanding of science processes and instruction, the contributions of different cultural groups in the sciences, and our growing understanding of the relationship between culture, language, and science.

Clearly, a number of barriers exist for the education of multi-cultural science teachers at both the elementary and secondary levels. Although barriers will vary from individual to individual, some are more common than others. The following are barriers identified by pre-service teachers:

- my class periods are too short and there's no time.
- I don't know enough.
- this is a new way of teaching for me.
- I don't have relevant materials and resources for teaching about traditional science.
- my colleages, parents, and/or principal aren't supportive.

It is worth pointing out that the list of personal concerns include barriers that teachers have control over. For example, teachers may feel that their lack of background in traditional knowledge is a significant barrier. They do, however, have control over what they can learn. They have the option to go forward and enter the learning process with the students. They can engage support from colleages and parents by informing them through letters and meetings of the findings of working TEK scientists, by describing government and court mandated co-management and sustainable development projects.

Pre-service programs can give teachers ideas, support, and resources for helping students learn more about multicultural science. Teachers will raise some of the following questions:

1. Why should we include multicultural science in our curricula?
2. How can we introduce our students to multicultural science without inviting a face-off or angering parents?
3. How can we locate information and help our students understand and address multicultural science issues effectively?
4. What skills do we and our students need to attend to multicultural science?
5. What things make it difficult to incorporate multicultural science in the classroom? How can we get around these barriers?

The authors have engaged pre-service teachers with questions and activities that allow them to examine the complexities that characterize the nature of science. For example, in groups of four or five pre-service teachers have addressed the following questions:

1. What is science? Write a shared defintion of one, two or three sentences.
2. Is traditional science real science? Defend your position.

Each group writes their definition on an overhead transparency and shares this with the class. The following shared definitions were developed by pre-service teachers:

- Science is a process of understanding the world which incorporates observation and interpretaion.
- Science is the study of living and non living things, and how they relate to each other.

- Science is the process of or intent to understand functions and relationships and their interconnectness.

After much debate and discussion, the great majority of students agree that traditional science is real science and ought to be included in the science curriculum. Such interactions add interest and excitement to science methods courses by challenge pre-service teachers to question taken for granted assumptions, think critically and reflectively, and develop a broader perspective when teaching children.

After one class, a student of East Indian background shared with us her excitement in acknowledging multi-sciences. "Are you saying that East Indian's had a science?" "Yes, we explained, "East Indians, like other long-resident traditional peoples had their own science and have made considerable contributions to scientific knowledge." A huge smile filled her face. She told us that her parents had been born in India, and she is a second generation Canadian. "Now I understand why my parents didn't want me to take science or environmental education as an area of concentration. They were afraid that I would loose my culture." She is currently enrolled in a Master's degree program with an emphasis in multicultural science education.

The acceptance of traditional science leads to a very different set of course proposals. The study of science would be framed by questions that relate to developing a broader perspective that is more culturally sensitive and more learner centered. Pre-service teachers might discuss the following: What are the origins and consequences of our practice of viewing western science as superior to other forms of knowing? Where did we get the idea that western science is the only "true" science? Where did we get the idea that humans have domination over the earth and all its living creatures? What are the consequences? Who were the thinkers and the historians who influenced our way of thinking? What are the limitations of western science (as well as traditional science)? What might be the benefits of acknowledging the contributions of traditional science and wisdom? What might be the benefits to mainstream children and to society? The point is not to establish that one form of science is more relevant than another, but to connect the study of the past to the central issues of our time.

The questions raised by preservice teachers (and teachers in workshops) provide the organizational structure for a teaching unit, which explains the importance for developing a rationale, teaching strategies, and suggestions for overcoming barriers. Also, faculty and teachers can work towards creating a more relevant science education for all children. The following considerations and experiences for teachers might occur:

1. take courses in native education and multi-cultural education;
2. attend seminars, debates and discussions;
3. arrange for special speakers of various cultures;
4. develop lesson plans and teaching units around science themes of interest to children of specific cultural origin;
5. develop lesson plans that address the nature of science, traditional science, and culture;
6. develop questioning strategies that encourage active listening, the identification of personal beliefs about science concepts, and the relationship of culture and science traditions;
7. observe children in multicultural classrooms;
8. interview teachers of multicultural students.

If teachers can learn how the purposes of scientific activity have varied in different cultures and historical times, and how different cultures have developed sciences to meet their needs, then they can work towards developing innovative and sensitive resource materials and teaching strategies that encourage students to broaden their understanding of the nature of science, and of the relationship between science and culture. Without the multicultural dimension, what we call "science eduation" is insufficient for our contemporary and future needs. Just as the theory of kinetic energy was a great achievement for modern science, the genius of traditional science is its deep appreciation and respect for nature, and the spirit in living creatures. The study of traditional science is a marvelous way for children (as well as adults) to talk about nature, environment-human communities relationships, and global education. Teacher education programs have the responsibility to deal respectfully with the knowledge and wisdom of long-resident indigenous peoples. This may be difficult, but these responsibilities cannot be ignored.

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