Experiential Learning for Pre-Service Science and Mathematics Teachers:

Applications to Secondary Classrooms

The SOUTHEAST EISENHOWER REGIONAL CONSORTIUM for MATHEMATICS and SCIENCE EDUCATION at SERVE

Experiential Learning for Pre-Service Science and Mathematics Teachers:

Applications to Secondary Classrooms

Co-Editors

Penny J. Gilmer, Lori Livingston Hahn, and M. Randall Spaid

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Associated with the School of Education
University of North Carolina at Greensboro

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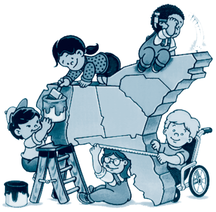

The Southeast Eisenhower Regional Consortium for Mathematics and Science Education @ SERVE

The Southeast Eisenhower Regional Consortium for Mathematics and Science Education @ SERVE is one of ten regional consortia created by Congress to improve mathematics and science education throughout the nation. The Consortium has three objectives:

- Coordinating mathematics and science resources
- Disseminating exemplary mathematics and science educational instructional materials
- Providing technical assistance for the implementation of teaching methods and assessment tools for use by elementary and secondary school students, staff, and administrators

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We offer the following services to promote our objectives:

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For more information about the Consortium, contact the main office:

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SERVE, directed by Dr. John R. Sanders, is an education organization with the mission to promote and support the continuous improvement of educational opportunities for all learners in the Southeast. The organization's commitment to continuous improvement is manifest in an applied research-to-practice model that drives all of its work. Building on theory and craft knowledge, SERVE staff members develop tools and processes designed to assist practitioners and policymakers with their work, ultimately, to raise the level of student achievement in the region. Evaluation of the impact of these activities combined with input from affected stakeholders expands SERVE's knowledge base and informs future research.

This vigorous and practical approach to research and development is supported by an experienced staff strategically located throughout the region. This staff is highly skilled in providing needs-assessment services, conducting applied research in schools, and developing processes, products, and programs that inform educators and increase student achievement. In the last three years, in addition to its basic research and development work with over 170 southeastern schools, SERVE staff provided technical assistance and training to more than 18,000 teachers and administrators across the region.

SERVE is governed by a board of directors that includes the governors, chief state school officers, educators, legislators, and private sector leaders from Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina.

At the core of SERVE's business is the operation of the Regional Educational Laboratory. Funded by the U.S. Department of Education's Office of Educational Research and Improvement, the Regional Educational Laboratory for the Southeast is one of ten programs providing research-based information and services to all 50 states and territories. These Laboratories form a nationwide education knowledge network, building a bank of information and resources shared nationally and disseminated regionally to improve student achievement locally. SERVE's National Leadership Area, Expanded Learning Opportunities, focuses on improving student outcomes through the use of exemplary pre-K and extended-day programs.

In addition to the Lab, SERVE operates the Southeast Eisenhower Regional Consortium for Mathematics and Science Education and the SouthEast Initiatives Regional Technology in Education Consortium (SEIR◆TEC). SERVE also administers a subcontract for the Region IV Comprehensive Center and has additional funding from the Department to provide services in migrant education and to operate the National Center for Homeless Education.

Together, these various elements of SERVE's portfolio provide resources, services, and products for responding to regional and national needs. Program areas include Assessment, Accountability, and Standards; Children, Families, and Communities; Education Leadership; Education Policy; Improvement of Science and Mathematics Education; School Development and Reform; and Technology in Learning.

In addition to the program areas, the SERVE Evaluation Unit supports the evaluation activities of the major grants and contracts and provides contracted evaluation services to state and local education agencies in the region. The Technology Support Group provides SERVE staff and their constituents with IT support, technical assistance, and software applications. Through its Publications Unit, SERVE publishes a variety of studies, training materials, policy briefs, and program products. Among the many products developed at SERVE, two receiving national recognition include *Achieving Your Vision of Professional Development*, honored by the National Staff Development Council, and *Study Guide for Classroom Assessment: Linking Instruction and Assessment*, honored by Division H of AERA. Through its programmatic, technology, evaluation, and publishing activities, SERVE provides contracted staff development and technical assistance in specialized areas to assist education agencies in achieving their school improvement goals.

SERVE's main office is at the University of North Carolina at Greensboro, with major staff groups located in Tallahassee, Florida, and Atlanta, Georgia, as well as satellite offices in Bonita Springs, Florida; Durham, North Carolina; and Shelby, Mississippi. Unique among the ten Regional Educational Laboratories, SERVE employs a full-time policy analyst to assist the chief state school officer at the state education agencies in each of the states in the SERVE region. These analysts act as SERVE's primary liaisons to the state departments of education, providing research-based policy services to state-level education policymakers and informing SERVE about key state education issues and legislation.

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Two pre-service teachers at
Oak Ridge National Laboratory

FOREWORD

Bringing Science Inquiry into Secondary Classrooms

Francena D. Cummings

> *Why do we educate teachers, both new teachers who want to come into the profession and those that are already experienced, in ways that we absolutely know don't work and are antithetical to everything that we talk about when we point out the ways that kids ought to learn?*
>
> —Mark St. John, 1991

Dr. Francena D. Cummings, Director of the Southeast Eisenhower Regional Consortium for Mathematics and Science Education @ SERVE

With the release of the National Science Education Standards, conversations about science teaching and learning have focused on students doing science rather than learning about it through teachers telling and showing or directing students to read textbooks about science. Teachers are expected to play key roles in facilitating learning by designing and/or selecting tasks that enable students to engage in inquiry-based activities that encourage them to explore the natural or material world around them. Students are then expected to construct knowledge from these investigative experiences. The ultimate goal is to help students learn scientific concepts and develop scientific thinking skills.

In the National Science Education Standards, the concept of inquiry is widely advocated, but the extent to which it is integral in science classrooms is marginal because the majority of teachers have not been prepared to teach in this manner. Inquiry-based teaching requires the teacher to serve as a facilitator or coach in the classroom. In this role, the teacher first chooses rich tasks by identifying and defining a domain of study and then facilitating the environment, choosing appropriate materials, and providing guidelines for completing tasks. Because students are expected to be self-directed, the teacher must play a key role in stimulating student thinking and actions through the use of process science skills. If science teachers are expected to make changes in how they teach, they must experience those changes.

Why do we educate teachers, both new teachers who want to come into the profession and those that are already experienced, in ways that we absolutely know don't work and are antithetical to everything that we talk about when we point out the ways that kids ought to learn (St. John, 1991)? This question posed by St. John is on target. If we want teachers to engage in inquiry-based teaching, they must have opportunities to become involved in those kinds of learning experiences. These learning experiences must occur at all levels, especially at the higher education level. At the higher education level, coursework must focus on conceptual understanding of the discipline as well as specific pedagogical content knowledge.

In this monograph, the writers offer the field a significant view of what happens when pre-service teachers, practicing teachers, and practicing scientists work together as co-learners. These co-learning experiences create professional learning communities that stimulate changes and growth for all of the learners.

Said one of the teachers, "I remembered it because I did it." For some of the practicing teachers, this was the first time they experienced the culture of science. Working in the laboratories or other settings offered first-hand experience in testing hypotheses in authentic work settings. Based on these experiences, they began to reflect on how their students might feel in settings where they learned science by doing science.

The theoretical framework that guided the CO-LEARNERS is constructivism, which emphasizes that knowledge is acquired through experience. In Chapter 7, Lori Hahn elaborates on this principle by emphasizing that "science knowledge is not something that teachers possess and transfer to students through lecture, the reading of textbooks, and paper and pencil activities." Instead, the emphasis is on students making sense of their science experiences.

The stories that the collaborators tell offer some understanding of the complexities of doing science in context. Most of the teachers have to accept the notion that they start off not knowing the answer. Generating problems and/or questions becomes the norm as they become acclimated to the culture of science. Through collecting and analyzing data, they learn to value the so often memorized scientific method. The real focus was helping teachers distinguish the difference between the culture of classroom science and the culture of science.

Some of the most convincing stories are those that offer glimpses of practicing teachers sharing their understandings with their students. Lidia Lanns offers some realities of class size and norm breaking. While she left the CO-LEARNERS program willing to take some of the activities to the classroom, she had to negotiate the setting and decide what was practical. Yet, with all of the struggles, she proclaims the following:

> *The CO-LEARNERS Program was an experience I will not forget. Before going, I never would have considered donning a pair of waders and stepping into muddy water....I did it and I would do it again because if students see teachers excited about going in and not caring about getting dirty, I think they will get excited about doing it themselves. Neither textbook nor traditional laboratory activities can compare to experiencing science as it occurs outdoors. (Chapter 4)*

The teachers in this monograph communicated clearly about several issues. They found their learning/working experiences valuable through a heightened awareness of the work environment, and they recognized a unique set of skills and qualities that are not content-related (i.e., communication, teamwork, community collaboration, and curiosity). Most of all, they recognized that relevancy is just not a student thing. Leslie Magalis offers a succinct view on this issue.

> *I feel that I have worked alongside real scientists and conducted real science research. I believe that all scientists are driven by curiosity; the way they satisfy this curiosity is through using the scientific method....I want them [my students] to experience "real science", too. (Chapter 5)*

If connecting content to real-world settings is important, teachers must find ways to connect to the community. Many of the participants made that connection and understand that community partners will be an essential concept in science education in the new millennium. There are similar implications for the higher education community. One important implication is teaching students how to research community resources.

The Southeast Eisenhower Regional Consortium for Mathematics and Science Education @ SERVE applauds the CO-LEARNERS Program because it advocates new approaches to providing basic educational practice at several levels. When universities embrace this kind of learning experience for pre-service teachers, they begin a significant step in preparing teachers who understand the value of experiential learning—experiencing the culture of science. Moreover, it points out the need to make science relevant. Offering practicing teachers opportunities to engage in the culture of science provides for diversity in professional development. Practicing scientists get to provide contextual scientific endeavors, but they also learn from their teacher partners. Janet McCauley, one of the scientists, said it best.

> *All the while I was teaching the teachers about science, they taught me about teaching. They have found practical ways to bring this constructivist philosophy into the classroom. Listening to their stories about methods of teaching and sharing science with kids instead of feeding it to them inspired me to look into teaching as a new career path. (Chapter 10)*

Congratulations to the co-learners featured in this monograph. The Southeast Eisenhower Regional Consortium for Mathematics and Science Education @ SERVE commends you for your desire to learn with and from each other and for your willingness to share with others. Achieving a vision for new teaching and learning in science education will only occur with "steady work" at crafting new strategies for change. Your work will certainly make a contribution to the field of science education.

Reference

St. John, M. (1991). *Science education for the 1990s: Strategies for change*. Inverness, CA: Inverness Research Associates.

The three co-editors of this monograph are (l to r) M. Randall Spaid, Lori Hahn, and Penny J. Gilmer. Randy and Lori are doctoral candidates in Science Education at Florida State University (FSU). Penny is Professor of Chemistry and Biochemistry at FSU.

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Middle-school students are working together in their collaborative group in Lidia Lanns' classroom.

Chapter 1

Impact of Scientific Research Experiences: Pre-Service Teachers' Ideas on How They Think About and Teach Science

Penny J. Gilmer

Abstract

This chapter introduces the monograph entitled *Experiential Learning for Pre-Service Science and Mathematics Teachers: Applications to Secondary Classrooms* and introduces the goals of the CO-LEARNERS program. Pre-service teachers worked with a practicing science teacher and a scientist in a research laboratory for one or two summers. The teachers have conducted scientific research, with a general focus on environmental science, using methodologies from chemistry, biology, microbiology, earth science, and computer science. It examines what they learned through the process of doing science first-hand and how they are thinking of teaching and learning science.

This chapter focuses on how such experiences have impacted how future high-school science teachers think about science and how they plan to teach science. Through qualitative data gathered during and following the research experience, I have examined patterns in what the pre-service teachers said, learned, and are currently doing. Lori Livingston Hahn, in Chapter 7, focuses on the pre-service teachers planning to teach in middle schools.

This monograph is the fifth in a series (Table I) published by SERVE with Florida State University (FSU). It includes chapters written by FSU teachers about their experiences conducting action research and/or scientific research. All five monographs are available for free in PDF format from SERVE (2001). The monographs were all edited by former or present faculty and graduate students from FSU.

Table I

Monographs published by SERVE[1] with Florida State University

Monograph	Title	Year	Editors
1	Action Research: Perspectives from Teachers' Classrooms	1995	Samuel A. Spiegel, Angelo Collins, & James Lappert
2	Science in the Elementary School Classroom: Portraits of Action Research	1997	Jane McDonald & Penny J. Gilmer
3	Meaningful Science: Teachers Doing Inquiry + Teaching Science	1999	Terrie L. Kielborn & Penny J. Gilmer
4	Language, Discourse, & Learning in Science: Improving Professional Practice through Action Research	2000	Aldrin E. Sweeney & Kenneth Tobin
5	Experiential Learning for Pre-Service Science and Mathematics Teachers: Applications to Secondary Classrooms	2002	Penny J. Gilmer, Lori L. Hahn, & M. Randall Spaid

[1] Available online: **http://www.serve.org**

The SERVE monograph with a similar perspective to this current one is the third in the series, *Meaningful Science: Teachers Doing Inquiry + Teaching Science* (Kielborn & Gilmer, 1999). Practicing teachers who were also graduate students at FSU wrote these chapters. They reported how they experienced the process of doing scientific research, of asking research questions, and of collecting data. They shared what it felt like to work side-by-side with scientists as they interpreted their data. They learned the importance of teamwork. Six of the teachers shared how they brought these experiences into their own science classrooms (Bosseler, 1999; Brock, 1999; Foley, 1999; Greenspan, 1999; Ballas and Kielborn, 1999a). Kielborn (1999) highlights the features of the program that make it work and indicates ways that teachers can find similar experiences for themselves.

Need for Teachers to Experience Inquiry

There is a growing consensus that it is critical for teachers who teach science to experience the process of science and scientific inquiry first-hand. The National Research Council (1989) pressed for the importance of all students to learn through inquiry. It stated, "Universities should develop programs that integrate all interested local pre-college science teachers into the various science communities of the university" (p. 75). Although they do not mention getting the pre-service teacher involved in scientific research, it makes sense to do so.

The focus for this monograph is hearing the voices of pre-service teachers who have chosen to work alongside scientists.

The *Benchmarks for Science Literacy* by the American Association for the Advancement of Science (AAAS, 1993) and the *National Science Education Standards* by the National Research Council (NRC, 1996) recommend that science teachers need to teach using inquiry. Within professional development programs, Loucks-Horsley, Hewson, Love, & Stiles (1998) also encourage teachers to become immersed in the world of scientists and mathematicians. In order for teachers to be able to teach inquiry, however, they need to experience it first-hand.

I report in this chapter that pre-service science teachers' inquiry experiences influence how they think of science and how they teach science in their own classrooms. Ongoing research will extend this project as each of these pre-service teachers graduates from undergraduate programs (and some from graduate school) and has more experience teaching. So far, of the eight pre-service teachers, four are currently teaching, one is in graduate school, and three are still pre-service.

Another example of a program for enabling practicing teachers to experience scientific research is a national effort called SWEPT (2001) directed by the Triangle Coalition for Science and Technology Education. These practicing teachers have, in general, taught for many years. There has been time to do follow-up case studies on some of those teachers.

The pre-service teachers had opportunities to ask their own research questions, design their own experiments, and analyze the data from varying perspectives.

However, the focus for this monograph is hearing the voices of pre-service teachers (i.e., pre-service refers to undergraduates who plan to become teachers), who have chosen to work alongside scientists. All the pre-service teachers were from Florida State University or the University of West Florida, and they planned to be middle- or high-school teachers. These pre-service teachers experienced the scientific process first-hand. The intent, of course, was to share that understanding and learning with their own students once they have their own classrooms.

The way that future teachers generally learn science is in traditional laboratory courses, in which they conduct experiments with a known answer. These future teachers find, though, when they conduct actual scientific research, no one knows the answers ahead of time. The teachers learn from analyzing their own data and from interpreting data from other sources from which they must infer an answer. Their ideas about what is happening may change in light of new data.

Lori Livingston Hahn and I decided to expand the idea of having just practicing teachers conducting scientific research (Kielborn & Gilmer, 1999) to include pre-service teachers in the research experience. Lori is a practicing teacher who did get to experience scientific research as part of her master's degree program (Hahn, 1999), and she thought it critical that pre-service teachers experience research, too, while they are still undergraduates. Other groups of researchers have started a multi-week inquiry experiment for groups of pre-service teachers (Grant & Vatnick, 1998; Weld & French, 2001; Melear, Goodlaxson, Warne, & Hickok, 2000).

Melear *et al.* (2000), for instance, have involved pre-service teachers in inquiry through a semester-long, open-ended laboratory. In this case, a group of seven students explored the spore of a particular fern for an entire semester. The pre-service teachers had opportunities to ask their own research questions, design their own experiments, and analyze the data from varying perspectives. Not surprisingly, many of their students were initially at a loss as to how to conduct an open-ended scientific experiment. However, with minimal direction from graduate assistants, all eventually learned the process of science, with some learning more enthusiastically. Scientists from the College of Arts & Sciences worked closely with the faculty in the College of Education to provide an inquiry-based program as part of the pre-service teacher education program.

The National Science Foundation (NSF) supports teacher preparation programs within the Collaboratives for Excellence in Teacher Preparation (NSF Collaboratives, 2001a). Some of these programs support pre-service teachers conducting scientific research, such as the one in Maryland (Maryland Teachers' Summer Research Program, 2001) and ours in Florida (Florida Collaborative for Excellence in Teacher Preparation, 2001).

The CO-LEARNERS Program

Lori Livingston Hahn and I developed a program in which we paired a pre-service teacher and a practicing teacher with a practicing scientist (Hahn & Gilmer, 2000). We named this program CO-LEARNERS because all participants learn from one another. The CO–LEARNERS Program is an acronym for Collaborative Opportunities–Learning Experientially And Research uNiting Educators and Researchers of Science. The pre-service teachers construct their understandings from their prior experiences and their new learning that is taking place within the research environment. Lori and I are co-learners as well, modeling what it is to be a learner in the inquiry process.

The CO-LEARNERS Program pairs a pre-service teacher and a practicing teacher with a practicing scientist. We named this program CO-LEARNERS because all participants learn from one another.

There are three locations where Florida teachers were part of the CO-LEARNERS Program. The teachers who planned to teach high school were at FSU in Tallahassee, and the middle-school teachers were at the University of West Florida in Pensacola. The third location in Tennessee involved two pre-service, high-school teachers, one in the summer of 2000 and one in the summer of 2001, at the Oak Ridge National Laboratory (ORNL). Oak Ridge is the site where the U.S. government during World War II learned how to separate uranium isotopes and first prepared the fission nuclear bombs, whose use helped end the war.

The two Florida teachers, Rebecca Brockwell and Angel Rogers, went to ORNL in the Pre-service Teachers Program sponsored jointly by the NSF-funded Collaboratives for Excellence in Teacher Preparation (CETP) and the U.S. Department of Energy (NSF, 2001b; DOE, 2001). ORNL is the Department of Energy facility where CETP students from Florida, Louisiana, and Virginia have an opportunity in the summer to learn to conduct research in science, mathematics, and/or technology. The ORNL summer program also had one practicing teacher working closely with three pre-service teachers from three states. One of the two ORNL teachers from Florida, Rebecca Brockwell, an FSU pre-service teacher, has a chapter in this monograph.

I visited most of the teachers during their research in the laboratories or field experiences and have visited some of their classrooms once the teachers began teaching. During the summer of research and/or afterwards, I interviewed all of the pre-service teachers who were planning to teach in high school. I transcribed their words to help me construct how the teachers learned the process, nature, and culture of science and how they were starting to bring those ideas into the classroom. This type of science education research is qualitative in nature (Erickson, 1998).

The following are some of the questions I asked myself:

- What are the future teachers' struggles as they engage in the scientific inquiry process?
- What facilitates (and what inhibits) their learning of science?
- What enables (and what inhibits) the future teachers to bring similar experiences to their own students?
- How do their students respond to scientific inquiry?
- How does technology influence their learning?
- How do the collaborative aspects of the learning influence how future teachers think about science and learning?

In this monograph, there are two chapters that are evaluative in nature. One is this chapter in which I focus on the pre-service teachers who planned to become high-school teachers. In Chapter 7, Lori Livingston Hahn evaluates the CO-LEARNERS Program for the teachers planning to teach middle school. Chapters 2 through 6 and 8 through 10 are first-hand accounts written by these prospective middle- and high-school teachers in their quest to learn science. They describe the struggles and joys they experienced in scientific research, and how they are learning to think of science and of teaching science differently. Co-editor M. Randall Spaid worked with some of the teachers to complete their narratives.

Florida Collaborative for Excellence in Teacher Preparation (FCETP) Logo

Of the participants in the CO-LEARNERS Program, Ron Wark and Leslie Magalis are just starting their second year of teaching, and they share not only their experiences in scientific research, but also how they are bringing science to their own middle- and high-school students. Lidia Lanns has taught for one and a half years in middle school in Miami. After Gregory Preston's teaching internship and four months of teaching in his own classroom in Miami, he decided to return to graduate school to pursue a degree in information technology. Christy Tarter recently graduated and is just finishing her first year of teaching at a middle school. Sandra Davis is finishing her final year of pre-service and will be doing her teaching internship during this coming academic year. Rebecca Brockwell just graduated as a certified science teacher.

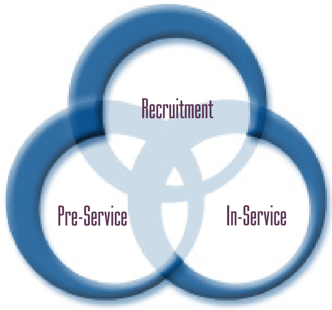
Chapter 10, by Jan Macauley, is unusual because she was one of our participating scientists in the CO-LEARNERS Program in Pensacola for two summers. After her second summer with CO-LEARNERS, she decided to go back to the university and become certified to teach science. Jan writes about realizing that she wants to work with people instead of test tubes. She recognizes that she feels more connected to the science when she is teaching the pre-service teachers in the CO-LEARNERS Program than when she is doing her technical work.

However, when I wrote her that her chapter has been set by the copy editor and asked if she wanted to see it again, she told me that she decided to stay in her job as a scientist. Jan decided to keep her own chapter as she originally wrote it because that is how she felt at the time.

Jan reflects on her first education class:

> *After my first class in curriculum development, plus some changes at work, I have again rethought my career path. There are some aspects of teaching that are quite daunting, and my job stability and responsibilities have increased at*

> *UWF. I now have a faculty post. I have once again shelved the idea of teaching, but not forgotten it. I realize that my brief introduction to teacher education doesn't give me much insight into the reality of the classroom. I enjoyed the lesson planning, but was surprised by the emphasis given to "multiculturalism". Teaching is a special calling, and I don't know yet if it is mine.*



FCETP symbol for bringing together the three foci of the grant

In my view, Jan experienced the large change in culture between science and education. Jan is very competent as a scientist, and I am sure that her supervisors want her to stay on her job, as evidenced by her being given more responsibility and now being in a university faculty line. I am sure that the difference in salary of a faculty post in science versus that of a beginning middle school teacher would be daunting.

This difference in salary coupled with the dramatic change in culture would be inhibiting. Therefore, the negatives overwhelm the positives for the K-12 level of teaching. Perhaps she will be able to bring her passion for science and interest in education to the postsecondary science classroom with science students and pre-service teachers.

Florida Collaborative for Excellence in Teacher Preparation

The CO-LEARNERS Program was an integral part of the FCETP (2001). All pre-service teachers were eligible to be FCETP Scholars and received scholarships through our NSF grant. The National Science Foundation currently has funded or is still funding 20 "system-wide" and 12 "institutional focus" projects in the CETP program (NSF Collaboratives, 2001a) to increase the number and quality of future teachers in mathematics and science throughout the United States.

The focus of our grant is to improve teacher preparation at the middle- and high-school levels in science and mathematics. In Florida, we have a total of 11 institutions of higher learning involved in the FCETP (2001). Our higher education institutions include three community colleges, one four-year, and seven full universities, working together with neighboring middle and high schools associated with each higher education institution. We represent our diverse culture in Florida with two historically black institutions (our lead institution, Florida A&M University and Bethune-Cookman College) and two primarily Hispanic institutions (Florida International University and Miami-Dade Community College). We have three components in the program: recruitment, pre-service, and in-service. Our motto is to "expand the sphere of learning."

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Most of the science courses that these prospective teachers have had were lecture courses or traditional laboratory courses. Therefore, providing an experience to conduct "real science" has enabled the pre-service teachers to see science as science is actually conducted. We are field testing this type of non-traditional laboratory to see how the teachers enjoy it, what they learn, and how they implement what they learn in their classrooms.

Lens for Viewing the Teachers

The reader may ask how I view these experiences and how I frame what I see and hear. My original education was as a Ph.D. (Doctor of Philosophy) in Biochemistry (University of California, Berkeley). My undergraduate degree (Bachelor of Arts, BA) was in Chemistry from Douglass College, and my master's degree was in Organic Chemistry (Bryn Mawr College). I have been a Professor of Chemistry and Biochemistry at FSU for 25 years. Since I started graduate school, I have practiced science and utilized quantitative research for studying molecules and cells for more than three decades. My research in biochemistry is cell-surface mediated reactions with a focus on carbohydrate chemistry of the cell surface and how that can modulate immune recognition of tumor cells.

Altha Manning, Director of the Florida Collaborative for Excellence in Teacher Preparation (FCETP), planning the CO-LEARNERS program with Dr. Penny J. Gilmer, co-Principal Investigator of the FCETP and Professor of Chemistry and Biochemistry at Florida State University

I am also one of three co-principal investigators of the FCETP program, and my responsibility is the pre-service component to our grant. I have supervised the entire CO-LEARNERS Program at FSU and UWF and worked closely with the high-school teachers who are involved in the project at the Tallahassee and Tennessee sites. I have met with the scientists and teachers at various research sites and interviewed some of the future and practicing teachers involved in this project. I am Lori Livingston Hahn's major professor in her graduate program in science education at FSU and have supervised her to help expand the sphere of learning of science through research.

In the last decade, I have learned the value of science education research. In particular, I have learned to appreciate the value of research in science teaching, especially using a qualitative methodology. Qualitative research methods include use of questionnaires with free response questions, case studies (of individual persons or small groups of people), and transcribed interviews. I utilize fourth-generation evaluation (Guba & Lincoln, 1989), utilizing their 12-step methodology for conducting qualitative research and evaluation.

The theoretical lens that we use to view what we observe influences how we see it and how we interpret what we see. This is true in science as well as in life, in general (Kuhn, 1970; Glasersfeld, 1989). Therefore, because my experiences include both being a scientist and a science educator, I view people and events in both ways simultaneously. To use a chemical metaphor, for me it is like a resonance hybrid, neither one side nor the other, but a view with special properties, some composite of both. I have chosen a theoretical lens for viewing the pre-service teachers while learning science through inquiry called social constructivism (Tobin & Tippins, 1993; Taylor, Gilmer & Tobin, 2002b). Noddings has written about constructi-vism in a powerful way. She says

> *Constructivism may be characterized as both a cognitive position and a methodological perspective. As a methodological perspective in the social sciences, constructivism assumes that human beings are knowing subjects, that human behavior is mainly purposive, and that present-day human organisms have a highly developed capacity for organizing knowledge. These assumptions suggest methods—ethnography, clinical interviews, overt thinking, and the like—specially designed to study complex semi-autonomous systems.*
>
> *As a cognitive position, constructivism holds that all knowledge is constructed and that the instruments of construction include cognitive structures that are either innate or are themselves products of development construction. The latter interpretation is more characteristic of constructivism as a cognitive position, and it is the one held by most constructivists in mathematics education. (p. 7)*

I think that most science educators who are constructivists would agree with Noddings. "People make sense of their understandings of the world based on their prior experiences" (p. 13, Gilmer, 1999). The word *constructivism* means a theory of how people learn (Glasersfeld, 1989) or "knowing-in-action (i.e., a theory of knowing embodied in our actions)" (Taylor, Gilmer, & Tobin, 2002a). A basic part of this theory is that your prior experiences influence what you choose to emphasize in what you observe and how you make meaning from those events.

The social part of social constructivism comes in because one of the powerful ways we learn is by having social interactions or discourse with each other, talking out what we know and do not know, organizing our ideas, asking questions, and clarifying for each other. Our entire sociocultural experience influences how we construct meaning in the world. Lemke (2001) states that we tend to "ignor[e] the sociocultural reality that students' beliefs, attitudes, values, and personal identities—all of which are crucial to their achievement in science learning—are formed along trajectories that pass only briefly through our classes" (p. 305). However, I do attend to the co-learners' "beliefs, attitudes, values, and personal identities", since I have chosen the theoretical lens of social constructivism. Social constructivism helps us think about the relationship between teaching and learning and what happens between teachers and students when we learn. It is an active and social process. We try to make meanings as we have conversations. When these conversations are about science, we engage in the discourse of science.

In the last decade, I have learned the value of science education research. In particular, I have learned to appreciate the value of research in science teaching, especially using a qualitative methodology.

However, teachers at the college level and at the high-school level generally utilize teacher-centered lectures. This is utilizing the "transmission metaphor of teaching as delivery of disciplinary knowledge...and learning as reception of knowledge" (Taylor, Gilmer, & Tobin, 2002a). While some students may engage as active learners while listening to someone else profess science content, many others are only passive learners who promptly forget. For the passive learners, it is often "in one ear and out the other." Social constructivism would say that most people forget such content or do not build deep understandings of science content because, through lecture, they are not encouraged to connect to their prior learning or to utilize the discourse of science.

> *Social constructivism promotes the joint metaphors of* **knowing as constructing** *(contingent and viable understandings) and* **knowing as participating** *(actively and collaboratively) in a specific discourse community (Taylor, Gilmer, & Tobin, 2002a).*

A critical component of social constructivism is getting students to participate actively and encouraging the students to use the discourse of the science, often in collaborative groups (Bruffee, 1995). Science research groups generally do work collaboratively. As one person in the group learns something, it helps someone else in the group use that knowledge to learn something else within a similar domain. We build a community of learners, constructing knowledge together and advancing in our understanding beyond what individuals on their own could do. The knowledge is not necessarily true, but it is our best construction at that point in time. As we learn more, we may reconstruct and develop new understandings.

Looking at the High-School Pre-Service Teachers

Therefore, with social constructivism as my theoretical lens, I have researched the four co-learners who did their scientific research in Tallahassee (Lidia Lanns, Gregory Preston, Leslie Magalis, and Sandra Davis) and Rebecca Brockwell who went to ORNL for the Pre-Service Student Teacher Training Fellowship Program. I will focus on these five teachers, but I will also introduce the three other Pensacola-based teachers (Ron Wark, Christy Tarter, and Jan Macauley).

I choose a qualitative methodology since it flows naturally from a social constructivist inquiry. I do this by sharing what I have written with the co-learners, working toward a joint consensus, utilizing what is called a "hermeneutic dialectic circle" (Guba & Lincoln, 1989). In this circle, one recycles the ideas, enabling others to hear what is said (or written). I may have missed some point or misinterpreted some occurrence. I might have constructions that the pre-service teachers had not formally considered yet. Therefore, as we communicate socially, we influence one another's constructions. There is not always consensus, but one works towards consensus. Negotiation with the participants in the CO-LEARNERS Program continually shapes and tests my ideas (Guba & Lincoln, 1989).

It is through this lens of social constructivism that I have encouraged the pre-service teachers to use the language of science. The pre-service teachers are engaged in discourse with the scientists and with each other at weekly group meetings, many of which I organized and in which I participated. We asked questions of each other and thought about the analysis of the scientific data. I audiotaped those meetings, transcribed them, and analyzed them using a qualitative software program called QSR NUD*IST. I looked for patterns in what the co-learners said in group meetings, interviews, and PowerPoint presentations. I have sorted the ideas into data trees, with branches and sub-branches, to help me organize what each pre-service teacher has said or written.

Research Topics and Research Mentors

All of the pre-service teachers chose environmental research, in part, because they wanted a topic that not only interested them but also would interest their students. Interestingly, all the practicing teachers in our earlier monograph also chose environmental research (Kielborn & Gilmer, 1999).

Social constructivism helps us think about the relationship between teaching and learning and what happens between teachers and students when we learn. It is an active and social process.

Some of the teachers worked on more than one project, so their names may be listed more than once. The research experiences described in this monograph include the following diverse topics:

- Diesel fuels for greater efficiency of automobiles (Rebecca Brockwell)
- Pattern of river sediments (Gregory Preston)
- Biological indicators of health of river systems (Lidia Lanns, Gregory Preston, Leslie Magalis)
- Fecal contamination of waterways (Ron Wark and Jan Macauley)
- Culturing grasses for reintroduction into bay bottoms (Christy Tarter)
- Rapid detection of pesticides in agricultural products (Sandra Davis)
- Manatee survival (Leslie Magalis)
- Estrogen-like and androgen-like pollutants in waterways (Leslie Magalis)
- Fluoridation of drinking water (Christy Tarter)

Our pre-service teachers work with scientists, who volunteer their time at a variety of sites, including state of Florida laboratories, academic laboratories, and one national laboratory. We recognize and appreciate the participation of the following scientists and the research institutions in which the research took place:

- Thomas Frick, Russell Frydenborg, Kelly Schratwieser at the Florida Department of Environmental Protection (DEP in Tallahassee)
- Taylor "Chips" Kirschenfeld and Erick Harter at the Florida DEP (in Pensacola)
- Jason Stepp and Michael Page at the Florida Department of Agriculture and Consumer Services
- Jim Ladner and Ron Hoenstine at the Florida Geological Survey (part of DEP)
- Jan Macauley and Joe Lepo at the Center for Environmental Diagnostics and Bioremediation, University of West Florida, Wetlands Research Laboratory (UWF)
- Edward Orlando, University of Florida (UF)
- Janet Hopson and David Greene, Oak Ridge National Laboratory (ORNL)

We also appreciate the following practicing teachers who worked with our pre-service teachers and scientists in the research experience:

- Paige Bowron and Sandra Porras worked with Christy Tarter
- David Staton worked with Rebecca Brockwell and Angel Rogers
- Mary Hartsfield worked with Gregory Preston
- Sherri Hood worked with Lidia Lanns
- Margo King worked with Ron Wark and Janet Macauley
- G.S. Rahi worked with Sandra Davis and mentored Leslie Magalis
- Troy Brown worked with Marcus Simpson
- Richard McHenry worked with Erika Reddick
- Jane McDonald was the coordinator of the 1999 CO-LEARNERS Program in Tallahassee; she mentored Lidia Lanns, Gregory Preston, and Erika Reddick

Science research groups generally do work collaboratively. As one person in the group learns something, it helps someone else in the group use that knowledge to learn something else within a similar domain. We build a community of learners.

About the Pre-Service Middle-School Teachers in Pensacola

Chapter 7 introduces the chapters written by middle-school teachers and focuses on the Pensacola-based program at the University of West Florida. The author of this chapter, Lori Livingston Hahn, studied this group of teachers more intensely because she lives in Pensacola, and she ran the CO-LEARNERS Program at that site, but she also refers to Lidia and Gregory, since she interviewed them as well.

Two of the middle-school teachers, Ron Wark and Christy Tarter, each have a chapter. Christy worked in the CO-LEARNERS Program for two consecutive summers in 1999 and 2000, while Ron participated only in the summer of 1999.

Christy made a commitment to be involved in the entire FCETP program and attended two of the annual FCETP symposia with attendees from all over the state of Florida. Christy contributed to a presentation made by Lori in 2000 and gave a presentation by herself on her experience in the CO-LEARNERS Program at our FCETP Third Annual Symposium in 2001. She is certified to teach science and mathematics and has just started her first year of teaching in a middle school.

Ron, who is retired military from Pensacola, returned to the university to earn a degree so he could teach social studies and mathematics. He is just finishing his second year of teaching. Ron describes how he has started to incorporate science into his mathematics lessons.

Jan Macauley's chapter is interesting because she was the scientist in the CO-LEARNERS Program with Ron Wark in 1999, but now since mentoring two more practicing teachers in the CO-LEARNERS Program in 2001, she has decided to become certified to teach in a middle-school setting.

About Each of the Pre-Service High-School Teachers

Gregory Preston

One of the co-learners, Gregory Preston, became certified in secondary mathematics and science teaching at FSU. In that program, a student needs two areas of emphasis, and Gregory chose biology and chemistry. Given that I am a biochemist and interested in the teaching profession, he and I have a lot in common. With Gregory, I am also able to share my abiding love for use of technology in my own learning and teaching. Technology ignited a creative aspect in Gregory's own career and interests.

When I first met Gregory, he was much less confident in himself than he was just 13 weeks later by the end of the CO-LEARNERS Program in 1999. It was a transforming experience. The path was not always easy, but Gregory was persistent. Initially, I thought that Gregory would be working on helping with the development of the educational aspects to the website of the Florida Geological Survey (FGS), part of the Florida Department of Environmental Protection (Florida DEP). However, the timing did not work out, as the head web coordinator had not yet been hired.

Fortunately, Mary Hartsfield, a practicing chemistry teacher, whom I had known for years through the Chemathon competition for high-school chemistry students at FSU, had found a position at the FGS. Through Mary, we found that Gregory could work with scientist Jim Ladner on collecting samples and taking sedimentation erosion table (SET) readings in riverbeds around Florida. I will never forget when Gregory returned from his first trip on the river collecting samples. He had seen a stingray and a shark. It was as if everything he had ever learned in biology classes suddenly came alive for him.

Gregory Preston

However, the research experience did not go smoothly. There were several problems that summer. He was enrolled in an evolution class, and that created transportation issues. Even though Gregory wanted to go on additional trips to collect samples, he could not do so, because the all-day trips to collect samples meant that he would have to miss the evolution class. In the end, Gregory learned about analyzing the samples from Mary and a graduate student on the project. Nevertheless, he was involved in the entire scientific process, from collecting and analyzing the samples to entering the data into an Excel spreadsheet and graphing the results.

At the end of the summer, Gregory still needed 40 more hours (to meet the 125-hour requirement for which he had signed a contract with me). He decided to learn more chemistry by working with one of the DEP scientists, Thomas Frick, with whom Lidia had worked earlier that summer. The second research site gave Gregory a different window into the science world. As I sorted Gregory's transcripts and writings of his experience, four themes emerged: science content, technology, collaboration, and self-confidence.

I will never forget when Gregory returned from his first trip on the river collecting samples. It was as if everything he had ever learned in biology classes suddenly came alive for him.

Science Content

I noticed by the end of the summer, Gregory seemed more eager to share his learning because he was learning. Gregory said in an interview

> *I feel more comfortable [than I did at the start of the summer]. When I came into it, I was so confused. I wasn't really getting the grasp of what Jim (Ladner) was saying. I knew what cryogenic was, by definition, but I didn't actually see it, so actually going out into the field and doing everything, I felt much more comfortable. It was like this biology stuff wasn't so hard after all. I had a good time!*

Gregory told me that he felt he was a "Geologist for a Day." Since he was given responsibilities on the boat, he said that he "will retain a true sense of worth." He is able to explain concepts, such as sedimentation and the environment, more thoroughly. This is because he has experienced them in a situation in which he had a role in collecting the data. Therefore, it is more than just being there; it is being a part of the learning process that made a difference to Gregory.

Gregory did bring some of his research experiences to his high school classroom. He designed a lesson plan using SET readings as part of the CO-LEARNERS Project. I gave him a ring stand and a clamp to set up his equipment in his classroom.

Technology

A key part of the experience for Gregory was learning and utilizing technology. At the start, Gregory was a true beginner, but he moved very quickly to advanced technology. He even taught his practicing teacher, Mary, about using the technology. As Gregory reflected on the experience two years later, he said, "What got me interested in the computer field was the PowerPoint I had to do for the initial CO-LEARNERS Program. I found out that I have somewhat of a creative side."

Gregory is understating his creative side. It was obvious when he showed me his first PowerPoint presentation. He had already learned aspects of the program that I had not utilized. As he showed me his program, his whole body posture and keenness were different than when he first came to my office to apply to be a part of CO-LEARNERS Program.

It is more than just being there; it is being a part of the learning process that made a difference to Gregory.

When Gregory began his teaching internship, good technology was available in his classroom. However, it was a different story once he had his first teaching job. He had hoped to have a microscope, which could project samples on the screen for everyone to see. Gregory said

> *There was a computer in every classroom [during the internship]. I think we had three in our classroom. There were TV units that could be connected to the computer, there were white boards instead of chalk boards, and it kind of gave me the wrong impression, really, because when I got my own classroom, I looked around and I noticed that I don't have these things. I had a computer, but it was nothing like we had at the internship school. So, I had to really improvise.*

I think that Gregory saw the writing on the wall. It was going to be tough for him to teach science the way that he wanted without the resources that would facilitate learning. He is still interested in teaching, but he wants to do it once he has earned a master's degree in information technology.

Collaboration

Instead of staying in teaching, at least for now, Gregory has decided to go to graduate school in Miami in the field of information technology. He learned his passion for technology during the CO-LEARNERS experience when he worked with Mary Hartsfield, the practicing teacher, and with Jim Ladner, the scientist. Gregory spoke about collaboration.

> *Both Mary and Jim helped out a lot. Jim was very cooperative...I was able to provide Jim with not only a much needed helping hand, but also describe to him the world of science through the eyes of a prospective teacher and current student.... All in all, working with Mary and Jim has molded my entire outlook on the field of science. They were able to make a great deal of the material exciting and understandable to me, and, in turn, I helped each of them by bringing my own knowledge to the table.*

One of the ways that Gregory contributed was by bringing a basic understanding of computer technology to Mary, to help her know how to use Excel and PowerPoint, so she could bring that into her classroom.

Gregory told me that the way he figured out which graduate school to attend was based on his experience with collaboration within FCETP and our CO-LEARNERS Program. Gregory also attended two of our annual FCETP Symposia, so he had experienced collaboration beyond the research project. He said that doing the PowerPoint presentation for the CO-LEARNERS Program helped him decide which computer school he would attend. The school that he was at used the collaborative approach. He said, "According to them, that's what they use in the computer industry—a collaborative-type learning environment."

Self-Confidence

The biggest change I noticed in Gregory during the summer of the program was an increase in self-confidence. This was also apparent when I sorted the interview and Gregory's e-mail data using the NUD*IST program as well. From an abstract that Gregory wrote about his project, he said

> *By actually showing the prospective and practicing teachers what [the scientists] do on a daily basis at work and allowing them to take part, gives the prospective and practicing teachers not only excellent hands-on experience, but also a substantial amount of confidence in their classroom settings.*

Gregory explained that it was important for the prospective and practicing teachers to have responsibility in the laboratory. Gregory was in charge of obtaining and labeling samples from the river. He had a responsibility to follow up on the analysis of these samples and to enter the data from the field notes into the Excel file.

Gregory is not sure exactly what he will do when he finishes his master's degree in information technology. Given that he is very creative and hard working I am sure that he will be able to do what he wants to do. He still is very interested in teaching, perhaps in adult education rather than K–12. For instance, he has mentioned to me that he could write a computer program for "optometrists where they can figure out what a disease is, based on the program, based on the symptoms of the patient, whatever they may be." Gregory closed with what is most likely in the future for him. He said

Lidia Lanns

> *Yeah, [a doctorate program] would be science education, more than likely. It's a toss up between that and going to optometry school. I'm leaning towards the education. If I do come back, I can contact you.*

It would be a pleasure to have Gregory back at FSU for graduate school in science education. He will bring with him all the information technology and collaboration that he has learned, which are critical in education. He would also bring his love for learning.

Lidia Lanns

Lidia conducted her scientific research during the summer of her senior year at the Florida DEP. Like Gregory, she was also enrolled in several summer classes, so she had to fit the research experience around her class schedule. I have organized Lidia's experience into three categories: science content, community involvement, and the learning experience.

Science Content

Lidia's interest is in biology, so we paired her with a new biology teacher, Sherri Hood, whose interests include chemistry and biology. Both Lidia and Sherri were interested in environmental problems. There were three scientists on their team: Kelly Schratwieser, who has a master's degree in Marine Ecology; Thomas Frick, a senior chemist who had worked at the DEP for five years; and Russell Frydenborg, an administrator at DEP for two years and previously a biologist with DEP for 17 years. All three scientists were very interested in environmental education of the public, so they adopted our CO-LEARNERS team.

Part of the scientists' motivation came from the idea that if the public learned to prevent pollution, we would not need to clean up the environment. Lidia summarized her experience at the DEP by saying, "It was beneficial in that I grasped the concepts of biology by analyzing an ecosystem in its natural habitat." She learned correct sampling techniques, methods used for quality assurance, the importance of habitat assessment and environmental education, and technical writing.

Lidia Lanns' classroom

The scientists were motivated to improve how they could explain the science that they do at DEP to the public. They figured that the teachers could be of help to them. I think that our team did help them, as they developed experiments and field-tested them at a camp for middle-school children during that summer. Lidia and Sherri taught the middle-school children at the camp the difference between the bugs that they would see at a body of water that were good, marginal, and poor. The children made pictures of the bugs and colored them green, yellow, and red so they could count up the bugs that represent good quality water.

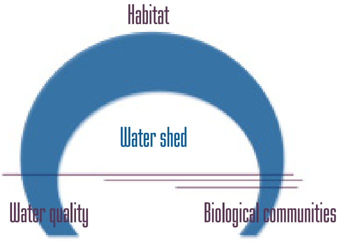
Russ Frydenborg is an eminent biologist with a tremendous amount of field experience. He is like a walking encyclopaedia in terms of what he knows about biology. He described the work that the CO-LEARNERS team would be doing as habitat assessment. He said habitat assessment has three corners to it:

- We learn about the habitat from what we expect for that particular type of habitat. We assess the habitat through observations.
- We test the water quality by measuring the various nutrients, such as nitrates, nitrites, phosphate, chlorophyll A, pesticides, and metal ions.
- We measure the intact biological communities by observing the insects, algae, vascular plants, and fish. The primary indicators of the health of a habitat are insects and algae.

"It was beneficial in that I grasped the concepts of biology by analyzing an ecosystem in its natural habitat."

These three indicators are tied together by the watershed concept. This is the model that the teachers had when they looked at the environment. Russ went with them in the field to collect data and shared with them what he knew. Lidia learned a lot from Russ. "I think he's really good because he's passionate about what he does," Lidia said. She referred to him as a "thoroughbred" because he is eminently trained and does his job well.

Lidia interacted with Kelly on the biological aspects of the water from the sites once they got back to the laboratory to see how biological samples would grow in the laboratory. She worked with Tom on developing the program for middle-school children. She worked with Sherri on developing a lesson plan for Sherri's high-school students. In the end, Lidia said about scientists, "Scientists come in all shapes, colors, and sizes, and each of us has the potential to make a difference." Knowing Lidia, I feel that she thinks the same about her students. We all can make a difference.



The water shed is tied together by the habitat, water quality, and biological communities.

Russ taught the teachers that you want to look for patterns in what you observe. It is through perceived patterns that scientists can make sense of data of different types.

Community Involvement

One of Lidia Lanns' student's decorated T-shirts

Lidia understood the value of collaboration and of learning from the community. I think she was attracted to our project because of the collaboration theme of the CO-LEARNERS Project and working with the DEP. Lidia said, "Community involvement is an integral component for science education in the new millennium." The project involved collaboration between scientists who wanted to reach out to the public, and teachers who wanted to learn from the scientists.

Lidia also knew that how a teacher utilizes the resources available can make all the difference in what the students learn. Lidia said

> *Teachers may not have many resources, but it's what you do with the resources that you have that really counts....You could have a great classroom with great computers and not learn a thing if your teacher is not motivated and making you apply that information to make it sink in.*

Kelly gave Lidia all sorts of posters on fish and turtles and storm warning manuals that she could take into her classroom. Lidia was eager to get her own classroom so she could display these materials. I visited Lidia's own middle-school classroom one year after she started a full-time job in Miami. It was filled with posters, just like she had hoped. It also had posters that her students had created, including paintings on T-shirts of topics on the environment, like deer, the sun, and Earth Day.

Lidia had her students work in collaborative groups to present lessons to the other students in her classroom. I saw this in an earth science classroom in which the students presented on the universe. I was impressed when the students asked me (in front of their peers) what I thought of their presentation and how it could be improved. I sensed the collaborative spirit of their school community.

"Our goal is to enhance the strategies presently used (lecture/textbook learning) and supplement it with experiential learning that directly relates to our environment and our efforts to improve it."

The Learning Experience

Lidia thought that learning through experience is critical. She said, "Our goal is to enhance the strategies presently used (lecture/textbook learning) and supplement it with experiential learning that directly relates to our environment and our efforts to improve it." She thought that bringing the experience of the practicing teacher to the table was important as well. There was much that Sherri, Lidia's practicing teacher, brought to the discussion as they learned in the field and thought of ways to bring concepts into the classroom. Lidia commented further.

> *As a prospective biology teacher through my experience at the DEP, I grasped the concepts of biology by analyzing an ecosystem in its natural habitat. Neither textbook nor traditional laboratory could compare with experiencing science as it occurs in nature.*

Lidia saw that the middle-school children learned about the environment at the camp where Lidia and Sherri taught about the environment. She mentioned that "most people do not think about the impact of litter on the groundwater supply. When rain washes items, such as cigarette butts, into a storm drain, water quality may be affected and an ecosystem can be subtly disturbed." There is a connection between what we do and what we end up needing to do to clean up the environment, and there's a cost to it.

After this one-day camp, Lidia had questioned whether she had the patience or nurturing skills to teach middle-school children. However, her first job was teaching seventh and eighth graders in a K–8 school in Miami. I had the opportunity to visit her classroom. It was getting near the end of the school year, and Lidia was about seven months pregnant, so it was getting tough for her to teach full time. However, Lidia had good command over the classroom, and she allowed her students intellectual space to learn and share their learning. I could see all sorts of creative ideas in her students' work in one group presentation and of projects displayed on the walls of the classroom.

Sandra Davis

"I want my students to really enjoy learning science and understand how it could be put to work for their interests."

Sandra participated in the CO-LEARNERS Program in 2000 as a returning undergraduate student. Sandra owns a beauty shop in Tallahassee, Florida, and has a young son. She is finishing her college education and wants to make a difference in the world, especially for young people.

As I set up the program each summer, I tried to provide experiences for teachers in areas that interested them. In Sandra's case, she had her heart set on working in the state of Florida Crime Laboratory in Tallahassee. As a beautician, Sandra had an interest in hair. Years ago, crime laboratories used hair from the scene of a crime as evidence. The Crime Laboratory no longer analyzes the hair as they used to do, but may use the DNA obtained from the root of the hair. Therefore, there were no experts on hair anymore at the Crime Laboratory, so I found something else for Sandra. Sandra had done some microbiology in the past, so she was familiar with working in a laboratory. I found a wonderful opportunity for her with the analytical part of the Florida Department of Agriculture and Consumer Services. Sandra had just finished taking analytical chemistry, so she was ready for this learning experience. As I sorted Sandra's comments, I classified them in three categories: the reflective learner, the reflective teacher, and the thoughtful advisor.

Sandra Davis

The Reflective Learner

What impressed Sandra about the research was "the opportunity to gain scientific information and techniques in a matter of weeks versus months or years." She found it a challenging, rewarding, memorable experience. About Jason Stepp and Michael Page, the research scientists with whom she worked, she said, "I appreciate the willingness and enthusiasm of the scientists to share their knowledge, experience, and input in my experience in learning, discovery, and the application of prior skills."

One day at the Department of Agriculture laboratory, Sandra asked permission to analyze a plum to determine the amount of pesticide in it. This was a powerful experience for her because she could follow her own interests. She ultimately found no detectable pesticide, which made her feel better about feeding her son fruits and vegetables. After this experience, she wanted to provide other opportunities for her students in which they could follow their own interests. Sandra said, "I want my students to really enjoy learning science and understand how it could be put to work for their interests."

Sandra learned from the readings that we discussed when the CO-LEARNERS group met weekly. We read from the earlier SERVE monograph on practicing teachers doing scientific research (Kielborn & Gilmer, 1999). The chapter by Jacqua Ballas and Terrie Kielborn really caught Sandra's attention (Ballas & Kielborn, 1999). This was because shortly after Sandra read the story of how Terrie and Jacqua had studied how to get rid of a non-native grass called cogongrass, she met some shepherds in a city park in Tallahassee. The shepherds were trying to get rid of an invasive plant called kudzu, a vine that can take over trees and anything in its way. The shepherds were grazing a type of haired sheep that could eat the roots of the kudzu. Sandra saw a parallel in what Terrie and Jacqua were trying to do to get rid of the cogongrass with what the shepherds were doing to get rid of kudzu. It started to click for Sandra. She could see the relevance of science right in her local park.

Hair sheep with close-up look at the kudzu

The Reflective Teacher

I think Sandra wants to make a difference as a teacher because she sees so many young people, especially African Americans like herself, turned off to education. She reflected on herself as a young learner and thought of how to improve things for children in school. For instance, she spoke about the advantages of block scheduling in which students take fewer classes but learn a school subject for a longer period per day. She thought that middle- and high-school students could profit from this because taking seven classes may overwhelm many of them. She thought that with such a crowded schedule in the school day that "it doesn't leave a whole lot of room for discoveries and learning."

She thinks it is important for young people (and their parents) to learn about different developmental stages that they are going through as adolescents and young adults. When she was young, she did not understand why she felt the way she did. She wishes that when she was young that she had learned what she is learning now in psychology classes. She feels that young people can be "hard on themselves and think they are not smart." She said, "I think that if the students had an idea about what is affecting them and what the teacher is trying to do, then maybe the students could relate to learning and understanding material better." She feels that as a teacher she needs to be aware of what is affecting her students and maintain close contact with their parents. Thus, the student and the parents can help facilitate what it is that she, as the teacher, is trying to do to increase that child's learning and understanding.

Sandra has decided that once she starts teaching, she will bring her students to the park to see the hair sheep that eat the kudzu. Then the students could explore aspects that interested them afterwards, to extend their knowledge. She wants to make learning experiences apply to life. She knows that discovery is important for people to learn. Sandra said, "My experience with the haired sheep and kudzu is a great example of interest-stimulated learning." "[My students'] interest in the actions of their environment and what is important to them in life could be used to stimulate them to make discoveries through science as solutions and adventures." I think that Sandra will provide a stimulating learning experience for her own students.

The Thoughtful Advisor

For those of us who teach pre-service teachers, Sandra said that it is important to "make future teachers feel that they can do it and make them feel competent." Science teachers feel more competent and self-confidant if they have first-hand experience with science, teaching, and technology. Sandra thinks that it is important to offer science experiences to pre-service and practicing teachers to provide "a greater awareness and appreciation of science that surrounds and influences our environment and daily lives." These experiences are "a great avenue to direct my future students through, to make explorations in science."

I had invited Sandra as the only pre-service teacher to attend a Faculty-Teacher Forum sponsored by our FCETP grant funded by the NSF. Sandra had the opportunity to speak to the faculty from the university and community college community and to some practicing teachers about her perspective in the forum. When Sandra was speaking at the FCETP Faculty-Teacher Forum, she made a powerful comment: "No one can change teaching but teachers." She sees teachers complaining but not banding together to change things. She feels that teachers are taking the role of victims rather than as problem solvers, that teachers need to confront the administration and to collaborate with the parents. Instead of complaining, she urged teachers to become proactive and find ways to solve the problems that are facing our K–12 schools. The experience helped her see the bigger picture of faculty working together to improve teaching and learning in science, mathematics, and education classes at the university and community college level.

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Leslie Magalis

Leslie participated in CO-LEARNERS Program in summer 2000 with Sandra Davis. One of our practicing teachers dropped out of the program a few weeks after it started, so our practicing teacher, G.S. Rahi, who worked closely with Sandra, also interacted with Leslie at our weekly group sessions. Leslie was finishing up her final semester of the Secondary Science and Mathematics Education major, with a specialization in chemistry and biology. Leslie's program with the CO-LEARNERS Program was a potpourri of activities that interested her. Leslie is now teaching science in the state of Maine.

Science Connections to the World

As evidenced in the analysis of her interviews, Leslie was particularly interested in environmental concerns and in science connections to the world. She had three major experiences:

1. Meeting Ed Orlando at University of Florida and hearing about how hatching of alligators is sensitive to environmental pollutants
2. Interacting with Tom Frick at the Florida Department of Environmental Protection and learning about indicator species and how streams are assessed
3. Canoeing on a north Florida river and getting to observe and appreciate a manatee mother and her calf for several hours

Leslie Magalis

It was a powerful experience for Leslie to hear about the alligators from then-graduate student, Ed Orlando, who had done research about pollutants influencing the sex of the hatching alligator. Leslie even held a young alligator. At that point, Leslie had accepted a teaching position in Maine, and she knew that there was a mill nearby that was affecting the river. She wanted to know more about pollutants in rivers. Ed told her about the mosquito fish and crayfish that are indicator species in Florida. She was more interested in the fish and other species than alligators because alligators are not found in Maine.

Leslie learned more about testing water quality and assessing river quality from interacting with Tom Frick at Florida DEP. She heard about the program for middle-school students that Lidia Lanns had developed during the previous summer. The DEP had planned to take Leslie out on a boat to assess a lake in Florida. However, Florida had received so little rain that summer that only one boat could go out, leaving no room for Leslie. Leslie was disappointed to miss out on that trip, but she did get a lot of information about the environment from DEP brochures and websites. Tom spoke with Leslie about what is "normal science" and how they go about doing their research on the lakes and rivers.

Leslie wanted to learn more about test kits about assessing water quality. Leslie said, "The first thing they do is look at the lake or the river to see what it is being used for, how many buildings are around it, and whether it is commercial or residential or wild; that way, they can have a direction. It was really fascinating."

The CO-LEARNERS Program was good for her because she was able to pursue her own interests and explore what she found meaningful.

One summer after the CO-LEARNERS Program, Leslie got a one-week, in-service course for teachers in water quality at an undergraduate college in Maine, so now she is ready to implement some of the ideas that she learned during the summers in her science classroom.

The trip to see the manatees was not formally part of CO-LEARNERS Program, but Leslie talked about it in group sessions. I interacted with her on this, as I am particularly captivated by the manatees myself. Leslie spoke of quietly sitting in her canoe, just appreciating the opportunity of seeing the amazing mammals up close. She could see the scars from boat propellers on the backs of the manatees. Just seeing a manatee come up out of the water and seeing and hearing it breathe in front of you is amazing. Leslie and I could share the exhilaration of being close to nature.

Thinking Ahead to Her Classroom

Leslie knew that her first teaching job would be with special education students. She would be teaching all subjects. She wanted to "integrate English and science and go on field trips and have [the students] write up stuff." However, she knew she wanted to "bring [her] own expertise to the classroom and have a nice integrated classroom." Leslie also said

> *I feel that I have a strong connection to doing science, and I know the value of trying to do real science and getting in touch with scientists in the local area and having them come in and talk with the kids.*

Rebecca Brockwell

After Leslie started her second year of teaching, she said that the CO-LEARNERS Program was the best experience for her. She built on some biological research that she had done earlier as an undergraduate at FSU. I think CO-LEARNERS Program was good for her because she was able to pursue her own interests and explore what she found meaningful. She knew what she wanted to learn, and she found ways to do just that.

Rebecca Brockwell

Rebecca Brockwell participated in a program developed in a collaboration between the U.S. Department of Energy and the National Science Foundation's Collaborative for Excellence in Teacher Preparation Program. I was one who was invited from an NSF-funded project to the Argonne National Laboratory in the fall of 1999 to provide some feedback on ideas that the DOE and NSF were developing for the Pre-service Student Teacher Training Fellowships. I met the representatives from the ORNL and told them about our FCETP CO-LEARNERS Program that we had started the previous summer. Afterwards, I sent them a copy of our *SERVE Meaningful Science* monograph on practicing teachers doing scientific research. ORNL decided to include a practicing teacher to work with the pre-service teachers in their program.

When it was time for CETP pre-service teachers to apply for the program at ORNL, I encouraged the pre-service teachers in my *Science, Technology, and Society* course to apply. Rebecca, one of my best students, was accepted. ORNL was the site for CETP pre-service teachers from Florida, Louisiana, and Virginia.

I decided to visit Rebecca on site and learn about this program. I interviewed her after dinner on the night of my arrival. The next day, she took me on a tour of the National Transportation Research Center (NTRC) where I met her research mentors, Drs. David Greene and Janet Hopson. I also saw the site where the diesel fuels were tested. Before this trip to ORNL, I did not know much about diesel engines, so it was an opportunity for me to learn. I sorted Rebecca's words from the interview and some e-mail into four categories: applied science, science policy, teaching, and mentoring by scientists and teachers.

Applied Science

Rebecca's project was to develop educational materials for a website on diesel engines [www.fueleconomy.gov]. First, Rebecca wanted to understand and learn the material herself and then to think of how to bring that learning to other teachers and their students. Therefore, in the interview, she initially focused on telling me about diesel engines being high-compression engines so spark plugs were not necessary. Since the fuel is so highly compressed (using a 30 or 40 compression ratio), it combusts on its own without needing a spark. Because more air is used in the compression, there is more for the catalytic converter to do to reduce particulates from the increased volume of air that must go through the converter. Engineers are designing catalytic converters that work well with diesel engines to meet the forthcoming emission standards.

Rebecca commented to me, "I figured out so much about how a car works." She could see the relevance of understanding how a car works for the students who are interested in such things. She said, "This will help me with the boy-factor in my classroom."

Science Policy

When I sorted Rebecca's text, the category with the most subheadings was learning science policy. This is not too surprising because Rebecca's mentor, David Greene, is an economist and works with others from Washington, DC, to develop policy on transportation and fuels.

In this category of science policy, there were seven subheadings:

- Exhaust systems
- National laboratories
- Spallation neutron source (i.e., source of a pulsed beam of neutrons [www.sns.gov] currently under construction at ORNL)
- Human genome project [www.ornl.gov/hgmis]
- Computing [www.csm.ornl.gov]
- Energy [www.ornl.gov/divisions/energy/energy.html]
- Global change [http://globalchange.gov]

She learned about many of these categories from the weekly meetings with her teacher mentor, David Stanton, and the two other pre-service teachers.

Over the summer, Rebecca became convinced that our federal government needs to insist on higher standards for our vehicular engines. She said, "I mean, there is no demand here for diesel cars because gas and diesel are both cheap." However, Rebecca added

> *I'm not a big advocate of government regulation for everything, but I have become convinced this summer that unless the federal government says these are the standards and that everybody has to meet them, there is no reason for any of it to change because people are willing to buy the cars like they are now.*

Greene has authored *Energy and Transportation* (1996). According to Rebecca, Greene encourages people to buy a smaller car because then everybody would be safer. Instead, we tend to think, "'Oh, I want to be safe', so you go out and buy a tank for your kids, when, in fact, you're making things more dangerous for everybody," Rebecca said.

In a course that Rebecca had taken with me, we studied the Manhattan Project and ORNL as being the site where uranium was separated into its various isotopes to get enough of the uranium isotope 235 to make a fission nuclear bomb during World War II. As an outgrowth of this development, first the Atomic Energy Commission and later the U.S. Department of Energy wanted to know how nuclear bombs affect human genetic material. The Human Genome Project started in 1989 with funding from the Department of Energy and the National Institutes of Health. In February 2001, the entire human genome was reported as essentially complete. This was ahead of schedule and was an enormous project, reporting on the sequence of 3 billion base pairs.

At ORNL, there is a "mouse house" where scientists test the effects of changing genes in mice and "seeing what happens." Rebecca was impressed by a "little CAT scanner for a mice, to look at their whole bodies. The scientists anesthetize the mice and then scan them, so that they can see physical things whereas otherwise they'd have to dissect the mice, which prevents them from seeing other things."

Lidia Lanns' students working in a collaborative group

More central to Rebecca's project on diesel engines, however, is the science and technology policy that Rebecca learned about energy use. Rebecca said, "My center is working on global warming, which relates to energy, and we are doing it because we are using all these hydrocarbons..." By this, Rebecca meant that we are using hydrocarbons for our fuel in automobiles, trucks, and airplanes for transportation. Rebecca is concerned with how quickly we are using up the hydrocarbons that were laid down by years of decomposition of plant material. Rebecca noted that it took millions of years for plants to take the carbon dioxide out of the air and for the plants to decompose it to build the reserves of oil that we have had available to us. Now in about 150 years, we will reverse all of that by using up the oil and putting the carbon dioxide back into the atmosphere. "What are we going to do? Do people really think nothing is going to happen, that we are going to go back to horses and buggies when it's over? I don't know how many people will be willing to do that," Rebecca commented.

Teaching

Rebecca knows that she wants to teach chemistry in high school. She has had some experience teaching Sunday school at her church to middle-school students, and she felt that middle school wasn't her calling. Rebecca said, "I think teaching is a gift, and some people are called to that, to that puberty level." Since the summer experience at ORNL, Rebecca has just completed her internship at Rickards High School in Tallahassee, and she's looking forward to teaching her own high-school students. It will be interesting to see by the end of the semester how she feels about that.

While Rebecca was at ORNL, she e-mailed me and said, "I just wanted to let you know that I had a breakthrough today." She had heard about the idea of constructivism beforehand when she was reading the SERVE monograph, *Meaningful Science*, but had not fully understood it. She said, "All the teachers spoke about constructing knowledge and becoming scientists." Plus, she had been hearing about the concept in all of her education classes, but she hadn't seen it in action. Basically, at ORNL she learned how important it was "to make a science topic relevant in order for them to carry the understanding out of the classroom." In her own searching for material to construct the educational website at ORNL [www.ornl.gov], she saw the website at Los Alamos National Laboratory [www.lanl.gov/worldview] "that has a wonderful program on curriculum development as well as examples of things people have done." The concept of constructivism became real to her through this experience.

Mentoring by Scientists and Teachers

Rebecca had two scientists at ORNL who acted as her scientist mentors, plus she had me as her science professor at FSU. Rebecca spoke about David Greene, an economist and social scientist, with whom she worked. She respects his energy and drive to get things accomplished. He brings things to fruition. He can listen and "talk the talk" of social scientists, natural scientists, and teachers.

Rebecca knew I would be interested to know that David was a member of the Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) at the National Academy of Sciences. David testified in Congress on this committee's report while Rebecca worked with him, and he wrote a dissenting opinion about smaller cars and safety. Rebecca found this very interesting. She saw how scientists can make a difference and contribute to our country's decisions.

The lessons Rebecca learned from her mentor teacher, David Stanton, were critical as well. Rebecca said, "The biggest thing that I think will help directly in the classroom is every week the PST has done a tour of some kind to a different part of the lab." For example, the pre-service teachers saw the graphite reactor one week and the "mouse house" another week. What has made a difference is that, as Rebecca said, "I've really been able to see a lot of different types of things and see how it all connects."

Conclusion

What I have seen with the pre-service, high-school teachers in the CO-LEARNERS Program is that there is much the teachers can learn. Each one's individual experience was shaped by prior experiences and by one's personal interests during the research project. I think that a program that accommodates a teacher's interest will be a powerful force for change.

What really counts is tactical authenticity. Guba and Lincoln (1989) say, "It is not enough to be stimulated to action. It is quite possible to want, and even to need, to act, but to lack the power to do so in any meaningful way" (p. 250). I ask to what degree are the pre-service teachers as stakeholders in the CO-LEARNERS experience empowered to act once they have their own classrooms?

Of the five high-school teachers I studied, only two, Leslie and Lidia, are teaching now. Leslie Magalis moved to Maine right after graduation, so I could not observe her teaching.

I visited Lidia Lanns, who was teaching middle school in Miami. My visit only lasted one day, but I did observe her students as active learners, mainly as they worked together in collaborative groups. I was there on a day with student presentations, so at this point, I would have to reserve judgment until there are more opportunities for me to interact with Lidia and her students in the classroom. However, I did sense a catalytic authenticity in how Lidia's students interacted with one another and how they learned from one another and from Lidia. I noted that the group that presented asked me (in front of their peers) for feedback on their presentation. It was obvious to me that they wanted to learn from the situation. On that same day, I also visited one of Lidia's biology classes, and these students were especially interested to hear about my work with leukemia cells and had many good questions to ask me. I could also see from the work that Lidia's students had displayed on the walls of the classroom that environmental science was a key theme, like in Lidia's science experience at DEP. Therefore, I could detect the echo of what Lidia learned in the CO-LEARNERS Program in Lidia's own students.

There were several themes that reappeared in the oral and written discourse of the pre-service teachers: science content, collaboration, and technology. These are the three triads of our CO-LEARNERS Program.

Science Content

One common theme that was clear from the analysis was that all five high-school pre-service teachers learned science content. The science content often included two areas, like earth science and biology, or biology and environmental science. It tended to be interdisciplinary at the boundaries of traditional disciplines, where interesting problems need to be solved. Rebecca's learning was focused more on applied science that had science policy implications connected to her learning. Most of the teachers emphasized the importance of a pre-service teacher seeing the connection of the science to the real world.

I could also see from the work that Lidia's students had displayed on the walls of the classroom that environmental science was a key theme, like in Lidia's science experience at DEP. Therefore, I could detect the echo of what Lidia learned in the CO-LEARNERS Program in Lidia's own students.

Collaboration

Another theme that permeated all the discourse was the importance of collaboration, whether it is among various scientists from different disciplines or of pre-service and in-service teachers or with teachers and scientists. It was important to the pre-service teachers to have connections from the schools to the rest of the community. Many of the teachers had tutored middle- or high-school students while they were still undergraduates. This gave the teachers valuable insights into teaching and learning.

For instance, Lidia collaborated with Sherri, the practicing teacher in Lidia's CO-LEARNERS team, to develop curricula on environmental concerns for middle-school students. This helped the DEP to reach students better, but it also helped Lidia to develop a deeper understanding of the environmental concepts that she was learning at the time and to think of how to bring such topics to students.

Technology

Learning to utilize technology to record and interpret scientific data was critical in Gregory's experience. He had been a novice at technology at the start of the summer, but he quickly learned how to utilize it, not only for the science but also for presentation of what he had learned. He presented his PowerPoint slides at a reception for our local science teachers' annual social meeting. This experience with technology opened a world to him, and now he is doing well in graduate school in information technology. He may bring this expertise that he's developing to teaching, perhaps at the higher education level rather than K–12.

Sandra also utilized technology in her science experience with the rapid solvent extraction method. This equipment had just been ordered, and Jason, her mentor scientist, was just beginning to do the standard curves on various known samples, so they could learn the utility of the method. Sandra saw the advantage of using this technology as it is much quicker to do the analysis than the usual method. Sandra emphasized that it's important for teachers to learn the new technology.

Influence of CO-LEARNERS Program on Scientists

Bybee (1998) encourages scientists and engineers to become involved in addressing the *National Science Education Standards* (NRC, 1996) and translating them into effectual science programs that meet the needs of our future teachers. We did have many scientists involved in the CO-LEARNERS Program, and they volunteered their time in effective ways. I think the CO-LEARNERS Program affected them as well. Many of the scientists had children still in K–12 school, so they felt more connected to the schools and enjoyed working with pre-service and in-service teachers. I contacted many of them to proof what the teachers wrote and get their feedback on the chapters, especially to get the science content correct. They were helpful in this respect.

When Lori Livingston Hahn contacted the scientist, Jan Macauley, to get her feedback on Christy's chapter, Lori learned that Jan was interested in going back to school to become a teacher. Consequently, I approached Jan to write her own chapter, which she did enthusiastically. With her background as a practicing scientist, Jan will bring much to the teaching of middle-school science. Therefore, we not only brought pre-service and in-service teachers together, but we also recruited a scientist into teaching.

Similar Themes to What Has Been Observed with Practicing Teachers

Some of the common themes that we have noted with pre-service teachers in this monograph have been observed with practicing teachers. In the *Meaningful Science* SERVE monograph (Kielborn & Gilmer, 1999), the practicing teachers chose environmental research, much like the pre-service teachers in this monograph. In the earlier monograph, we emphasized the importance of teachers becoming "part of the culture and discourse of science in a 'contextual learning' experience" (p. 11).

It was important to the pre-service teachers to have connections from the schools to the rest of the community. This gave the teachers valuable insights into teaching and learning.

In the NRC (2000) book, *Inquiry and the National Science Education Standards*, one practicing high-school physics teacher, after a three-year masters program that involved learning inquiry, said, "These experiences demonstrated the complexity and importance of learning to **do** science as well as learning **about** science" (p. 89). The NRC stated the importance of "the need for teachers to **do** inquiry to learn its meaning, its value, and how to use it to help students learn" (p. 91) and of developing a community of teacher-learners who "mirror the scientific communities" in which teachers have been immersed.

What We Would Do Differently Next Time

I would require a written report on what each teacher learned as a result of the summer's research. During the first summer in Tallahassee, I required that both the practicing and pre-service teachers make a presentation at a local teachers' group social meeting. In some ways it was good, because other local practicing teachers found out about opportunities with FCETP and the CO-LEARNERS Program. The teachers in the CO-LEARNERS Program chose to do either a poster or a PowerPoint presentation. Although there were positives to this, in the next summers I required a written report, due right at the end of the summer, while all the ideas were fresh in the teachers' minds. The teachers had a chance to get clarification on concepts while they were still working with their scientist mentors. Also I learned to go over the report with the teacher. The teacher and I revised the paper online, as ideas became clarified through discussion, and that became the final report.

In Lori Livingston Hahn's Chapter 7, she has indicated other areas that we could change. One of those I think is critically important is to have at least two scientists involved in the mentoring. It is good for the teachers to see the culture of science, how scientists interact with each other, and how they debate methodologies to utilize in the experiments and how to interpret results. Also, if one sci-entist is busy or traveling, there is another scientist available.

I also think it would be good to arrange for the pre-service teacher to do the internship in the classroom of the teacher with whom the pre-service teacher worked in the scientific laboratory. It would continue the connection and enhance the communication.

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CHAPTER 2

Real Science for Real Science Teachers

Sandra Davis

The Learning Experience

My research project was a challenge, yet it was a rewarding and memorable experience. As a participant in the Florida Collaborative for Excellence in Teacher Preparation and CO-LEARNERS Program, the director, Penny J. Gilmer, placed me with Jason Stepp and Michael Page, scientists at the Florida Department of Agriculture and Consumer Services, in Tallahassee, Florida. Jason's summer research assignment was to develop and validate a pesticide residue test procedure using the recently acquired Accelerated Solvent Extraction equipment. Michael was Jason's supervisor.

I wanted to learn analytical chemistry and methods of separating and isolating molecules. In addition, I wanted to use sophisticated instruments that can separate and quantitate molecules using liquid and gas chromatography. I was excited about the project because I would have a lot to bring to my future science classrooms from this experience. I planned to share with my future students the importance of mathematics and science, how they are applied to solving real-life problems, and why mathematics and science should not be forgotten when the school year ends.

My awareness will guide me to plan more hands-on activities in my science classroom in order to stimulate student learning.

The scientists were enthusiastic about sharing their knowledge and expertise. As a result of this experience, I have increased my science knowledge, learned new laboratory skills and techniques, and gained a new perspective toward the work that scientists do in an analytic research laboratory. Concurrently, I fulfilled three credit hours that I needed for my undergraduate degree in teaching secondary science.

Activities in the CO-LEARNERS Program

The Weekly Meetings

Each week, the CO-LEARNERS Program participants and scientists met with Dr. Penny Gilmer to discuss assigned readings and talk about the upcoming activities and tours on the schedule. We updated each other about our research projects and shared the new and interesting events we were experiencing. We reflected on how our experiences were influencing our views toward the teaching of science and how we anticipated this would impact our classroom planning as future teachers.

The Readings

Our readings were from the earlier SERVE monograph, *Meaningful Science: Teachers Doing Inquiry + Teaching Science*.[1] At first, I was not very enthusiastic, although I thought it might be somewhat interesting to read about science teachers. I quickly discovered that the assigned readings were thought-provoking. The authors revealed the nature of science that surrounds me daily and helped me direct my questions as I discovered new things during the research project and on the field trips. I learned to apply the scientific method to consider factors that affect our environment; therefore, I gained a better understanding of the problem.

Tours and Field Trips

Dr. Gilmer planned a full schedule of fascinating activities and field trips for the FCETP students and students from the Alliance for Minority Participation.[2] Such trips included the Odyssey Science Center in Tallahassee, the Florida Department of Law Enforcement Crime Laboratory, research facilities at the University of Florida in Gainesville, and Sea World in Orlando. We also spent time in the computer laboratory visiting interactive websites. The tours, readings, personal experiences, and research opportunities enlightened me about scientific research and prompted me to consider students' expectations in my classroom and how they may view science class activities.

FCETP Faculty-Teacher Forum

At the end of the summer, I was invited to attend a FCETP Faculty-Teacher Forum sponsored by the Florida Collaborative for Excellence in Teacher Preparation in Orlando. Those in attendance were university and community college science and mathematics faculty members as well as six practicing science or mathematics teachers. I was the only prospective teacher to attend.

Personal Experience

The Readings

The readings in *Meaningful Science* complimented my personal discoveries at the laboratories. Most applicable was the article about cogongrass by Jacqua Ballas and Terrie Kielborn.[3] When I began reading this article, I was not very impressed with studying a type of grass as a research project. Then I became intrigued by how tough and troublesome the cogongrass problem is and how important it was to Terrie and Jacqua to map the area the cogongrass covered, apply an effective herbicide, and get the invasion under control.

Chance Opportunity to See a Connection to Research

Grazing hair sheep

Not long after I read about the cogongrass research project, my family and I visited a local park for an after-dinner stroll. When I got out of the car, I noticed the smell of animal manure; somehow I had overlooked the group of sheep grazing in a field at the entrance to the park. As we walked over to see them, we decided that they were not sheep but goats. They were unique looking, marked with spots and patches one would expect to see on Elsie the cow.[4] The animals were happily eating the grass and weeds within the electric fence that enclosed a section of the field. Later, as my 13-month-old baby pointed at the animals, I spoke with the shepherd to learn more about these animals. It turned out that the grazing animals were hair sheep, a unique breed of sheep that grows straight hair instead of wool. The sheep are part of a pilot project to eliminate the kudzu vine that grows rampant in many areas of the park, choking and killing the trees. Kudzu is an exotic plant species that runs rampant through parks in Florida. These sheep eat the kudzu to the base of the plant, which often kills the vine.[5]

These researchers were determined to control the kudzu invasion, like Jacqua and Terrie who wrote about the cogongrass, so I told the shepherds about the cogongrass control project. One of them mentioned that they had tried to graze hair sheep on cogongrass to try to eliminate it in another study, but the sheep choose not to eat it. I remember reading in the SERVE monograph that the cogongrass leaf has rough edges due to the presence of silica bodies in the plant tissue.

The Crime Laboratory Research Tour

I was the only CO-LEARNERS Program participant who went on the tour of the Florida Department of Law Enforcement Crime Laboratory. I expressed a desire to see it because for my research study, I had hoped to study hair samples from crime scenes. My interest in hair stems from my owning a beauty shop in Tallahassee while I am finishing my undergraduate degree. I deal with hair every day and thought I could bring something to the table with my knowledge of hair. Also I could increase my own learning while working at the Crime Laboratory. Much to my dismay, I learned that hair analysis is not done nearly as much as it used to be, with the advent of DNA analysis. Therefore, there was not a research place for me there.

However, the Crime Laboratory tour was fascinating. I was not aware of the different departments and types of analysis that are conducted there. Some of the forensic analyses include chemical testing, serology, and fingerprint identification using powerful computers.

In the chemical laboratory, sophisticated chromatographs are used to detect the presence of illegal drugs and identify their purity. In the serology laboratory, technicians analyze samples of bodily fluids, such as blood and saliva, from crime victims or suspects to determine the blood type or DNA profile. In the fingerprint laboratory, various techniques are used to "lift" prints from different surfaces, including the use of preservative methods to lift fingerprints from severed hands. We learned that sometimes this evidence is used to link a suspect with a crime. At other times, fingerprints are used when a victim's identity cannot be determined because of a disfigured face.

The computer laboratory picks up where the fingerprint laboratory leaves off. In many cases, fingerprints can only provide limited details of a person's identity. If a photograph is available, it could be quite old. In many cases, a victim's face may be disfigured; not to mention that when "missing person pictures" are posted, the photo is sometimes old (and therefore not very helpful). However, in the computer laboratory, images can be produced to show restructuring of a disfigured face or create the effects of aging based on the individual's facial features and structure.

With my new understanding of what scientists do and how researchers are working to solve real-life problems, I can show my students that school mathematics and science should not be forgotten when the school year ends.

My Research Site

Pesticide Laboratory with State of Florida

I was assigned to work with research scientists at the Pesticide Laboratory with the Department of Agriculture and Consumer Services in Tallahassee, Florida. Michael Page, a Florida State University alumnus and laboratory manager, had a project already in progress when I started. He had assigned Jason Stepp to develop and validate a procedure for using the newly acquired Accelerated Solvent Extraction (ASE) instrument [Test Methods for Evaluating Solid Wastes Physical.Chemical Methods, SW-846. EPA Method 3545, Third Edition, December, 1996.]. The Environmental Protection Agency has recently approved the ASE, an automated device designed to extract semi-volatile organic compounds (SVOCs) from solid materials. The resulting solution contains the targeted analyte, such as pesticide residue or fertilizer components. Using the ASE can reduce sample preparation time and speed up analysis while using smaller volumes of solvents that are less toxic than methylene chloride, such as acetone and hexane.

Michael Page, an FSU alumnus, was my research mentor.

Sample Preparation

Samples are brought to this laboratory to test for the presence of pesticides; in addition, the laboratory equipment is used to verify the composition and formula of commercial pesticides and ensure that the manufacturer accurately states the percentage of active ingredients. Calibrating and maintaining the analytical equipment is tedious and complicated, and preparing samples traditionally is labor-intensive. The method used prior to receiving the ASE was very lengthy due to the number of extractions and large quantities of diverse solvents required for partitioning of an analyte and cleaning up the sample. The original extractions usually take three to six hours, and the instrumental analysis takes one to two hours in "real" time. Work is performed in sets, which may take from 24 to 48 hours.

The motivation for developing the new ASE method is that it would speed up the preparation and analysis of samples. In addition, it would require much less solvent, thereby saving on expense of not only purchasing the solvents but also on disposal of used solvents. A critically important motivation for developing the new method is to reduce the volume and dependence on ozone-depleting chemicals, such as methylene chloride.

Here I am preparing a sample in the hood.

Many semi-solid or solid samples (i.e., grass, hay, soil, animal tissue) are analyzed for pesticide residues. Such samples required specific preparation before the ASE can analyze them. For instance, most solid samples must be ground and dried for extraction. This procedure is simple when the soil sample is free of roots, rocks, or hardened clay. When fruits and vegetables are received for testing, the samples are cut into small pieces and placed in a blender for further grinding. A solvent is added, and the slush is filtered through a funnel plugged with glass wool. I watched samples of watermelons being prepared for analysis. Aside from all of the water; it did not appear to be a difficult procedure.

On the other hand, preparing the shrubbery samples took more effort. Cutting the branches into small pieces with scissors was tedious. It is not unusual for the laboratory to receive samples that require a great deal of preparation work, thereby delaying the process of extraction and analysis.

The Saving Grace of the ASE

I believe hands-on laboratory research activities can be a valuable experience for enhancing teaching and learning.

The Accelerated Solvent Extractor uses high temperature and high pressure distillation to speed up the extraction and analysis process and eliminates the need for multiple solvents and a lot of glassware. Whereby previous analytic methods used hundreds of milliliters of volatile solvents for each sample, the ASE uses only 15–40 mL of acetone or hexane per sample. Using the ASE, extraction time is only 15 minutes per sample, and a full chemical analysis can be completed within 24 hours. I read a lot about the traditional and ASE methods of extraction; the comparisons helped me to appreciate the speed, accuracy, and convenience of the ASE.

My Role in the Project: Assisting in Validating ASE Procedure

When I started at the laboratory, Jason had already started to validate the procedure for using the ASE. Jason described his plans for each step of the validation process, and I assisted him in the preparation work and set-up of sample runs. Once we extracted the samples by the ASE, Jason directed the analysis using a chromatograph. We continued to run sample matrix blanks and "spiked" matrices using various pesticides.

Once we got acceptable recoveries, we began testing the parameters for method detection limit (MDL). Jason spiked the sample matrices with specific quantities of one group of pesticide to be analyzed each day. The ASE performed as expected on every prepared sample matrix. The "blanks" were always blank, and we detected the spiked sample matrices at the expected levels. We analyzed one spiked sample matrix at 0.06 ng/g (i.e., at parts per billion); this is very low in comparison to what is considered a "hit."

At this point, Jason's work was nearly complete, and his final task was writing the report to clearly show the accuracy of the procedure and the results of the analyses. The testing procedure will be considered valid "for official use" after being reviewed and approved by the laboratory's Quality Assurance Quality Control Committee.[6]

My Reflections

Rethinking My Plans to Teach Science

How will my summer experience influence my future teaching? When I become a science teacher, I will have a greater awareness and appreciation of what scientists do in research laboratories. I believe that my awareness will guide me to plan more hands-on activities in my science classroom in order to stimulate student learning. Perhaps my students will discover that science class is an adventure. I would love for them to understand scientific concepts and enjoy my teaching so much that other students hear about it and want to take my classes.

Hair sheep with a shepherd

My experience with the hair sheep motivated me to learn more about what animals eat as well as how to control kudzu. I wonder how a field trip to the park would stimulate my students' interest in science. The logistics are fairly simple. The trip would not be expensive, the students could bring a brown bag lunch, and it would take very little time from their other classes. Perhaps they would want to learn more about the sheep's diet, behaviors, and how their grazing on kudzu helps to maintain a balance in the park ecosystem. It could be a great opportunity for individual and group discoveries.

Rethinking the High School Day

I think administrators and teachers should rethink the way the school day is designed. When I was in high school, we had only six classes per day; by my tenth-grade year, the seventh period was optional. That's a daunting schedule for students because they cannot focus a lot of attention on each class, and if they *do* focus on one class, then they are pushing another class aside. If every teacher is demanding, then some students may not be able to keep up. I think that block scheduling has potential benefits, although some children might get a little bored or tired of sitting in one class for too long. I don't think the school schedule leaves much room for discovery learning. Often students either decide to actively participate in classes in which they are interested and work less in the other classes, or they decide not to pay attention in any of their classes. It seems that there are few students who are willing to tackle the demands of all of their classes.

As a result of this experience, I have increased my science knowledge, learned new laboratory skills and techniques, and gained a new perspective toward the work that scientists do in an analytic research laboratory.

Utilizing Hands-On Science Activities

I believe hands-on laboratory research activities can be a valuable experience for enhancing teaching and learning. Learning about chromatography and how pesticides are analyzed may lead students to become curious about the use of pesticides on their favorite fruits and vegetables, and how the use of pesticides in areas near their local water supply is being monitored. I brought a plum to the pesticide laboratory one day for lunch this summer and wondered how many pesticide residues were present. Jason and I decided to screen it using the ASE. The results were negative for the presence of pesticides.

Although my science students may not have access to sophisticated pesticide laboratory equipment to analyze their plant samples, I would like to stimulate this type of thinking and explorative interest in my students. I want my students to really enjoy learning science and understand how it could be put to work for their interests.

Attending Professional Meetings

I suggest that future teachers attend professional meetings, such the FCETP Faculty-Teacher Forum. When speaking with the undergraduate and graduate students for a special session, I shared how taking an education of psychology course at Florida State University influenced me. As I learned about the different theories of sociologists and psychologists, I wondered why someone had not told me about "normal" child development when I was younger. Perhaps if they had, I could have been a better student when I was in elementary, middle, and high school. If students could better understand the different stages that they are going through, I think it would help their learning in school. For example, they might say to themselves, "Oh, okay, this is normal for me at this stage—it's normal to want to fit in at high school and normal to have an identity crisis." If they can accept themselves, they may keep trying in school.

Here I am at the FCETP Faculty-Teacher Forum.

There is a strategy that teachers use in the classroom that is based on educational theory, but students do not usually know it. I think that if students can understand what a teacher is trying to do, then maybe they can relate to learning and understanding the material better.

Conclusion

I now have a lot to bring to my future science classroom from the summer CO-LEARNERS experience. I am eager to share with my future students the importance of mathematics and science. With my new understanding of what scientists do and how researchers are working to solve real-life problems, I can show my students that school mathematics and science should not be forgotten when the school year ends.

Endnotes

[1] Kielborn, T. L., & Gilmer, P. J. (Eds.) (1999). *Meaningful science: Teachers doing inquiry + teaching science*, Tallahassee, FL: SERVE.

[2] The LS-AMP (Louis Stokes Alliance for Minority Participation) program is open to minority students [http://skcweb.skc.edu/amp]. It provides a summer of workshops in mathematics and sciences courses for students to attend the summer before they start college. The workshops are designed to strengthen the students' skills and expand their career opportunities.

[3] Ballas, J. L., & Kielborn, T. L. (1999). Teachers can be scientists, too! In T. L. Kielborn & P. J. Gilmer (Eds.), *Meaningful science: Teachers doing inquiry + teaching science* (pp. 27-38). Tallahassee, FL: SERVE.

[4] Elsie is a Holstein cow featured in Borden chocolate milk TV advertisements, circa 1970s.

[5] The biological mowing machines are hair sheep, which are non-wool-producing ovines. Hair sheep are recent immigrants to the United States from more tropical climates and are well suited to heat, humidity, and rain like you find in Tallahassee, especially in the summers. Most of the flock in my chapter are the St. Croix White, the Barbados Black Belly (brown with black bellies) and the South African Dorper (black heads and white bodies). Bellwether Solutions of New Hampshire has leased this flock to Tallahassee, Florida's park service for a five-year pilot project to kill the kudzu.

The idea is to employ a technique called "mob grazing," in which hundreds of shoulder-to-shoulder sheep strip down every green thing in their path. Before the sheep get a chance to tear into any desirable trees, the shepherd moves the flock. A few days later, the sheep are back again, stressing the kudzu vines' underground tubers so much, officials hope, that the plants can at last be eradicated for good by using a potent dose of weed killer.

[6] *Method Development Process (8 Steps)*

1. Conduct literature search
2. Set up experiment
3. Establish instrument parameters
4. Run reagent blank & fortification tests
5. Run sample matrix blank tests
6. Perform sample matrix residue tests
7. Determine method performance parameters (i.e., method detection limits)
8. Write up experimental results

I am using the ASE equipment with Jason Stepp, one of my research mentors.

STEP 1: Conduct Literature Search
- Check all resources
- Utilize the library
- Search the Internet
- Read relevant articles in journals and magazines
- Search the method files
- Find a usable method or portion of a method
- Decide your strategy

STEP 2: Set Up Experiment
- Order supplies
- Coordinate instrumentation and equipment
- Set up a designated area for method development
- Limit equipment and apparatus needed for project so that materials are off-limits to others until the development of the project is complete

STEP 3: Establish Instrument Parameters
- Determine the setting of chromatographic parameters
- Demonstrate delectability, sensitivity, efficiency ,and resolution of target analytes
- Conduct sample calculations

STEP 4: Run Reagent Blank & Fortifications Tests (extraction/cleanup)
- Run one reagent blank and three reagent spikes
- Analyze matrices using proposed method
- Ensure that calculated recoveries fall in range of 80–110%
- Keep trying until there is success with the chosen solvent extracting the desired analyte

STEP 5: Run Sample Matrix Blank Tests
- Test matrix (i.e., fruit, vegetable, or soil) that is known to be free of analytes
- Eliminate matrix interference in the area where targeted analyte elutes in the chromatogram

STEP 6: Perform Sample Matrix Residue Tests
- Obtain matrix known to be free of targeted compound
- Fortify matrix with targeted compound
- Run matrix through proposed procedure
- Ensure recoveries fall between range of 70–120% (thus, proving that the matrix theory/strategy works)

STEP 7: Determine Method Performance Parameters
- Use results from sample matrix blank test and dry calculations to estimate the mass detection limit (MDL) (thereby determining the parameters of the proposed method, i.e., the minimal amount of the targeted compound that can be detected using the proposed method)
- Fortify sample matrix at estimated MDL

STEP 8: Write Up Experimental Results
- Write the methods and results
- Submit to laboratory quality assurance/quality control (QA/QC) officer for review

With my new understanding of what scientists do and how researchers are working to solve real-life problems, I can show my students that school mathematics and science should not be forgotten when the school year ends.

NTRC is the National Transportation Research Center in Oak Ridge, Tennessee, where Rebecca Brockwell conducted her summer research project.

CHAPTER 3

Making Sense of Science

Rebecca Brockwell

Choosing the Summer Research Opportunity

My research experience began with a nine-hour drive to Oak Ridge National Laboratory[1] (ORNL) for a summer internship program. Because of the need for secrecy and safety during World War II, the Oak Ridge laboratory and town were founded in a fairly remote part of eastern Tennessee. I was able to experience some of the most exciting research in the nation in some of the prettiest country I have ever seen. The weather in Tennessee was beautiful, and although the locals complained about the heat, I never thought it was too warm. An enormous benefit of the location for me was relief from the sweltering Tallahassee, Florida, summer temperatures.

Before I arrived at ORNL, I had completed all of the education methods courses required for graduation as a secondary science teacher. But I really did not feel like I had a complete understanding of many of the science topics and teaching strategies we had discussed. When my ORNL mentor, Dr. David Greene, called before my arrival and said, "We need an education expert," I really felt like they had the wrong person. But it was certainly too late to back out. I was committed to ten weeks of service, and I wanted to leave feeling like I had not only gained knowledge from the laboratory experience, but also that the people I worked with had benefited as well.

I went to ORNL as a part of the Pre-Service Teachers (PST) pilot program,[2] called the Energy Research Undergraduate Laboratory Fellowship (ERULF) program. The Department of Energy (DOE) and the National Science Foundation (NSF) co-sponsor the program. Its goal is "to enhance the nation's source of proficient K–12 science, mathematics, and technology teachers." It was designed to enhance the undergraduate experience of students participating in NSF Collaboratives for Excellence in Teacher Preparation (CETP).[3]

Dr. David Greene was my research mentor. Here we are standing by the car that tests the diesel gasoline.

Participants spend the summer working with a researcher at the national laboratory teamed with a practicing teacher. From the researcher, the pre-service teachers learn about the laboratory, and from the practicing teacher, they learn more about the world of education.

David Greene, a Corporate Fellow of ORNL at the Center for Transportation Analysis, was my mentor. With Dr. Greene and Dr. Janet Hopson, I developed educational materials for the website at [www.fueleconomy.gov]. The website is designed to educate the public to make informed decisions about the cars they purchase. David Staten, a technology teacher at Wartburg Central High School, located not far from Oak Ridge, was the education mentor for the other two pre-service teachers and me. ORNL has employed David for several summers before the PST program began, so David knew his way through the research complex and was able to arrange tours of various areas at the ORNL. This really enabled us to get a feel of the work being done in the laboratory as a whole.

Addressing the Task

When I arrived at the ORNL, Janet escorted me to the National Transportation Research Center (NTRC).[4] She told me David Greene had left a stack of reports for me to sort through. I thought I was well informed about greenhouse gases and air pollution problems when I started the summer program. I soon discovered how little I knew. For example, throughout the 1990s, our carbon dioxide emissions increased, but our gross domestic product (GDP) increased even

I am standing by a poster that highlights the research at NTRC.

faster. This suggests that our economy became less dependent on energy intensive industries over the last decade. We are using more fossil fuels than ten years ago, but we are making better use of them.

After learning about transportation, greenhouse gases, and global warming, I began to think about how my new understanding could be conveyed to high school students. As I was trying to figure out how students could be convinced that their personal decisions *do* make a difference, I realized that each student must conclude that on their own. The realization occurred to me as I was browsing at a website developed by a team at Los Alamos National Laboratories at [http://set.lanl.gov/programs/cif]. To investigate nuclear energy issues, the scientists and web developers had created a series of activities and research projects for students. With in-depth topics designed to provide a semester's worth of work, students can learn about the history of nuclear energy and nuclear terrorism to form their own understanding about controversial and difficult topics. I wondered how I could scale this concept down and apply it to the narrow topic that my summer project required.

Thinking About My Own Project

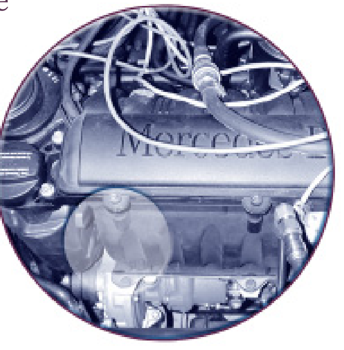
Fuel Efficiency of Automobiles

My project had a narrow focus: how can people be encouraged to choose a more fuel-efficient vehicle when they are ready to make a new car purchase? The goal is not that everyone drive around in subcompacts without air conditioners, but rather that people assess their needs and then consider the most fuel-efficient model to suit those needs.

Choosing a fuel-efficient model at the time of purchase is the most significant choice an individual can make to reduce emissions of greenhouse gases from burning fossil fuels. Plus, it is something that anyone can do. Even if teenagers (like my own students) do not own a car now, chances are that they will in the future. If they can internalize the impact of personal vehicle choice upon air pollution, then when the time comes, perhaps they will make the purchase with emissions data in mind.

I will remember more about what was going on at ORNL when I am in my classroom because I was able to see research projects, hear about them, and ask questions.

One of my first questions upon my arrival was how the fuel economy data are determined. I learned that vehicle tests are run indoors on a machine called a dynamometer that functions like a big treadmill. The car is "driven" by a person who follows a pattern of acceleration and deceleration for a set period of time. The exhaust is collected in plastic bags and analyzed. These experimental values are adjusted to reflect more real-world driving conditions.



Here is our Mercedes test engine.

When I began reading about the greenhouse gases, the status of energy supplies, and global climate changes, something "clicked" for me. I quickly realized that this was an area where high school students could make a big impact. In a meeting with my mentor scientist, I said, "Students don't think that their cars are polluting unless there is black smoke coming from the tail pipe. They don't even know about all the carbon dioxide that is produced and the impact it has." David Greene and I decided that the first thing we wanted students to understand was the amount of CO_2 they produced while driving around in their cars. Each gallon of gas burned produces over 8 kg of CO_2 that has a volume of almost $5 m^3$ at standard conditions.[a] Yet, because this gas is completely odorless, colorless, and generally harmless to people, most of us do not realize the effect it can have on the environment.

I am beginning to see how an effective science lesson or activity can potentially change a student's thinking. If a student chooses to purchase a car with low greenhouse gas emissions over a less efficient car in the same vehicle class, not only would the student save money with lower gasoline bills (and often a lower purchase price), but the emissions over the lifetime of the car would easily be lowered by 20 tons. The idea that such a simple choice could have such an enormous impact was amazing. One of my goals as a classroom teacher is to help my students understand the impact their choices have.

Hands-On Learning

Our attempts to devise a practical and safe way for students to see vehicle exhaust required several trips to the local hardware store. We drew plenty of interest from others working in "real labs" when we headed outdoors with our dryer vent and garbage bags, but we developed a laboratory activity that safely directs students to collect exhaust gases and show that the gases will not support combustion. This laboratory activity fits in nicely with the time-honored method of demonstrating that a lack of oxygen extinguishes a burning splint. Everyone in our group was delighted by the simplicity of the laboratory and the minimal complications and materials required. Even our observers commented that they thought we were doing a "real lab" and were impressed with the significance of the final product.

David Staten was our education mentor. He is a practicing teacher from a nearby high school and has worked at ORNL during other summers.

The activity demonstrates the relationship between engine size and production of greenhouse gases. By adjusting engine speed, students can determine the speed at which these gases are produced while driving. While no one decided to get rid of their full-size pick-up that day and buy a fuel-efficient subcompact car, if hundreds or thousands of students discover the part they play in contributing to the rising levels of carbon dioxide, many more car buyers could make a more informed decision at the automobile dealership.

The Purchasing Reality

Of course, consumers are limited in their purchasing options. Manufacturers may say they produce what people will buy, but as individual consumers, we are at their mercy. We can only choose from the products made available to us. This realization hit home for me when I considered the vehicles I drive. I own two cars of the same model name—one is a 1994 model and the other is a redesigned 2000 model vehicle. When I looked up the numbers for fuel efficiency on the government website, I was shocked to discover that my newer car had a poorer fuel economy! What happened? Since the new car is slightly bigger and more powerful, apparently the extra increases in engine efficiency went to improving the comfort and performance of the car and not to boost fuel economy. Without government regulations, I question whether car manufacturers will be willing to increase the efficiency of their inventory. This is probably because designing engines with increased fuel economy is expensive. Manufacturers may not get enough incentive to conduct the research required to improve fuel economy. It is only when the entire industry is forced to change that increases in fuel economy are seen.[5]

Everything is Political

During my summer at Oak Ridge, David Greene testified before the U.S. Senate about a National Academy of Sciences report[6] he had been working on since February. The report, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, analyzed the fuel economy policies of the United States.[7] The committee documented ways that CAFE standards have been effective and described some of the unanticipated consequences of the fuel efficiency guidelines. For example, the committee reported that the CAFE standards have worked to increase fuel economy over the last two decades, but it was not anticipated that the demand for light duty trucks, minivans, and sport utility vehicles would shift the consumer market away from cars. Watching the hearing was interesting. Most of the session was taken up by the senators' questions, and each senator seemed to preface his or her question with prepared remarks. Apparently, this was a photo opportunity for them, and the proceedings were not focused on the panel members. When David returned, he said that the senators' staff members were attentive and interested, but the senators seemed to know they were in the spotlight when the official hearings began.

Here I am showing the other pre-service teachers and staff from ORNL our previous SERVE Monograph on practicing teachers conducting scientific research.

Role of Practicing Teacher

Perhaps for me, the most interesting part of the PST program was what was made possible by David Staten. David is a mathematics and technology teacher at a nearby high school. He had worked at the national laboratory for several summers and was a natural choice for the master teacher position. Every week, he met with each pre-service teacher individually and regularly arranged activities for all of us. He planned these activities to enhance our understanding of the work being done by the entire laboratory complex. These activities are an integral part of the PST program and greatly benefit the participants. It enabled me to see how the entire laboratory functions.

Weekly Meetings With Other Teachers

Each week, we attended a lecture given by someone working at the laboratory. Often David would arrange a tour that related to upcoming lectures. This gave PST students a distinct advantage over the other students at the ORNL sitting with us in the auditorium. We already had an understanding of the topic and had seen some of the equipment to which the speaker referred. The advantage to me was that it really reinforced the lectures. I will remember more about what was going on at ORNL when I am in my classroom because I was able to see research projects, hear about them, and ask questions.

Tour of Graphite Reactor

Our first tour was to the famous and historic graphite reactor.[8] It was an exciting experience because this was not just a historical place—it was the site of a historical event that determined the world's future. This was the place during the 1940s where the United States developed its nuclear capabilities. During the previous spring at FSU, we had discussed the Manhattan Project in a course on Science, Technology, and Society. I recalled that Oak Ridge formed a part of the nationwide sites to build nuclear weapons, and in less than a year, an entire town was built in the mountains of East Tennessee. I am fascinated that the site of this secret laboratory project was influenced by the depression from which the country was emerging. The location was chosen, in part, because of the access to large amounts of inexpensive electricity generated by the Tennessee Valley Authority hydroelectric plants. Much of the surrounding area lacked electric service before Oak Ridge was built to process uranium.

I was awestruck thinking about the effort required to build not only the reactor, but all the laboratories and housing for the city of Oak Ridge. Here in this remote laboratory complex, scientists revealed the secrets of the atom. How different the world might have been had none of this been built. As a child of the Cold

War, I grew up with the apprehension that another superpower could quickly and completely destroy my own country with nuclear weapons; however, standing before the reactor I realized that this capability is relatively new. It is only recently that humans have had to contemplate the notion that we can destroy ourselves completely. Other societies have fought brutal wars, and some groups of people have been exterminated, but we now have the nuclear weapons to annihilate all life on the planet.

Bringing it to the Classroom

My mentor for my teaching internship, Rick Davies, is a 27-year veteran chemistry teacher at Rickards High School. As a student teacher, it is too early to alter the lesson plans to reflect what I learned at Oak Ridge Laboratory. However, I am eager to discuss current events in my classroom. I hope I can show my students the real-world application of what we are doing in class. For example, we are studying a unit about pollution's effects on the environment. I want my students to recognize that what we are learning in class deals with issues that are affecting their lives in Florida. They need to be informed about the fragility of the Florida ecosystem.

Kissie Anderson was a pre-service teacher in the same program with me.

My summer research experience prompted me to notice some differences between the teacher and the scientist. The following are some of my thoughts:

1. High school teachers "make do" with the laboratory equipment and supplies that are available to schools; scientists do not always use "off the shelf" equipment—they sometimes have to invent the methods and instruments to conduct their experiments.
2. Scientists know that they do not have to be an expert in every thing, so they look for other scientists as resources to solve a problem. They recognize their limitations and accept that it is OK to be wrong. However, the honors students in the classes that I teach cannot accept when they are wrong; they want the right answer and are unsettled when they cannot easily find it.

All high school science teachers should encourage their students to help plan the lessons and laboratory activities. Rather than just doing a "cookbook" laboratory, students can actually help the teacher design a laboratory activity and carry it out. Usually, science students are not given that opportunity.

This poster highlights activities of ORNL related to education.

The problem I found when I try to involve my students in planning what I am teaching in science class is that I have to guide them and keep them focused on the lesson or concept we are learning. I sometimes have to pull them back to the lesson. High-school students' minds tend to drift off to personal issues, such as their social lives, their weekend plans, or what a classmate said or did.

Conclusion

My summer at the ORNL changed my perspective on teaching. I experienced the life of a research scientist. When I combine my knowledge of science and teaching methodology with my hands-on experience at the ORNL and my teaching internship, I feel I will be able to blend the theoretical with the practical. Eventually, as an experienced teacher, I hope to design a classroom environment that combines the best of both of my experiences.

Endnotes

[a] Assuming that gasoline is octane, C_8H_{18}, burns completely in oxygen, O_2, to carbon dioxide, CO_2, and water, H_2O, one can calculate that for each mole of octane, there will be eight moles of carbon dioxide. If one assumes a density of octane of 0.7 g/mL and knowing that a gallon has 3.78 L (or 3.78 dm^3), one can calculate that there would be 8.2 kg of CO_2 product. Using the ideal gas law and standard pressure and a temperature of 300K, there would be 4.6 m^3 of CO_2 gas produced. That volume of CO_2 gas from one liter of fuel would fill a cube that measures approximately 1.7 meters on each side.

Scott Clark, a PST from the University of Tennessee, works on modeling software.

[1] Oak Ridge National Laboratory. [www.ornl.gov].

[2] Pre-Service Teachers Program, with the U.S. Department of Energy: [www.scied.science.doe.gov/scied/PST/about.htm].

[3] National Science Foundation funded program called the Florida Collaborative for Excellence in Teacher Preparation [www.fcetp.org].

[4] National Transportation Research Center, part of Oak Ridge National Laboratory [www.ntrc.com].

[5] Greene, D. L. (1996). *Transportation and energy*, Lansdowne, VA: Eno Transportation Foundation, Inc.

[6] U.S. Senate report on the National Academies' Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards [http://www4.nationalacademies.org/ocga/testimon.nsf/aac7d56ca8fd884b852563be00610639/9e7abd240b48795a85256a9c00641bd6?OpenDocument].

[7] Effectiveness of impact of corporate average fuel economy (CAFE) standards [http://books.nap.edu/html/cafe].

[8] Oak Ridge Graphite Reactor [www.ornl.gov/tour/tour.html] and photograph of reactor at [www.ornl.gov/science-to-life/graphite-reactor.html].

This is the treadmill portion of the dynamometer. The car "runs" on this treadmill, clocking up the miles, while the diesel fuel is being burned in the engine.

CO-LEARNERS in action: (l to r) Sherri Hood (the practicing teacher), Lidia Lanns (the prospective teacher), and Kelly Schratwieser (the scientist), looking at test organisms

CHAPTER 4

Teaching Science is Teaching Life

Lidia Lanns
with M. Randall Spaid

The CO-LEARNERS Program is designed to give practicing and prospective teachers an opportunity to gain hands-on experience within a science research facility in our community. The state Florida Department of Environmental Protection (DEP) was my host research site. Our goal was to displace the teacher-centered strategies typically practiced by high school science teachers (i.e., lecturing, textbook assignments), with student-centered experiential learning. Our focus was to assess an environmental habitat and decide how to improve it.

Practicing teachers, prospective science teachers, and scientists worked together for a six-week collaborative science research experience. We followed a blueprint for success—learning together, practicing real science, and working to find solutions for real problems. We used the discourse of science every day as we collected and studied macroinvertebrates and analyzed data to explain changes in stream ecology. Neither textbook nor traditional laboratory activities could compare to experiencing science as it occurs in nature. In a world where change is our only constant, I decided that teachers must expose students to learning outside the classroom. Effective methods of teaching science have evolved; community involvement is now a critical component for science education in this new millennium. Now I am eager to share the experiences with my own students.

Neither textbook nor traditional laboratory activities could compare to experiencing science as it occurs in nature.

A Look at Experiential Learning Outside the Classroom

I worked in a science laboratory as part of my program at Florida State University. Many of my professors are involved in various research projects. I was interested in working in a science laboratory during the CO-LEARNERS Program because I wanted to gain hands-on experience with tools not available in a normal classroom. Also, I was interested in seeing the methods of collecting data from sample sites and the empirical and inferential statistics used to analyze the data for a scientific report.

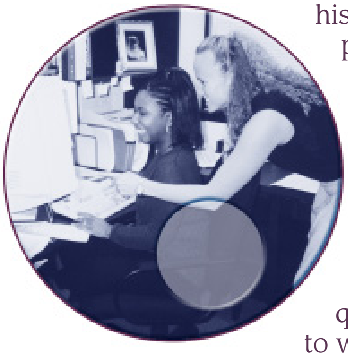
I feel that the difference in the true culture of science and the classroom culture of science is due to the fact that most teachers do not relate concepts to everyday life. This leads to science being characterized as a difficult subject. I view the study of science to be a never-ending journey and scientists to be crusaders looking for answers that are never truly complete.

The scientists at the Florida Department for Environmental Protection (DEP) demonstrated many aspects of scientific research to the teachers in the CO-LEARNERS Program, including accurate biological sampling, methods used for quality assurance, technical writing, habitat assessment, and environmental education. As a prospective biology teacher, my experience at the DEP helped me to grasp the fundamental concepts of biology as I analyzed an ecosystem in its natural state.

Educating the public about protecting our environmental is an enormous, ongoing task. For example, most people do not think about the impact of litter on the groundwater supply. When rain washes items, such as cigarette butts, into a storm drain, water quality may be affected and an ecosystem can be subtly disturbed. To monitor potential problems from storm runoff, ecosystems throughout the state are assessed regularly by the DEP using a 20-sweep dip net method[1] or a 4-sweep dip net method for bioassessments.[2]

My Research Journey with the Department of Environmental Protection

At first, I thought of the DEP's assessment process as using the basic scientific method. I had a question about water quality in a specific body of water—in this case a stream—so I decided to assess the type of habitat. My initial question: What are some possible causes for the water disturbance or loss of taxa within the stream? My hypothesis was that it was due to contamination or runoff affecting the stream. Next, I decided to collect some data about the macro-invertebrates, water chemistry, and turbidity. I planned to research any historical events that may have affected the stream or look for previous assessments of that stream. In addition, I would find the information on an FAC-rated stream[3] with similar structure and similar taxa, in order to compare water quality to a reference site. Then the data would be analyzed to reveal any imbalances.



Kelly Schratwieser, the scientist, is guiding me in analysis of our data on the computer.

Using Macroinvertebrates as Bioindicators

The DEP scientists use macroinvertebrates as bioindicator species[4] because they are easy to collect, and they respond very quickly to disturbances in their environment. Scientists do not have to wait a month or two to test for changes in water quality because indicator species respond very quickly and can show what conditions have been over time. Stream-bottom macroinvertebrates include such animals as crayfish, mussels, aquatic snails, aquatic worms, and the larvae of aquatic insects. It may be difficult to identify stream pollution with water analysis, which can only provide information for the time of sampling. Even the presence of fish may not provide information about a pollution problem because fish can move away to avoid polluted water and then return when conditions improve. However, most stream-bottom macroinvertebrates cannot move to avoid pollution. Therefore, a macroinvertebrate sample may provide information about pollution that is not present at the time of sample collection. We went into the field and made some observations, searched the historical background of that particular site, and compared the data—pH, salinity, water temperature, stream velocity, turbidity (in NTUs)[5]—to a reference site.

We collected other data from "productive habitats"; these are snags (woody debris), rocks, roots, leaf packs and mats, and aquatic vegetation in the water. If there is good habitat, such as submerged roots for them to live in, we will find them, unless there is something out-of-balance in that habitat. Russell (Russ) Frydenborg, one of my scientist mentors, collected bottom sediment and compared the macroinvertebrate species he found to notes from a previous visit he had made there. He noticed that the water level had dropped, and the sediment buildup and new sandbars may be affecting the macroinvertebrate populations.

Working with scientist Kelly Schratwieser, I analyzed our data by identifying and counting the organisms and calculating the dissolved oxygen. I learned that if there is insufficient dissolved oxygen due to uncontrolled algal growth, some macroinvertebrates will not survive. If there is enough turbidity in the water, then sunlight cannot reach certain aquatic plants that the tiny animals prefer to live near. I want to teach my students that a high population of any particular organism may disturb the balance of a water habitat.

Applying to My Classroom What I Learned

After student teaching at Barbara Goleman High School, I graduated in December 1999 with certification in secondary science. I was recruited in January to team-teach sixth-grade gifted students at Everglades Middle School for the remainder of the school year. When I considered teaching gifted students, I thought, "Oh, that's fabulous! They are going to be great kids!" I soon discovered that they bounce off the walls like every other middle schooler; they just may have the potential to learn more. The students soon became adjusted to me working alongside another teacher as I learned school and classroom procedures. My co-teacher and I shared teaching duties. This experience was similar to my internship, but it was more valuable because I was offered a teaching position with these students the following year in my own classroom. The students and I learned what to expect from each other.

One DEP experience that was valuable for me as a classroom teacher was related to environmental science. The hands-on activities and explanations of how ecosystems work, and learning about the food web and how each link is important helped a lot as I prepared my lesson plans. I wish that I could have conducted some of the activities like those we did at the DEP lab, or taken a field trip to local streams, the Everglades, or the canals, but my classes were too large.

Florida offers so many outdoor resources available for hands-on activities. I invited two DEP representatives to visit my class and discuss the geology of South Florida and talk about wildlife in the Everglades. During the recent drought and water shortage, we had experts from the Storm Center come talk with our students about the water shortage and why restrictions are enforced. After the lecture, the students understood that while we may be getting rain, sometimes it may not rain in the right place.

Two practicing teachers, Sherri Hood and Richard McHenry, worked with me and the other CO-LEARNERS at DEP. Here they were collecting biological samples.

New Constraints and Obstacles Arise

With a lot of people are moving into our area, this middle school is close to capacity. Classes are big, and we do not have an empty classroom in the building. I started the year teaching sixth grade, seventh- and eighth-grade gifted, and then was assigned all the rest of eighth-grade students as well. I now have four preps—I teach seventh-grade comprehensive science, seventh-grade gifted comprehensive science, two eighth-grade regular science classes, and an earth-space class.

As a new school, it was the baseline year for my eighth-grade students tested by the Florida Comprehensive Assessment Test (FCAT). This test, which is given each year to students in fourth, eighth, and tenth grades, has always tested reading and mathematics, but will soon include science, as well. Since our students scored in the 88–90th percentile as fifth graders last year, making Everglades an "A" school, the administration wanted this to be an "A" school in all grades. This created stress for our eighth graders to perform, but the results we have received so far have been good. Our students are actually doing better in the mathematics than they are in reading, so we are working on reading and critical thinking skills.

The seventh graders are sharp, so I look forward to next year's eighth-grade class. Because most of them have been in this school since kindergarten, and they know the school and the teachers, it feels like a family. Our science department is small (only three teachers), so my job is stressful. I have to put together portfolios for Dade County administrators, who track new teachers. Another stressful situation is when assistant principals observe my classes. There is a lot of material I did not know about observations when I started working here. Administrators check students' folders and emphasize classroom management. In a class of 42, it is hard to manage the students, especially when I do not have that many chairs. During one of the observations, I had 100 percent attendance, so I had students sitting at the corner of their desks because they could not see the board.

Many additional factors contributed to my stress, making it difficult to implement ideas that I garnered from the CO-LEARNERS Program. It is difficult to be creative and innovative in a class that large. I have PC equipment that I would love to use, but with 42 kids and only three computers, not everyone can have access to a computer for group projects. I would love to form groups of three or four, but when I have so many students, the obstacles can seem insurmountable.

This is a habitat at my school.

Bringing the Environment into the Classroom

During the CO-LEARNERS Program, I picked up many resources to use in my classroom, such as PowerPoint presentations. Russ has a presentation that he uses when he lectures about protecting the environment and what the agency does. This can serve as an outline for my unit on the environment; to me it is the best image of what I want my students to do when they go on field trips. The DEP has a list of environmental sites where teachers can take their students.

I look forward to next year's science fair. I am trying to eliminate the big poster boards and have the students do PowerPoint presentations instead. They were reluctant this year, and many parents objected when I encouraged my students to learn to create a slide show. But once they saw their children pointing and clicking through graphics they put together, the praises came. Initially, I heard the complaint, "We don't know how to use the computer; we just bought it because everyone else bought one....We're used to spending $5 on the big board and decorating it." I explained that there is nothing wrong with being bold, bright, and beautiful, but you can do it on a disk as well. Administration supported me on that. Preparing a PowerPoint slide show was not mandatory, but I did give extra credit for making an attempt to do the science fair project.

I am convinced that science teachers must expose students to experiential learning outside the classroom.

I believe middle school students have a lot of fun going out into a habitat, but safety issues may preclude this. So I attempted to put together my own biological habitat. I started with a large fish tank, pebbles, and aquatic plants, and I tried to create a habitat for students to study as a visual aid. I mixed dried cloves up to simulate the dark water color of a typical stream habitat, prepared leaf packs for the middle of the tank, and placed a lamp over it. I wanted to explain to my students how the environment is self-contained and how water conditions and quality may change due to weather conditions. Unexpectedly, all of the rocks had tumbled over the next day; I explained to the students that this could represent how sediment flows into a stream. We discussed rainfall, runoff, and turbidity levels. My fish tank could not simulate a stream, so I was not able to simulate flow and have my students measure velocity. Perhaps an air bubble pump could be used, but I have to work on it.

Conclusion

The CO-LEARNERS Program was an experience that changed me. Before, I never would have considered donning a pair of waders and stepping into muddy water. That has totally changed. I did it, and I would do it again because if students see teachers excited about going in and not caring about getting dirty, I think they will get excited about doing it themselves. Neither textbook nor traditional laboratory activities can compare to experiencing science as it occurs outdoors. I am convinced that science teachers must expose students to experiential learning outside the classroom.

Endnotes

[1] Macroinvertebrate sampling using a standard D-frame dip net with a U.S. 30 lb. mesh bag. The sampling method consisted of collecting 20 half-meter (in length) discrete dip net sweeps for a given site and combining and sending them to the FDEP Central Biology Laboratory for processing and taxonomic identification.

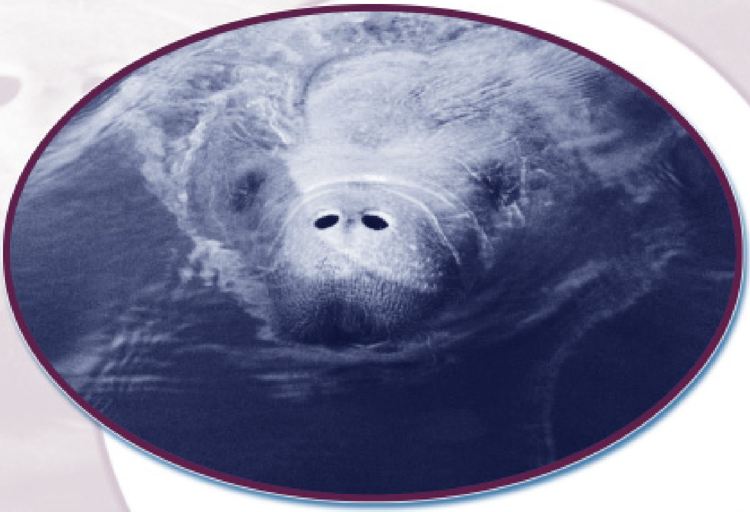
[2] Bioassessments are based on the premise that the community of plants and animals living in an aquatic ecosystem will reflect the health of that ecosystem. When an aquatic ecosystem is damaged, the diversity of animals and plants often decreases, and the composition of species changes. Typically, the organisms that are intolerant to human disturbances die, and organisms that are more tolerant to the disturbance make up a larger proportion of the individuals. For example, the farmed wetland will most likely have fewer kinds of plants and animals than the healthier wetland and will be dominated by organisms that can tolerate poor environmental conditions. After examining an assemblage of plants or animals in aquatic ecosystems ranging from high quality to poor quality, scientists can use this known range as a measuring stick to estimate the relative health of other aquatic ecosystems. The bioassessment results will show if an aquatic ecosystem is damaged in any way. To learn more about biological assessments, visit [www.epa.gov/owow/wetlands/bawwg/biobasic.html].

Here I am learning to identify organisms with Sherri Hood, the practicing teacher. I am on the left.

[3] FAC: The Food & Agricultural Council is an organization of Federal agencies spearheaded by the USDA to coordinate their activities. The Water Quality subcommittee is chaired by the Natural Resource Conservation Service, USDA, and includes participation by other USDA agencies (Forest Service & Farm Service Agency), DOI agencies (Bureau of Land Management, Bureau of Reclamation, Geological Survey & Fish & Wildlife Service), U.S. Army Corps of Engineers.

[4] Once sites are selected, sampling can begin. Typically, researchers sample at least two groups of organisms, including algae, amphibians, birds, fish, macroinvertebrates, and vascular plants. Researchers then measure the number of individuals and the number of taxa that show clear patterns of response to human disturbance.

[5] Turbidity in water is measured in units called NTUs, or Nephelometric Turbidity Units. It is calculated by measuring the dispersion of a light beam passed through a sample of water. Fine particles, silt, and suspended matter will cause a light beam passing through the water to be scattered. It has been found that the amount of scattering is proportionate to the amount of turbidity present. Therefore, this process gives a good indication of the relative turbidity of a water sample.



Here is a Florida manatee up close. She was so close Leslie Magalis could hear the manatee breathing and see her whiskers.

CHAPTER 5

Making Science More Personal

Leslie Magalis
with M. Randall Spaid

My research experience was different from the others in that mine was more of a *potpourri* of opportunities to provide experiences in scientific research rather than one single, in-depth opportunity. This was in part because Dr. Penny J. Gilmer, our CO-LEARNERS Program director, had a hard time finding a scientist who could offer an experience that fit my interests, needs, and timetable; and, in part, because I really wanted a more diverse experience. Therefore, this chapter highlights the key points in my summer of research.

Going on a Road Trip to Central Florida

My journey began with a trip on the bus with about 40 African-American high school students from the FCETP[1] and Florida-Georgia LS-AMP[2] programs. We were on our way to the University of Florida in Gainesville for a tour of the science facilities and then on to Sea World on Saturday. I was impressed with my traveling companions, who were selected for the program based on their high grades. They were bright and had high hopes for their futures. The girl next to me was from Michigan and told me she was studying to become a medical doctor.

Science class activities become more authentic when students can connect them with real-life experiences.

When we arrived at the University of Florida, we headed to a lecture hall in the biology building. Once there, several professors told us about the opportunities in various science careers, such as genomics or genetics research. They described the pros and cons of each field, such as job security and volatility, as well as the financial benefits. For example, with a Master's degree in genomics, one could work for a pharmaceutical company or a related industry and earn from $60,000 to $100,000 in annual salary. In contrast, the annual salary for a university researcher could range from $35,000 to $50,000 annually.

All of us were excited to learn about careers in science. I was interested because I was majoring in secondary science and mathematics teaching. It was my last semester of my senior year. As I listened to what they said about careers in science, I thought about beginning my first day of teaching school with a class discussion about careers in biology or chemistry and the potential salary range that could be expected. I think this knowledge could help motivate my students to do well in science, especially those students who are working at jobs in fast-food restaurants with a minimum wage. The prospect of earning a salary at least 12 times higher than their present income might be an incentive to study harder.

The speakers at the university also emphasized the importance of keeping up with advances in technology and described the sophisticated equipment they provide graduate students for their research projects. Dr. Dan Brazeau was the Director of the BEECS Genetic Analysis Core within the ICBR group[3] at that time. He talked about some of the instruments, such as a microarray technology that maps genes on computer chips. Such chips make it easier to work with the gene sequences. There are also high throughput sequencing machines that order the individual nucleotides in the DNA. The ICBR offers a one-week workshop in biotechnology for graduate students. The participants are taught how to do the science as well as how to interpret it. There are wet laboratories so the students do the laboratory work, learn how to deal with the necessary equipment, and are introduced to analysis programs.

The university also has several very powerful MRI machines, including one worth $1.5 million. These are part of the National High Magnetic Field Laboratory, originating at my own institution, Florida State University, with primary partners at University of Florida and Los Alamos National Laboratory.[4] Many other institutions are associated with this collaborative.

It was fascinating to hear about the advances in technology. One student in the audience asked Dan how he keeps up with the changes; he replied that it is not easy and that he uses the Internet for the most part. One website he mentioned was the Web of Science, an interface for institutional access to the ISI Citation Databases, which includes over 8,000 international journals in the sciences, social sciences, and the arts and humanities.[5]

I hope to involve my students in technology as much as possible. I want them to discover that technology plays a big part in scientific research.

Our faculty tour guide stressed the importance of technology to scientists, and I realized just how important using technology should be in my science classroom. I hope to involve my students in technology as much as possible. Granted, we will not be using million-dollar MRI equipment. However, by devoting some time each week to exploring recent advances in science and technology, I intend to keep them informed. The Internet will be my instructional tool to accomplish this. There are many websites for my students to visit; some feature interactive virtual laboratory activities for students to investigate high-tech equipment. I want them to discover that technology plays a big part in scientific research.

Here I am, holding a small alligator in my hands. I'm on a tour with high school students at the University of Florida .

Assessing the Environment

My experience with the CO-LEARNERS Program also introduced me to Tom Frick, a Senior Chemist for the Environmental Assessment Section for the Bureau of Laboratories at the Florida Department of Environmental Protection (DEP), and Amy Bennett, who also works for the DEP. I learned about the protocols they use to assess the quality of water in Florida's rivers and lakes. As part of their job, they help educate people about fresh water ecology and the problems that living organisms can have when the environment in which they live is polluted by industrial waste, runoff from private land use, and airborne pollutants from as far away as South America.

The DEP staff conduct field trips to nearby rivers and lakes to demonstrate the use of water quality testing equipment such as the Secchi disc. This simple instrument, a metal disc painted with black and white quadrants, is lowered into the water by a rope until the black color quadrant can no longer be distinguished from the white color quadrant. The length of the rope at that point indicates the limit of visibility (the absolute limit of light penetration is about twice our limit of visibility). Pollution and silt from runoff are two factors contributing to poor water visibility. This visual depth reading is an indicator of water quality and shows the depth at which plants may survive as they need light for energy.

Tom and Amy described the larval insects that live in fresh water as indicators of water quality. I joined with some children on a field trip, and they all loved looking for the insects in the water. We learned that some stream-bottom macroinvertebrates, such as certain species of stone fly, feed mostly on decaying leaves and algae and cannot survive in polluted water. Crayfish are sensitive to pollution, too. Other macroinvertebrates, such as leeches and midge flies, may actually thrive in polluted water.

To assess habitat quality, the DEP scientists study a grid of the area for water turbidity, dissolved oxygen levels, and type of leaf litter. In addition, they tally the numbers of bottom-dwelling macroinvertebrates living in a unit of area. They identify them and see how many there are compared to how many should be present to determine whether or not there is a pollutant affecting the populations. They look at the lake or the river to see what it is being used for, how many buildings are around it, and if it is in a commercial, residential, or wild area. Assessing the quality of the habitat helps them determine how many macroinvertebrates can be supported in the body of water. If there are too few macroinvertebrates living in the area, pollution is suspected and further study is warranted.


Manatee dies from watercraft collis

Tallahassee Democrat, July 13, 2000

The scientists talked about how they go about doing their research on the lakes and the rivers and how they try to educate the general public and the school children. They shared some handouts and described a program they designed for high school students, which integrates science field trips and writing about the experiences in English class. This program is similar to the one that Lidia Lanns developed with Sherri Hood for middle school students during the previous summer in the CO-LEARNERS Program. (For more information, see Chapter 4.)

Studying macroinvertebrate populations as a measure of water quality is practical for the DEP and can be conducted by science teachers and students as well. Macroinvertebrates are relatively easy to collect, and because they do not move around much, they provide information about water quality over a long period of time. Testing the water quality of rivers and streams with chemical test kits is only accurate at the time of sampling and may not be practical in the classroom. Netting mosquitofish may not be reliable because they tend to move away from polluted water and then return to the area when conditions improve. Little equipment is needed to survey macroinvertebrates, and best of all, it is great fun to collect and identify them!

Canoeing With the Manatees

As I canoed up a shady tributary, I spotted a pair of manatees. Looking at these animals up close, I was saddened to see propeller scars on their backs.

I went canoeing on the Wakulla River recently, hoping to see one of the 20-to-30 manatees that spend the summer there or in the nearby St. Marks River. I was about to graduate from Florida State University, and this was going to be my last chance to see one of the endangered manatees before moving to Maine in August 2000. Sadly, the 2,600 remaining manatees in Florida are endangered for several reasons: (a) they have a low reproductive rate, (b) they are killed by collisions with watercraft, (c) they are crushed in floodgates and canal locks, or entangled in fishing gear, and (d) the greatest long-term threat to manatees is loss of habitat.

The beautiful, spring-fed Wakulla and St. Marks Rivers are only a 25-minute drive from my home in Tallahassee, so I felt a sense of ownership for these rivers and a strong desire to protect them. My luck was good. As I canoed up a shady tributary, I spotted not one, but a pair of manatees feeding tranquilly on water hyacinths, eel grass, and elodea. I had the privilege of observing them from only a few feet away for two fascinating two hours. Looking at these animals up close, I was saddened (but not surprised) to see propeller scars on their backs. Powerboats traveling too fast most likely caused these scars. Manatees are slow-moving and can easily be run over when they surface for air. Ironically, the propeller scars are so common among manatees that the Florida Department of Environmental Protection uses them to identify individual animals.[6]

A few weeks after my canoe trip with the manatees, Penny told me about a manatee that was found dead in the St. Marks River. The manatee was reported in the *Tallahassee Democrat*[7] to have died from an infection and injuries as a result of a watercraft collision. I felt like one of my neighbors had died. My memory of watching those two manatees casually munching underwater plants was bittersweet when I considered that these enormous, gentle animals may become extinct in the wild within my lifetime.

Hands-on Science Activities Are More Authentic and Interesting

As a future biology teacher, I have long believed that hands-on experiences can make learning more fun and interesting for students. Fifth grade is when I really became interested in science. One day I remember doing testing for carbohydrates with an iodine solution, and I thought, "Wow! This is cool!" Unfortunately, in my school experience, students mostly observe things that the teacher demonstrates. I think that some physics students think the teacher is a magician.

As a future biology teacher, I have long believed that hands-on experiences can make learning more fun and interesting for students.

How to Bring Similar Experiences to My Students in Maine

In Maine, provided the rivers and lakes have not frozen over, I intend to conduct field research with my students. I plan to contact the Maine DEP and find out all that I can about the local water quality, macroinvertebrate populations, and other biological indicator species that we can study in science class. The local watershed and environment will become my teaching laboratory. Science class activities become more authentic when students can connect them with real-life experiences. I will be teaching in an area of Maine where the Penobscott River is being polluted by at least one paper mill in the town. I want to teach my students a variation of the kind of work Ed Orlando,[8] a former science teacher-turned-doctoral student at the University of Florida (UF), conducted on the Fenholloway River. There is a paper mill on the river that has allegedly been introducing androgenic substances to this river for many years.

Leslie Magalis, a participant in the CO-LEARNERS Program of the Florida Collaborative for Excellence in Teacher Preparation

When I met Ed, he was studying the effects of pollutants from the paper mill upon alligator embryos. Researchers at UF found that they could control the sex of the alligator hatchlings by manipulating the temperature of the egg. In his study, if they incubate the eggs at 30°C (86°F), they produce a female hatching. However, if they expose the eggs to the paper mill chemicals at the same temperature, then the hatchling is a male. This same sort of effect may be happening in the wild.

Ed told us that mosquitofish can be used as a bioindicator of the river's health. Researchers have collected female mosquitofish (*Gambusia holbrooki*) living downstream from this mill and discovered that they express male secondary sex characteristics (e.g., altered anal fin and male reproductive behavior). Previous studies suggested that in the papermill, effluent—an androgenic substance—was produced from the microbial conversion of phytosterols. These scientists have confirmed that water samples collected downstream of the paper mill contain a substance from the paper mill, which can interact with the human endocrine system. The studies suggest that chemicals polluting the environment can bind the human androgen receptor (HAR) and may induce masculine gene expression in humans.[9]

I wonder if the paper mill in Maine is polluting the river with the same kinds of chemicals. I will contact the Maine DEP and learn about bioindicator species and take my students on field trips to study the health of the Penobscott River and several nearby lakes. Perhaps my students will feel some ownership of their learning experience and get a feel for the interconnectedness of humans, industry, and the natural environment.

The Value of Doing Real Science

I enjoyed the CO-LEARNERS Program very much. Combined with my own experiments with hermit crabs at the FSU Marine Laboratory with Dr. William Herrnkind, I have worked alongside real scientists and conducted real science research. I believe that all scientists are driven by curiosity; the way that they satisfy this curiosity is through using the scientific method.

I feel that I have a strong connection to doing science, and I know the value of trying to do real science and getting in touch with scientists in the local area and having them talk with my students. I want them to experience "real science," too.

Perhaps my students will feel some ownership of their learning experience and get a feel for the interconnectedness of humans, industry, and the natural environment.

Although it may not be practical or realistic to expect to take a large class out canoeing with manatees, it is possible to take a class outside to observe the natural world. There are fascinating creatures that inhabit the school grounds, including the many species of insects, annelids, snails, amphibians, reptiles, birds, mammals, plants, algae, and even soil bacteria. I think that canoeing with those manatees made me want to learn more about them because they became a real part of my understanding about the environment in which I live.

There is something about observing an animal in the wild that makes me want to learn more about the creature; perhaps it is an element of ownership here that I have never found in a zoo. Learning about the living organisms that exist in our own back yard is inexpensive, immediate, and hands-on, and can give my students the opportunity to appreciate a part of the natural world that they may have taken for granted. My students may have a natural curiosity about the living world around them, and they may discover the quality of ownership that for me makes learning science more real and more important.

Editor's Note

Leslie graduated with a bachelor's degree in Secondary Science and Mathematics Teaching from Florida State University with an emphasis in chemistry and biology. After graduation, she moved to Lincoln, Maine, where she taught an integrated classroom setting for high school special education students. She is just finishing her second year of teaching ninth- through eleventh-graders in earth science, biology, and chemistry.

Endnotes

[1] Florida State University works with ten other universities on the Florida Collaborative for Excellence in Teacher Preparation (FCETP). This program is a collaborative between the Florida Department of Education, 11 of Florida's colleges/universities/community colleges, and a number of K–12 school districts. The goal is to recruit and educate outstanding scholars to teach mathematics and science. It provides students an opportunity to develop their abilities to become outstanding teachers [www.fcetp.org].

[2] The FGLSAMP (Florida Georgia Louis Stokes Alliance for Minority Participation), open to minority students, has a pre-freshman summer program of mathematics and sciences. The program is designed to strengthen the students' skills and expand their career opportunities and is funded through the National Science Foundation [www.fg-lsamp.org].

[3] BEECS is the acronym for the Biotechnologies for the Ecological, Evolutionary and Conservation Sciences Biotechnology Program at the University of Florida [www.biotech.ufl.edu/%7Epccl/beecs/beecs.html]. It includes the Interdisciplinary Center for Biotechnology Research (ICBR) [www.biotech.ufl.edu].

[4] The National High Magnetic Field Laboratory is online: [www.nhmfl.gov]. Of particular interest to teachers, there is an excellent site for curricular materials on magnets,

optics, and tobacco. In addition, there is information concerning the summer program, Research Experiences for Teachers.

[5] ISI Citation Databases [www.isinet.com/isi/products/citation/wos].

[6] The Florida Fish and Wildlife Conservation Committee recently produced and has made available two ten-minute videotapes on manatees. One is entitled, "A Closer Look at Manatees," and the other is, "The State of Manatees." Both are excellent.

[7] The *Tallahassee Democrat* published an article entitled, "Manatee Dies from Watercraft Collision" by Bruce Ritchie on July 13, 2000.

[8] Edward Orlando studied at the University of Florida for both his undergraduate and graduate degrees. He conducted his doctoral research on the reproductive physiology of the largemouth bass and the longnose gar in the Escambia and Blackwater Rivers in Florida. He has done other research with a variety of aquatic species under the auspices of the U.S. Environmental Protection Agency and has taught classroom and laboratory courses, as well as mentored undergraduate senior theses. He currently teaches at St. Mary's College of Maryland.

[9] Effluent from a paper mill discharging into the Fenholloway River, Taylor County, Florida, USA, contains chemicals that masculinized females of the resident population of eastern mosquitofish, *Gambusia holbrooki*, as evidenced in females by elongated anal fins, normally a male-specific trait. To identify androgenic components in the effluent, free-flowing water was collected from the Fenholloway River and a control tributary in acid-washed carboys. Water samples were filtered through acid-washed glass wool and fractionated using C-18, solid phase extraction (SPE) and high-performance liquid chromatography (HPLC: 20%-100% acetonitrile gradient in 0.25% H_3PO_4).

The 80% and 90% methanol SPE fractions induced human androgen-receptor-dependent transcriptional activity in transient transfection cell culture assays. From these SPE fractions, two fractions collected from HPLC gradients induced androgen receptor transcriptional activity. Of these androstenedione was confirmed by liquid chromatography mass spectrometry (LCMS) with multiple reaction monitoring and was quantified by HPLC at concentrations of 0.14 nmoles/liter of effluent. See Jenkins, R., Angus, R., McNatt, H., Howell, M. W., Kemppainen, J. A., Kirk, M., & Wilson, E. (2001). *Androstenedione is Present in a River Containing Paper Mill Effluent and Masculinized Fish* [http://e.hormone.tulane.edu/e2000/posters-2000/2k-Poster-14.pdf].

Underwater photo of fish taken at Sea World

CO-LEARNERS team of (l to r) Mary Hartsfield, the practicing high-school teacher; Gregory Preston, the pre-service teacher; and Dr. Jim Ladner, from the Florida Geological Survey

CHAPTER 6

Teaching and Learning Science: A Team Approach

Gregory Preston
with M. Randall Spaid

Introduction

When I began the summer CO-LEARNERS Program at the Florida Geological Survey (FGS, part of the Florida Department of Environmental Protection), I was confused by the scientific terminology that research geologist Jim Ladner was using. I knew what cryogenics was, by definition, a branch of physics that relates to the production and effects of very low temperatures. However, I had never actually seen anyone use liquid nitrogen that boils at atmospheric pressure at 77 K (or -196°C or -321°F). It is very, very cold! After having the opportunity to go out into the field and help collect cryogenic core samples using liquid nitrogen, I felt much more comfortable with the language that he was using to describe field tests the FGS conducts.

As I helped collect data alongside Jim and my teacher-mentor, Mary Hartsfield, I began to think of ideas for applying what I was learning for use in my future science classroom. My summer with the CO-LEARNERS Program could be reflected in my lesson plans, hands-on activities, and PowerPoint slide shows, which illustrated my personal experiences with the Florida Geological Survey and the Florida Department of Environmental Protection. Working with the scientists and a veteran science teacher required my focused attention but was quite enjoyable.

"By taking part in the CO-LEARNERS Program, I planned to enter student teaching with a substantial amount of confidence due to these hands-on experiences."

The CO-LEARNERS project is a pilot program designed to link practicing and prospective science teachers with science researchers. Scientists from the Florida Department of Environmental Protection (DEP) and the Florida Geological Survey had an opportunity to interact with science teachers and discover a teacher's perspective of what scientists do. The prospective and practicing teachers and scientists learned from each other, hence the term CO-LEARNERS.

The CO-LEARNERS Program

Collecting SET Data with the FGS

Only a few days after meeting Jim and Mary, we left on an excursion to Port St. Joe to take "SET readings" for the Florida Geological Survey. For a SET (Sediment-Elevation Table) reading, a benchmark pipe is driven into the marsh soil to a depth of three-to-six meters, which forms the base for the table. Changes in elevation of the marsh surface relative to the bottom of the benchmark pipe and are measured by lowering pins from the SET to the marsh surface. This technique measures both surface and subsurface processes occurring between the surface and the bottom of the pipe. The difference in rates between the SET and the marker horizon provides an estimate of the rate of subsurface processes or what is called shallow subsidence. We recorded the water elevation at each point for comparison to previous measurements.[1]

To avoid disturbing the soil structure, we used cryogenic coring and marker horizon techniques. A "bullet" was used to inject liquid nitrogen into the ground; the frozen core was then pulled out and examined. The level of sediment accretion (i.e., growth by external addition or accumulation) was then measured for comparison with the last coring.

Working with Mary and Jim molded my entire outlook on the field of science. They were able to make the fieldwork exciting and understandable to me, and in turn, I helped them by offering my own knowledge. Being fairly computer literate, I was able to simplify some of the computer lingo for constructing

PowerPoint presentations and Excel spreadsheets for Mary. She hoped to incorporate more computers and technology in her classroom. I was able to describe to Jim the world of science through the eyes of a prospective science teacher and current undergraduate student. Jim was very cooperative, and Mary helped me envision learning activities for students. Feeling pleased with my overall experience at the Florida Geological Survey, I began a new journey into science at the DEP.

Constructing a PowerPoint slide show for my CO-LEARNERS Program presentation had an impact on me——I found out that I have somewhat of a creative side.

Assessing Stream Habitat with the DEP

At the main facility of the Florida Department of Environmental Protection, I met Tom Frick, Senior Chemist; Kelly Schratwieser, a staff biologist; and Russell Frydenborg, a staff administrator. I learned how to conduct a habitat assessment to determine the "health status" of a body of water, such as a stream. The procedure is partially based upon a scoring system of the number and types of plants, animals, and organic substances that are present. Factors such as bank stability and vegetated riparian buffer zones, along with other factors, also contribute to scoring.

First, we measured a 100-meter stretch of terrain. Second, we divided the stretch into ten-meter sections. At this point, a "trained observer" drew the terrain to scale while moving upstream, illustrating the number of physical characteristics recognized along the way: roots, snags, and leaf packs. After determining the percentage of each stream characteristic based on scaled size, the observer then recorded the percentage in which they exist in the stretch. Finally, the chemical characteristics were added to the scoring of the habitat. I helped by weighing each sample that was collected from the stream while a coworker was responsible for titration and chemical testing.

Practicing teacher, Mary Hartsfield, is titrating some chemical samples.

I was interested in the protocols these DEP scientists used to assess the terrain, and what criteria they used to select a section of the stream for testing. How did they decide where to test for turbidity? Which section of the stretch would be chosen to gauge the snag habitats? Russ explained that he chose to work in the middle of the stream because, based on his previous experience, the water drained into the middle. He began collecting his samples 50 meters downstream from the beginning of the stretch.

Transferring My Field Experiences to the Science Classroom

I wondered how I was going to apply these field experiences to my science classroom. I decided that it is possible to feature these stream assessment activities during a field trip and to have the students take part in the science firsthand. As Mary and I discussed the possibilities, I made plans to visit Mary in her classroom during the fall semester to see her in action as a teacher. By taking part in the CO-LEARNERS Program, I planned to enter student teaching with a substantial amount of confidence due to these hands-on experiences. I even considered graduate school and earning a Master's degree in science education.

I had my teaching internship at Barbara Goleman Senior High School in Miami and graduated during the following spring semester. My internship supervisor taught six periods, and I was assigned to teach four periods of anatomy and physiology. My supervisor was the department head, so her responsibilities became mine. For instance, the teachers came to me asking for keys to the stockroom, so I got a taste of everything that school teachers do.

During my internship, there was at least one computer in every classroom, there were white boards instead of chalkboards, and the TVs could be connected to the computer. The experiences that I had in the CO-LEARNERS Program during the summer had only a minor influence on my teaching because I was teaching anatomy, but I had my students work with PowerPoint. They really enjoyed it. When I shared my experience with FGS and the DEP and showed them my slide show presentation, they were awestruck.

Teaching with a New Understanding

The Culture of Science

The culture of science has no limitations, whereas, with the culture of classroom science, a teacher is limited to his/her available resources for facilitation. The collaborations provided a means for me to understand what was being done on a more technical level. It is easy to teach something straight out of a book, as I learned during my internship. However, by actually doing something hands-on, one truly gains a better understanding. I have made a few contacts with two other scientists—an astronaut and an engineer—and had them present to my internship class.

Dr. Jim Ladner is the practicing scientist who worked with me.

I don't think my student teaching experience enabled me to see what teaching is truly like. I say this because when I got my own classroom the following fall, I wasn't given the same resources with which to teach. I had a computer, but it was nothing like what we had at Barbara Goleman. So I had to really improvise.

I had my students do a lot of laboratories because I wanted them to do hands-on activities. The students loved me for that. I always wanted one of those microscopes where you can display slides to the entire class. I never got around to getting it, though, because I got moved to teach sixth grade. I was teaching six periods in a row with no planning period. The classes of 35-to-40 students were too much. I couldn't continue teaching because of the outside demands, like all the paperwork that I had to do, plus taking night classes at the same time. It was beginning to overwhelm me. I had students there with psychological problems, and I did not feel that the administration was supportive of new teachers. I taught there for five months before deciding to resign and start working toward a Master's degree in information technology.

Conclusion

Exploring Career Options

In deciding which graduate school to attend that would provide the best training in computer science, I chose a program that emphasized a collaborative approach to learning, just like the CO-LEARNERS design. I have discovered that collaboration is the model utilized for project work in industry—everybody teams together. In every graduate school class, we use a collaborative approach to complete course projects. We have learned to lean on each other's strengths and take turns being the team leader. I am amazed that I now have other graduate students looking to me for advice. Constructing a PowerPoint slide show for my CO-LEARNERS Program presentation had an impact on me—I found out that I have somewhat of a creative side. When I first transferred to Florida State University, I had no idea even of how to turn on a computer, let alone use it. Look at me now—I'm writing computer programs!

I still have an interest in science, and because I like to write computer programs, I am thinking about writing a program for optometrists to identify a disease based on the patient's symptoms. That's something that I'm going to be working on within the next year or so. Although my summer experience with CO-LEARNERS Program will not be reflected in school lesson plans and hands-on science activities, working with a veteran teacher and with the scientists from the Florida Geological Survey and Department of Environmental Protection gave me a new perspective toward problem-solving and critical thinking. The collaborations provided a means for me to understand what was being done on a more technical level. I think the desire to teach is still in my blood. I definitely want to stay in the school system in some capacity, perhaps at the high school or college level.

Endnotes

[1] Sediment deposition, plant growth, decomposition, and subsidence are measured in regionwide field studies to complement laboratory experiments. Data are compared to local rates of sea-level rise to determine the potential for coastal marsh submergence.

Several innovative field methods are employed for this program. Surface accretionary processes are measured from artificial marker horizons. To minimize disruption of these horizons during coring, we use a cryogenic coring apparatus that freezes the marsh, allowing the removal of only a small segment of the substrate while still maintaining soil stratigraphy. Surface elevation change is measured with a Sedimentation-Erosion Table (SET). A benchmark pipe is driven into the marsh soil to a depth of three-to-six meters and forms the base for the SET. Changes in elevation of the marsh surface relative to the bottom of the benchmark pipe are measured by lowering pins from the SET to the marsh surface. This technique incorporates both surface and subsurface processes occurring between the surface and the bottom of the pipe. The difference in rates between the SET and the marker horizon provides an estimate of the rate of subsurface processes or what we call shallow subsidence.

Our findings indicate that the assumption of a one-to-one relationship between vertical accretion and surface elevation change is too simplistic a generalization of the complex interactions between accretionary and substrate processes. In many marsh types, particularly those with highly organic or deteriorating mineral substrates, surface elevation change is lower than the vertical accretion rate. In some cases, the two processes appear to be completely decoupled. Consequently, the potential for coastal marsh submergence is often being underestimated and should be expressed as an elevation deficit based on direct measures of surface elevation change rather than accretion deficits. These findings also indicate the need for greater understanding of the influence of subsurface and small-scale hydrologic processes on marsh surface elevation [www.nwrc.usgs.gov/set/elev.html].

6

I was out in a boat measuring
the depth of the river sediments.
I saw nature in all its
beautiful form.

Lori Livingston Hahn is the graduate student (at FSU) evaluator of the CO-LEARNERS Program at the University of West Florida. Lori is with M. Randall Spaid.

CHAPTER 7

Making Connections to Science Through the CO-LEARNERS Program

Lori Livingston Hahn

Introduction

Development of an Experiential Program

Providing courses in which future classroom science teachers actually "do" science in a research setting as opposed to those that are lecture-driven, text-book-dictated, and laden with "cookbook" science experiments should be the goal of any teacher preparation program. In fact, this is exactly the type of science classroom that current U.S. national science standards recommend for the K–12 classroom.[1] We teach the way that we are taught, so why aren't teacher education programs teaching pre-service science teachers the way that current standards and research suggest they should teach? SWEPT (Scientific Work Experiences for Programs for Teachers) programs,[2] such as the one at Columbia University,[1] have demonstrated over several years that such experiential science programs have a positive effect on in-service science teachers and their classroom instruction strategies.[4] The redesigning of teacher preparation programs should include experiential programs for pre-service science teachers.

Co-Learning, Collaborating, Researching, and Teaching

As a doctoral student in Science Education, I conceptualized the notion of a program in which pre-service science teachers could work alongside practicing science teachers and science researchers. The impetus for this idea was based on my own scientific work experiences as a practicing middle school science teacher. These experiences made a major impact on my classroom teaching, as well as my understanding of teaching and learning science. Under the guidance of my major professor, Penny J. Gilmer, I was able to make this concept a reality. Dr. Gilmer and other colleagues of hers were developing a major grant proposal to the National Science Foundation for one of the Collaboratives for Excellence in Teacher Preparation. My idea, which evolved into the CO-LEARNERS (**C**ollaborative **O**pportunities—**L**earning **E**xperientially and **R**esearch u**N**iting **E**ducators and **R**esearchers of **S**cience) program, was a pilot project of the Florida Collaborative for Excellence in Teacher Preparation (FCETP).[5] FCETP, a statewide initiative funded by the National Science Foundation, seeks to improve science and mathematics teacher preparation programs across the state of Florida through collaborations with community colleges, universities, secondary schools, and other agencies. The retention and professional development of in-service science and mathematics teachers are goals of the FCETP, as well.

"All three sets of participants (i.e., the pre-service teacher, the practicing teacher, and the practicing scientist) made significant contributions towards the enhancement of science and mathematics education within their teams."

Through the CO-LEARNERS Program, an experiential science course was offered to undergraduate teacher education students at two participating state universities. In-service middle- and high-school teachers, as well as research scientists, serve as mentors for the pre-service teachers.

During the second summer, there were two teams of teachers in Tallahassee and three teams in Pensacola where I am located. In Pensacola, two of the pre-service participants from the first summer participated again but in a different research project. Both were eager to have the opportunity once again to be a part of science research. One of the participants, Christy Tarter who had a second opportunity to conduct research, is included in this monograph (Chapter 9), while the other participant was unable to contribute to the writing of this monograph due to personal matters. I have mentioned some of his accounts in this chapter, however.

I was not involved in the CO-LEARNERS Project during the third summer. We had only practicing teachers with science researchers. The experience of one of the science researchers from Pensacola (Jan Macauley in Chapter 10) is included in this monograph. Her chapter has a different twist because she, as a practicing scientist, has become interested in teaching science, perhaps at the university level.

"If pre-service science teachers have only been taught using textbooks, lecture, and cookbook-type laboratories, then can we truly expect them to allow students to experience science inquiry in their classrooms?"

At one university, all teacher participants, both pre-service and practicing, were middle-school science educators. Teacher participants at the other university were mainly high-school educators, with one middle-level educator.[5]

The Science Researcher's Role

The science researcher's role was to mentor the in-service and pre-service science teachers with respect to science content acquisition, to expose them to the nature of science through the research, and to provide them with an opportunity to become immersed in the culture of science. All researchers of science worked either in a university research setting or at a state governmental agency. These researchers were not paid by the grant, but voluntarily agreed to mentor the educator participants.

Pre-service Teachers as Researchers

At the University of West Florida site, pre-service teachers—for their course requirements—were to complete the following:

- A paper describing their research and how this research can help with their classroom
- A lesson plan that was based somewhat on the science research; the plan was coded to the Sunshine State Standards in science (The lesson plans have been compiled and will be posted on the SERVE website [www.serve.org] in conjunction with this monograph)
- Research, as assigned by the researcher(s)
- A reflective journal (only required in the second summer)

Students were encouraged to participate in local and national conferences. Christy Tarter, one of the pre-service teachers, helped to prepare a PowerPoint presentation and discussion at the Florida Collaborative for Excellence in Teacher Preparation annual symposia in Tallahassee and Orlando, Florida.

Students at the Florida State University site were required to present either a poster or a PowerPoint slide show on their research at a citywide meeting of science teachers.

We paid the in-service science teachers a small salary at both sites, while at one site we offered the pre-service teachers three hours of course credit and a tuition waiver for their participation. The in-service science teachers provided the pre-service science teachers with pedagogical assistance in translating their summer research experience into classroom lesson plans. The pre-service science teachers, too, helped in-service teachers with instructional technology and exposed them to current education research.

All three sets of participants (i.e., the pre-service teacher, the practicing teacher, and the practicing scientist) made significant contributions towards the enhancement of science and mathematics education within their teams. This was accomplished through a collaborative and sharing process. Throughout the entire research, each participant, including me as the doctoral student conducting the evaluation, assumed the role of learner; hence, the acronym, CO-LEARNERS.

Programs or alternative courses, such as those offered through the CO-LEARNERS Program, could prove very beneficial to pre-service science teachers in a myriad of ways. It is my opinion, based on the interviews and the writings of the pre-service teachers in this monograph, that the re-designing of teacher preparation programs should include experiential science courses for pre-service science teachers.

The chapters offered in this monograph are the stories in the voices of the pre-service teacher participants in the CO-LEARNERS Program.

Christy and Paige look at the seagrasses at the DEP. A "team" discusses their project on sea grass cloning.

For the third summer of the program, the pre-service part of the program was different in two respects. At the University of West Florida, only in-service teachers participated with the researcher, Jan Macauley, in the CO-LEARNERS Program. We had one Florida State University pre-service teacher who was accepted into the Pre-service Teacher Internship Program, sponsored jointly by the Department of Energy (DOE) and the National Science Foundation (NSF).[6] Rebecca Brockwell participated in research at Oak Ridge National Laboratory (ORNL)[7], a national facility that is part of the Department of Energy. Rebecca Brockwell writes of her experiences at Oak Ridge in Chapter 3. The DOE-NSF Pre-service Teacher Internship Program at ORNL was similar to our CO-LEARNERS Program, but with one practicing teacher facilitating three pre-service teachers rather than one practicing teacher per pre-service teacher.

Intra-University Collaboration

Collaboration

Penny J. Gilmer (at Florida State University) and I (at University of West Florida) collaborated on the design and implementation of the CO-LEARNERS Program in order to provide pre-service teachers an opportunity to experience authentic scientific research.[8] Bringing the in-service science teacher and science researcher into the learning community has brought the cultures together, enabling the pre-service teacher to understand the nature of science, experience the culture of science, and demonstrate how "science" can be brought into the classroom. We provided an opportunity for the in-service teachers to be immersed in this contextual learning experience as well. For many of the teachers, this was their first experience in a scientific research setting.

University-School Collaboration

According to the National Science Board, only 63% of high-school science teachers and 17% of middle-school science teachers hold undergraduate degrees in science.[9] These data suggest a limited background in science for our in-service secondary school science teachers. Besides not having the formal coursework in science, most in-service science teachers we interviewed indicated that they have little or no science research experience prior to teaching science in the classroom.

In other teaching fields, the teacher has at least experienced his/her subject within a contextual situation. For instance, it is rare to find a physical education teacher or coach who has never participated in sports. Many English teachers are writers. Band directors are often proficient with several musical instruments, while art teachers have painted, sketched, or sculpted. However, many science teachers with whom I have communicated may have experienced science only through textbooks and laboratories with instructor-assigned experiments. They have never experienced scientific research. We found this generally to be the case with our in-service teachers, as well.

Evaluation Questions

Based on the findings of the pilot study, as well as the stories of the participants, my evaluation focuses on the following three questions:

- How do pre-service science teachers gain content knowledge through science research opportunities?
- How do pre-service teachers gain access to the scientific community through collaborations with researchers of science?
- How can the immersion of the pre-service science teachers into a constructivist-based contextual learning experience in science change their beliefs and teaching practice?

Significance: A Different Way to Learn

A new element to the collaboration is bringing the pre-service teacher into the collaboration with practicing teachers and research scientists. This work builds on the studies edited by Kielborn and Gilmer, in which in-service teachers wrote about their experiences working alongside with research scientists in scientific research.[10] The earlier monograph in this series examines how scientific work influenced in-service teachers' beliefs about science, and some cases looked at its influence on how the teacher taught science and how their students learned science.

Two students are constructing their project.

Future science teachers must be taught the ways that current research suggests they teach their own classrooms. We tend to teach in the way we are taught. If pre-service science teachers have only been taught using textbooks, lecture, and cookbook-type laboratories, then can we truly expect them to allow students to experience science inquiry in their classrooms? Pre-service teachers must also be exposed to the many community resources they can use with their students. Immersion in a scientific research setting enables them to experience the culture of science, explore the nature of science, acquire science content in a con-structivist-based learning environment, and gain access to the variety of community science resources that are available to them.

Fosnot asserts that teacher education programs should provide opportunities for teachers' beliefs to be illuminated, discussed, and challenged.[11] Fosnot planned a program for pre-service teachers to engage in learning experiences that confront traditional beliefs. She also encouraged field experiences in which pre-service and in-service teachers can experiment collaboratively. Her approach to teacher education stresses the involvement of both pre-service and in-service teachers in processes of their own learning, cooperative fieldwork, and reflective fieldwork.

The design of the CO-LEARNERS Program incorporates Fosnot's approach and adds contextual learning in a scientific setting as a component of the collaboration between in-service and pre-service teachers. We blended the research of Fosnot and the positive results of SWEPT (Scientific Work Experiences for Practicing Teachers) programs from across the country. CO-LEARNERS Program is a model vehicle for meaningful change in pre-service teachers' beliefs about the culture and nature of science, as well science content acquisition and the establishment of a community resource base through collaborations with science researchers and their affiliated research sites.

Theoretical Framework

The theoretical framework of the CO-LEARNERS concept is that of a constructivist epistemology. According to Glasersfeld,[12] constructivism emphasizes that knowledge cannot be separated from knowing. We do not receive knowledge passively, but we, as cognizing subjects (i.e., the learners), construct it, based on our prior experiences. In constructivism, science knowledge is not something that teachers possess and transfer to students through lecture, the reading of textbooks, and paper and pencil activities. Instead, students construct science knowledge (as do science teachers and researchers) to make sense of their world. Students construct their own meaning based on past experiences and words or visual images they hear or see.

The immersion of teacher participants into the nature and culture of science in CO-LEARNERS Program enables teachers to experience constructivism first-hand. This would hopefully aid in their formation of empathy as a learner. In this case, the teacher has empathy for a student/learner. This growing empathy will hopefully catalyze a change in their own thinking about teaching and learning, and ultimately the teaching of science and/or mathematics in their respective classroom. This would include more constructivist-based teaching and contextual learning experiences for their own students.

Methodology

Giving Voices to the Participants

As one of the evaluators of the CO-LEARNERS Program, I am utilizing the methodology of fourth generation evaluation outlined by Guba & Lincoln,[13] using a qualitative methodology as discussed by Erickson.[14] Denzin and Lincoln state the following:[15]

> *Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret phenomena in terms of, the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials—case- study, personal experience, introspective, life story, interview, observational, historical, interactions, and visual texts—the described routine and problematic moments and meanings in individuals' lives. (p. 3)*

Two students construct their own meaning based on past experiences and words or visual images they hear or see.

One of the most significant and meaningful aspects of studying an educational environment with qualitative research is that it gives each participant a "voice."[15] Quantitative studies are objective in nature and tend to reject the significance of the participant's learning process and reflections, relying mostly on numbered data and statistics. The voices of the pre-service teachers in this study are critical in regard to improving teacher education programs and, thus, classroom science for our children. Ignoring the perspectives of educators and students may be detrimental to an educational system. Education evaluators cannot rely totally on test scores, numbers, and other statistics without listening to the voices of individuals who can provide valuable insights in the new context.

Pre-service secondary science teachers authored chapters two through six and eight through ten in this monograph. In this chapter, I have included some of the voices of the pre-service teachers, the practicing science teachers, the researchers of science, and other participants who are not authors in this monograph.

Learning Science Content Within a Contextual Environment

One of the criticisms of science education in the United States cited in the 1997 TIMSS report was that U.S. teachers try to cover "too much information."[16] The TIMSS report is consistent with what I emphasize. Teachers teach "too much content" because standards and standardized testing (such as FCAT) mandated by the state dictate that they must.

The CO-LEARNERS Program places each participant in the role of teacher, learner, and researcher in a contextual learning environment. Contextual learning in science is learning in the context of doing, thinking, speaking, and experiencing science.[17] Within the context of science, each participant is immersed in the nature and culture of science through his/her interactions with other scientists.[18] This context involves using the equipment to accomplish the scientific procedures, the language of science to converse with others conducting the research, and analytical thinking skills to make sense of the research.

Rick Harter, a DEP scientist, demonstrates an "invention" used in the laboratory. Teachers learned that scientists must improvise when budgets are limited, just like teachers do!

To help illustrate this acquisition of science context, I will use voices of some of the participants of the summer programs. Gregory Preston, a pre-service teacher, who wrote Chapter 6 of this monograph, demonstrates his ease with the language of the science used at his research site at the Florida Department of Environmental Protection:[19]

(Excerpt from Gregory's writings):

One such activity involves taking SET site readings. SET stands for Sediment Erosion Table. The purpose of taking such readings is to determine water elevations of various marshes throughout North Florida. The degree of shifting will help in the determination of what may have accounted for such movements. In conjunction with this technique is a procedure known as Cryogenic Coring. Liquid nitrogen is injected into the ground through a pipe, causing the ground to freeze. Analysis of the frozen core determines the level of sediment accretion. These results were recorded in a spreadsheet format and then were graphed. They suggest that the majority of estuaries in this area contain limited sediment input from offshore sources and minimal sediment contributions from those rivers draining the region.

The research that Gregory conducted is part of recent coverage in the *New York Times* on how geologists use the sediment record to reconstruct the history of past hurricanes.[20] Prior to his summer research experiences, Gregory was described by one of the professors as "shy and very quiet." In describing one of the activities from his research, Gregory appears to be much more comfortable with this type of science knowledge than he was prior to his research experiences. In an interview, he discussed how this type of experience helped him to retain this knowledge better than when he had mostly read material in earlier courses dealing with similar topics. We have all heard the expression that you "learn by doing." This appears to be true in Gregory's case.

I heard of a case similar to Gregory's experiences in an interview with Troy, an in-service middle-school teacher who worked in the Pensacola area.

(Excerpt from an interview with Troy):

I think the classroom can only do so much for learning. The university ought to take a hard look at the program and see how it could be incorporated in a science program. I know from my experience that I have learned as much from experienced teachers as I did in college classes. There is no substitute for on-the-job training.

Troy is expressing his thoughts on the benefits of experiential learning. Troy realizes that experience is the best teacher. Troy holds an elementary education degree, although he is currently teaching sixth-grade science. Having no prior scientific experience and very few science courses, this experience helped him gain a new perspective on science.

When asked if he believed that pre-service teachers gain as much content on a certain topic by doing research as they would in a lecture-driven course, Erick, a

scientist participant, explained his perspective as a science researcher.
(Excerpt from Erick's interview):

I believe [the pre-service teachers] gain much more understanding of the details related to the research but may not be able to cover nearly as many different scientific concepts as they would in a lecture-driven course. But most importantly, I think they gain a better appreciation of the practicality of science and its real-life implications by participating in hands-on research.

Nine months after his summer research experience, I asked Marcus, another pre-service middle-school teacher, whose paper was not included in this monograph due to family and school obligations, to describe his research to several students. My request to him was completely impromptu. Marcus, without hesitation, eloquently and accurately recounted the procedures that he and his team had used to study water quality and pollution levels. He accurately used the scientific names of the two species of mollusks he had studied. He quickly answered a fellow student who had posed a question about the relationship between pollution and using "filter feeding" animals as indicator species. When I commented on how impressed I was with how he remembered so much of the content he had learned, he said, "I remembered it because I did it!" This was a critical insight for Marcus, especially as he begins to teach his own students.

Teacher education programs should consider this when designing and/or requiring specific science courses for pre-service teachers. The science course considered should be inquiry-based, hands-on, and should involve meaningful "real-world" experiences for the student teachers. We should teach future teachers using the methods research supports as a model for teaching science to their future students.

The Culture of Science Versus the Culture of Classroom Science

Madsen and Gallagher discuss the "culture of classroom science" in their study on teacher change and beliefs.[21] The culture of science is different from that of the culture of classroom science. The culture of science is seen as constructivist in nature, as scientists must experience their research to discover "answers" and obtain knowledge. By contrast, the traditional culture of classroom science is seen as positivist in nature, in which students are given factual information. Textbook and lecture-driven, the current culture of science in the classroom does not enable students to experience authentic science.

"Working with people who love what they are doing made me want to bring that feeling back into the classroom."

Christy, one of the pre-service teachers who wrote Chapter 9 in this monograph, worked with plant cloning and environmental restoration. Here Christy describes the "culture of science" and how this differs from the culture of the science classroom:

(Excerpt from Christy's paper):

The culture of science is very interesting. Working with people who love what they are doing made me want to bring that feeling back into the classroom. Research, discovery, focus, and a love of science make the culture of science exciting. Again, the culture of science in the classroom lacks excitement and interest. Students are not motivated to seek answers to questions and research interesting topics. I want to make science fun and interesting. I do not want my students to just read chapter after chapter and answer questions at the end. I want students to develop their own questions and then research to find answers. I want students to share with their classmates what they discovered and why it was important to them. I hope to make students aware of how much fun science is and that everyone can be a scientist.

Immersion into the culture of science has obviously opened Christy's eyes to the relevance of doing and experiencing science. Her classroom boundaries appear to be broadened, and I predict that in her future classroom, there will be much excitement and interest in science.

Connecting the Community of Science with the Educational Community

Many beginning teachers do not realize that they can access the scientific community through industrial, academic, or governmental facilities. CO-LEARNERS Program provided an opportunity for pre-service teachers to work with practicing scientists and realize what is available to them.

"The voices of the pre-service teachers in this study are critical in regard to improving teacher education programs and, thus, classroom science for our children."

(Excerpt from Christy's interview):

> *I plan on using less lecture, more hands-on activities, research, and student participation. I want my students to want to learn more and apply themselves in science education. I want to invite scientists from the community into my classroom so students can learn what their options are in the future. I also want to communicate with scientists to create new science plans to implement in my classroom. Having contacts in the community is beneficial for in-service and pre-service teachers. During this summer program, I gained several contacts and teaching materials from the people I worked with at the DEP. One person... gave me bookmarks, magnets, lesson plans, case studies, and fun activities that I can give to and implement with my middle-school students no matter what level they are on. Knowing that people in the community are willing to contribute to science education makes my job easier.*

The impact on her newfound ability to access science resources within their community is evident as well. Christy has made initial connections and contacts within the community. Whether or not she decides to remain in the same community to begin her teaching career, she knows that there are scientists in every community eager to be called upon as resources in the science classroom. When I was a first-year teacher, I lacked this insight and did not begin to access the scientist community for several years into my teaching career.

All of the participants saw the value of making early "connections" to their local science community for support in the classroom.

In the first summer of the CO-LEARNERS Program, Lidia was a pre-service teacher who planned to teach biology in high school. She worked at the Department of Environmental Protection[19] and did field work and analysis of samples from rivers in northern Florida.

(Excerpt from Lidia's interview):

> *Some of my students will enter my class knowing more or less than that of other classmates, but by pulling together all of the resources in the community, we will all benefit.*

From this statement, Lidia appears to realize the importance of the collaborations with the science community. Just becoming aware that the community is available is a valuable lesson for future science educators. The knowledge and experience that research scientists can share with educators is extremely valuable. We asked scientists such questions as, "What inspired you to be a scientist?" and "Did a certain science teacher inspire you to pursue science as a career?" Their answers can shed light on what teachers can do in their classrooms to capture their students' interest in science.

By providing a window for pre-service teachers to get a glimpse into the scientific community and what is available for them as resources, their students will ultimately benefit. Benefits range from receiving Science Fair mentoring to accessing laboratory equipment (which may not otherwise be available to them) to working alongside a role model who may inspire them enough to pursue a career in science.

Contextual and Experiential Learning

A Catalyst for Teacher Change in Belief and Practice

Keeping with the science terminology, I use the expression "a catalyst for teacher change" to describe any experience that may impact the way a teacher practices in his/her classroom. In this study, the catalyst is the actual contextual and experiential learning in science and its impact on his/her teaching to consider and/or to include more contextual and experiential learning strategies in his/her own classroom. Placing pre-service teachers or practicing teachers in a contextual and experiential learning situation enables them to experience their own learning in a new way and forces them to realize that this type of learning is more meaningful and lasting.

I experienced this catalyst effect when I engaged in scientific research as a practicing middle-school teacher.[8] It had such a powerful effect on me that I was convinced that pre-service teachers should have such an experience before they start teaching. If pre-service teachers are given this opportunity while they are still enrolled in teacher preparation, their teaching practice would be influenced from the beginning of their teaching careers rather than after more than ten years of teaching (like me).

In a recent study of Columbia University's Summer Research Program for Secondary Teachers, Silverstein and Dubner found that students of practicing science teachers who had participated in summer research received higher GPAs and higher scores on the science section of the Regents Examination.[3] Additionally, these students participated in Westinghouse projects, science clubs, and extra-curricular activities in science at a higher rate than students whose teachers had not participated in summer research experiences.

Paige and Christy get "dirty". Science teachers immerse themselves into science. Their students will ultimately benefit.

Development of Empathy from Being a Learner

Teachers can develop empathy from being a learner through their science research experiences. This emerging empathy will ultimately benefit the students in their respective classrooms. The catalyst for this teacher change is their own research experiences, and the change occurs when their empathy generates enough desire for them to change their old beliefs about the teaching and learning of science to the degree that they utilize a more constructivist epistemology in their own classroom. In my opinion as an educator, teachers can read about the types of instruction and teaching methods that they "should" use, but when one actually experiences experiential or contextual learning, teachers are more likely to implement the methods. This is due to the simple fact that the type of learning worked for them. The experience of Ron Wark, a pre-service middle-school teacher and an author in this monograph in Chapter 8, provides a beautiful illustration of this notion.

Ron states in an interview:

> *Hands-on experience makes you realize that you, the teacher, had fun learning. Whoa, if I had fun, then do my students have fun in class learning just from books? Every once in a while, teachers need to be a student to bring them back to the reality that learning needs to be fun. Learning also needs to be hands-on and pertinent to their everyday life.*

I believe that Ron encountered a catalytic experience during his own research, and a change in his teaching is emerging. He understands that his own learning was more fun and more meaningful when he was actively involved with his own learning. This realization that his students need this type of learning is very significant for him as a teacher. Although he admits that this style of teaching will be a challenge for him, his own immersion and experience is much more powerful than reading the research of others that call for more hands-on learning.

(Excerpt from Christy's paper):

> *Teachers should leave textbooks alone as much as possible. It is too easy to just tell students to open up their book and start answering questions. Student involvement in planning activities could make students more involved in what they are learning. Allowing students to work in groups for research and laboratory activities is a good idea to improve student interest. Also, if we want students to have positive attitudes about science education, then we must make what they are learning useful and applicable in the real world. How we do that is by planning more laboratory exercises, bringing community scientists into the classroom to answer questions and promote interest, and taking the time to plan better lessons.*

Christy's statement suggests that she experienced this catalytic effect with regard to her ideas about teaching and learning. Again, the words "useful" and "applicable in the real world" indicate a strong desire to make the learning of science rel-evant to her students. This can best be done by allowing pre-service teachers to experience science, by providing opportunities to interact with scientists within their own unique communities, and by allowing students to think about their own learning and what encourages others to learn.

This indicates Christy's better understanding of the need to include more involvement on the part of students in their learning versus using a lecture-based classroom. Having experienced this type of learning, she appears to have developed a stronger empathy for her future students.

(Excerpts from e-mails from Troy):

> *In the science classroom, teachers assume that every kid is interested in science. In reality, it is the teacher's job to make the science lessons as interesting as they can be for the students. If I can make the lessons more realistic, I think it will influence my students' perception of science. I would like to see students get a chance to experience science in a more realistic way. I feel this would change students' perception of what scientists are all about and about what their job includes. I will try to include more hands-on activities with students. I would also like to get students in the field and lab more. If I can get students into a science experience, such as the one I was involved in this past summer, I know that students will be more enthused about their science education.*

Troy, as one of the practicing science teachers, also appears to have encountered a catalytic experience with respect to the inclusion of relevant and meaningful science in his teaching practice. This indicates a shift away from the science classroom filled with facts and information blasted by the TIMSS study.

Administrators often frown upon a teaching style that strays from the traditional, lecture-based, and information-laden teaching style with which teachers are mostly familiar from their own past experiences. However, teachers who have experienced the catalytic effect of having done scientific research feel more compelled to change not only their beliefs, but practices as well. This is more powerful than reading or hearing about the benefits of contextual and experiential learning.

Economic Feasibility

In terms of economic feasibility, experiential course offerings for pre-service science teachers require minimal costs to the university other than the supervising faculty member's salary. The researchers are not paid, but rather offer their assistance on a voluntary basis. Therefore, the laboratory space and facilities, most of which are stocked with state-of-the-art equipment, become accessible to the pre-service science teachers. The researchers at one site were all volunteers from a state laboratory, so the cost sharing was extensive. We have found that many scientists are willing to help, sometimes due to the fact that they are parents of school-aged children, and they wish to do their part to improve science education in their community.

The summer pay for teachers is minimal and is generally based on the district in-service rate. Collaboration with the school districts could provide the summer salary through in-service or other grant funding. Other options include asking a research facility to pay the teachers. The Florida Department of Environmental Protection paid the in-service teachers at one site on an experimental basis. We are hopeful that in the future, with additional funding, we could expand this program throughout the state, continuing to work with the Florida state laboratories, such as the Florida DEP and Florida Department of Agriculture and Consumer Services.

Teachers are more than willing to participate as most need the extra income, and are eager to mentor a pre-service teacher. Many teachers desire to update their own science content and understanding of science. For those who are pursuing advanced degrees, course credit could be offered in lieu of a salary. At one site, two of the three in-service teachers registered for graduate credit. While an experiential course could involve just the pre-service teacher and science researcher, the extended collaboration with the in-service science teacher is highly recommended. There are many creative alternatives to establishing such a program.

Accessibility of Research Scientist/Mentor

One of the major problems that we have encountered was the inaccessibility of some of the researchers at times, as Christy points out in her chapter. Some of the pre-service teacher participants often felt as though they were not given the direction that they needed to complete an effective research investigation. This negative aspect could, however, be debated by some as providing more opportunity to enable the pre-service teacher to become more self-directed, thus gaining the content knowledge based on constructivist principles. However, several of the pre-service teachers did express a desire for more direct communication with the researchers.

This problem can be remedied, as in a few cases, by assigning an extra researcher to work on the project. Therefore, when planning a program of this nature, this inaccesibility issue should be discussed thoroughly with the researcher before assigning him/her a pre-service teacher. The researcher and his/her assistant must be made aware that the pre-service teachers need some guidance and are not at the research facility to do menial labor. The teachers are there to gain science research experience, to acquire science content, to experience science within the context of an actual science laboratory versus a lecture-based and/or cookbook laboratory setting, and to become acquainted with working with the science community to gain access for their respective classrooms.

Scheduling Issues

Scheduling is also a key factor. The pre-service and practicing teacher need to work with each other for the majority of the time, therefore, scheduling can be challenging. This can easily be worked out through collaboration and compromise, however.

A key component of the CO-LEARNERS project, a practicing science teacher, Paige Bowron, prepares a specimen for propagation.

(Excerpt from Gregory's interview):

All in all, working with Mary and Jim has molded my entire outlook on the field of science. They were able to make a great deal of the material exciting and understandable to me, and in turn, I helped each of them by bringing my own knowledge to the table. By being afforded the opportunity to take part in the CO-LEARNERS Program, I can now go into my future classroom with a substantial amount of confidence and hands-on experience.

Change of Career Plans

One of Gregory's advisors, Penny J. Gilmer, told me that prior to Gregory's experience with CO-LEARNERS Program that he was very timid and reserved in discussions. She described him as "blossoming" from his participation, and expressing a great deal of interest, excitement, and knowledge based on his experiences. However, after less than one year of teaching in Miami, Gregory has chosen not to pursue teaching as a career due to the low pay and high stress of the teaching profession. Instead, he is pursuing a master's degree in Information Technology. However, his teaching experience taught him many things, like the power of collaboration. In fact, he chose his graduate school because of its emphasis on collaboration. On a positive note, the access and exposure he was given during his summer research experience may have ignited his interest in technology. It is better to find out early in one's career what s/he truly finds interesting and fulfilling and pursue that. While the teaching profession has suffered a loss, the information technology field has profited; they've gained a valuable worker in Gregory. Gregory shares his perspective in his chapter.

On a reverse note, Jan McCauley, the laboratory manager for the Wetlands Research Laboratory at the University of West Florida has decided to consider a job in teaching, perhaps at the university level. Her chapter on this monograph highlights her journey from scientist to science teacher. Earlier in her college education, Jan had considered pursuing teaching as a career. The low salary, student disciplinary problems, and a certain intimidation factor led her away from teaching and into science research.

The impact the science teachers made upon Jan was instrumental in her decision to consider teaching as a new career. This collaborative experience, paralleled with observing her new son's learning and wonder about the world, helped spark her interest in science teaching. Jan is extremely excited about venturing down a new career path and learning how she can touch the lives of future scientists and non-scientists who simply love science.

Conclusion

Based on the stories from the pre-service teachers, as well as the in-service teachers and researchers, we found that the contextual and experiential learning opportunities for pre-service teachers is most beneficial in a variety of ways:

- Teachers increase their science content knowledge. Teachers experience the culture of science first-hand. The difference between the culture of science and the culture of the science classroom is more evident to the teacher who has experienced scientific research. A merging of the two cultures is seen as a necessary step towards making science seem more real to the students.

- Teachers gain empathy for their students. 'Teachers-as-learners' experience the frustration of having to encounter sometimes previously unknown subject matter. The catalyst, in this case, is represented by each teacher's own experience with contextual and experiential science. The change resultant from the catalyst involves the pre-service teachers' ability to re-create a similar type of learning experience for their own students, as teachers are able to realize that this type of teaching is an important part of the classroom.
- Community resources and contacts are more accessible to the pre-service CO-LEARNER teachers. They, too, are more aware of how to make appropriate contacts when they begin teaching within their own classroom.

In closing, Christy expresses her thoughts on the value of experiential course for pre-service teachers:

(Excerpt from e-mail from Christy):

> *The program is worthwhile. I learned valuable information this summer that will make me a better teacher. The scientists were very helpful and excited about helping me learn about their field. The lead teacher was excited, as well, and helpful in suggesting ways to implement various ideas into the classroom. This program should be a part of teacher preparation programs so future and current teachers can realize the importance of meaningful science education. University students need more field experience in their content areas if they are to make learning meaningful and exciting.*

This program should be a part of teacher preparation programs so future and current teachers can realize the importance of meaningful science education.

I find this summary quite powerful and supportive of the notion of immersing pre-service science and/or mathematics teachers in an experiential science program. The word "meaningful" appears many times among the discourse of the participants. I find this very significant and consistent with current standards in science education, which stress the importance of meaningful science and call for opportunities to "connect" students and teachers to science.[1]

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Ron Wark states, "Every once in a while a teacher needs to be a student to bring the reality back that learning needs to be fun. Learning also needs to be hands-on and pertinent to students' every day lives."

A house wrecked from a hurricane on a Pensacola, Florida, beach.

CHAPTER 8

Science from a Different Perspective: Through the Eyes of a Mathematics Teacher

Ronald L. Wark

A New Career

Unlike the average novice, I am a 52-year-old, first-year teacher. Retiring after 24 years in the United States Navy, I decided to embark on a new career. Two years of technical school and a year and a half of junior college finally led me to the path of becoming a teacher. Eventually, I became a middle-school mathematics and social studies teacher.

My summer as a "scientist" proved to be the first step in my process of experiencing hands-on learning. I like to think that I might eventually evolve into the type of teacher who provides my students with many hands-on experiences and opportunities for inquiry. This is what the current research[1] and my recent education courses stress for optimal student learning. If I learned to appreciate the importance of hands-on learning, then I would realize that my students would also like to learn in ways other than by the book. So far that style of teaching presented a steep learning curve for me.

Making Science and Mathematics Connections

Science is a learning evolution just like any other discipline. Based on my own schooling, I always believed that a lot of hard work and hours of study are required to earn a degree in science. I chose, instead, to major in mathematics and social studies. I had even taken enough hours to become certified in language arts. I was a bit intimidated at the thought of being "immersed" in science. But, when I was asked to participate in a summer research project at the university, which would also count as a course for credit towards my degree, I was intrigued.

What better way is there to experience and learn a different discipline than in an actual laboratory setting? I was told that a middle-school science teacher, a middle-school pre-service teacher, and a research scientist would be teamed together to experience real-world science research. We would learn through the execution of experiments and the analysis of results. The project, entitled CO-LEARNERS Program, was funded through a National Science Foundation grant. This team of learners would collaborate and decide on ways that science could be brought into our classrooms. I felt that I needed more experience with hands-on learning in the classroom. I needed to learn science content as well. Since mathematics and science go hand in hand, I felt that this would be very worthwhile in my teaching and would ultimately benefit my students.

Students show delight at their design and construction. Hard work pays off!

I had two reasons for participating in this scientific project. First, the activity enabled me to experience an unfamiliar discipline while working together with a teacher and a researcher. According to the Third International Mathematics and Science Study (TIMSS)[2], high school students from the United States lag dramatically behind other countries in science and technology. Practicing teachers strongly adhere to the belief that to learn science, teachers and students must also have a connection to science[3]. I felt that this experience would prepare me for interdisciplinary teaching and help my future students through my own connection to science. The second purpose of my participation was to get a three-hour credit in mathematics, as I wanted to graduate as soon as possible and pursue my new career.

Forming A Team

Why would a pre-service and a practicing teacher team with scientific researchers? We could gain knowledge, build confidence, and acquire skills. According to Gilmer[1], teachers who are given the opportunity to practice methods of science and experience inquiry will come to experience the culture of science. Science no longer means abstract "facts" but a way of understanding the world.

I was teamed with a middle-school science teacher, Margo King, at the Wetlands Research Laboratory, located at the University of West Florida. Margo and I worked closely with Jan Macauley, the laboratory manager. We were originally placed under the guidance of Dr. Joseph Lepo, a biology professor and Acting Director of the Wetlands Research Laboratory. Because of his multiple duties, Joseph was unavailable for in-depth collaborations. We learned the demands upon the time of a true researcher. Jan worked closely with us, however, in all aspects of our research.

Our Investigation

In the Wetlands project, Margo and I tested the waters in the area near Pensacola, Florida, for levels of fecal coliform[4] bacteria. Fecal coliform bacteria come from the intestinal tract of humans and warm-blooded animals. Contamination of water supplies or bathing areas by sewers, septic tanks, or animal feces may increase the level of fecal coliforms present. Consumption of or contact with water contaminated with feces may cause gastrointestinal distress and, in severe cases, death. Local, state, and federal agencies contract with the Wetlands Research Laboratory to test the waters in the Pensacola area in order to monitor environmental health or to meet permit requirements.

Utilizing Science in the Investigation

Prior to our actual research investigation, Margo and I read the literature and procedures involved with such a study assigned to us by Joseph and Jan.

There are five steps in the process used to test for fecal coliform bacteria in the waters: sampling, dilution, inoculation, incubation, and the reading of the results. The first step, the sampling process, involves going to the site and collecting the samples. The procedure is discussed in another section of this chapter. The second and third steps involve the serial dilution and inoculation of the sample. We pipetted portions of the sample into test tubes containing bacterial growth media specific for growing fecal coliforms. As a control, we mixed sterile water at the same dilution with the growth media. We prepared three serial dilutions (undiluted, ten-fold, and 100-fold) if we collected the sample during normal weather and four dilutions (up to 1,000-fold) if we collected the sample after a rain. Rainwater run-off from up stream usually increases the amount of fecal coliform. Therefore, the sample must be further diluted to enable the final count falls within the counting range. After the media are inoculated with the sample, any fecal coliform bacteria, if present, should grow.

Ron Wark in his classroom.

There are many types of media, but the one used mostly by the laboratory for fecal coliform testing is called A-1 medium. The laboratory also tests for *Enterococcus* bacteria, which uses three different media: azide dextrose broth, bile esculin azide agar, and Brain-Heart infusion broth. I helped Margo mix Brain-Heart media on two occasions, but the A-1 media is one I used most often.

The fourth step in the process is the incubation of the samples. Margo and I placed the test tubes in an oven incubator for 24 hours after which we checked for the presence of bacteria. Using the A-1 broth medium, the positive test for bacterial growth is the presence of a gas bubble in an inverted tube inside the sample tube. The method used is called multiple tube fermentation. This test provides an estimate of the most probable number (MPN) of bacteria per 100 milliliters of sample as determined from the number of test tubes in which gas bubbles form after incubation. The last step is to record all positive and negative test results on a chart.

Ron labels and stores water samples taken from a local marina. It's a hot day, but Ron looks cool!

I wondered what the gas bubbles were, so I asked Jan. She said, "The multiple tube fermentation method is based on the fact that fecal coliforms, along with some other bacteria, ferment lactose (milk sugar or $C_{12}H_{22}O_{11}$, a disaccharide, or galactose linked ß1→4 to glucose). When the bacteria are grown in a medium (agar or broth) containing lactose, they will produce gas by fermentation, as if you were making champagne. The A-1 test for fecal coliforms uses a small inverted glass tube inside the culture tube. The inverted tube captures gas released by the bacteria. Any bubbles collected in the tube are considered a positive result for the presence of fecal coliforms in the sample. Her description helped me connect to my prior knowledge; I remember from a biology class that I had taken that the final products of fermentation are carbon dioxide and water, so the gas must be carbon dioxide (CO_2).

$$2\ C_{12}H_{22}O_{11}\ (aq) + 23\ O_2\ (g) \rightarrow 12\ CO_2\ (g) + 22\ H_2O\ (l)$$

or

Lactose (in solution in water) + oxygen gas → carbon dioxide gas + liquid water

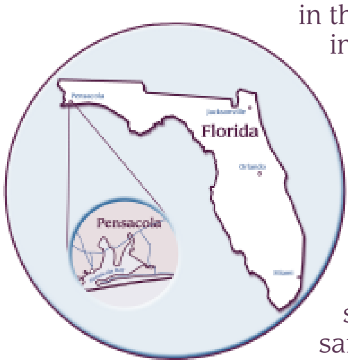
I also wondered what Brain-Heart media meant, so I asked Jan about it. She replied

> *The full name of what we use as the third medium for the old* Enterococcus *multiple tube fermentation (MTF) test is 'Brain Heart Infusion' broth. I believe it is a dehydrated broth infused with brain and heart material, probably bovine. Think of the basic chicken broth agar we all used in school. Any growth medium involves a nutrient source, and brain and heart tissues are rich with nutrients. A selective growth medium also involves other components that kill or inhibit certain types of bacteria, thus selecting against them. You put together the right series of selective growth media and you can select for almost any specific bacteria by inhibiting the growth of some other types of organisms at each stage until you have only one left. We add 6.5% salt (i.e., plain old sodium chloride) to the Brain-Heart infusion broth at the last step of the test because* Enterococcus *is one of the few bacteria in the environment that can tolerate that much salt, which is why it grows so well in the marine environment. An earlier step in the* Enterococcus *MTF test involves use of sodium azide (bile esculin azide agar), which is lethal to most higher living organisms, but* Enterococcus *tolerates a certain amount of salt too. It's a tough group of bacteria.*

"My summer as a "scientist" proved to be the first step in my process of experiencing hands-on learning."

Here again, I remembered something from my biology class. I remember that azide is a potent killer. I looked it up, and it is a killer because it blocks the electron flow, which a eucaryotic cell needs to generate significant energy from metabolism. Apparently, the azide in the growth medium blocks higher order cells from using the lactose as an energy source. Therefore, any growth must be prokaryotes such as bacteria.

By adding salt to this medium, scientists put another block on most forms of bacteria, so they cannot survive under those conditions. Because the *Enterococcus* is able to grow in a medium containing salt, the presence of gas bubbles indicates a group of microorganisms that will tolerate salt and multiply. I guess that these organisms must be able to grow in various concentrations of salt in the area where we collected them, as the water we tested was infused with salt water as the tides from the Gulf of Mexico come into the Pensacola Bay. Pretty neat stuff! I can bring this to my students who live here in the area around the Pensacola Bay!



Pensacola Bay area

Using Mathematics to Analyze the Data

I used the Standard Methods for Examination of Water and Wastewater, 19th edition[5] to convert our results on the data chart to the Most Probable Number (MPN) of bacteria present in each sample. There are several agencies that contract the laboratory for sampling. The Wetlands Research Laboratory gives the agencies the MPN values for their site based on its findings. The Environmental Protection Agency (EPA) sets the MPN standard for safe water, and the business or agency will use the MPN to determine if the water is safe or not. If the data do not fall within the parameters of the standards book, there is an equation that can be used to determine the MPN.

"This field trip opened my eyes to the importance of getting out of the classroom every once in a while."

Not long after we participated in this summer project, Jan wrote, "Since the time that Margo and you were here, we changed our *Enterococcus* test to a new, much simpler version. It is a plate method called membrane filter analysis, which involves filtering a water sample through a membrane filter, which catches the bacteria on the filter and putting the filter on a plate of mEI agar. Instead of taking five days like the previous test, it takes 24 hours. After 24 hours of incubation, the researcher counts the number of blue colonies and reports the number directly in CFU (colony forming units) per 100mL. No statistics or tables."

My Part...as a Scientist!

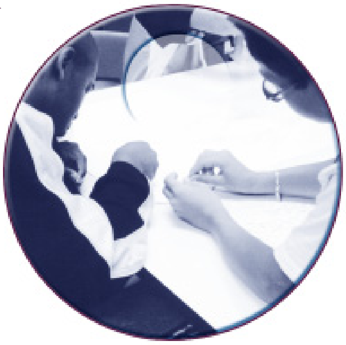
Teamwork in science benefits us all. Margo and Ron collaborate on the sample collection and water testing.

Kielborn endorses the idea of "teacher as researcher" to proclaim professionalism and professional development in teaching.[6] As we were teamed, Margo was the science person, and I was the mathematics person. Because mathematics is such an integral part of science, I was eager to be part of this project. I helped with collecting the data for the science projects and even more with the mathematical calculations involved with the investigation.

My mathematics studies during this summer, coupled with this project, made me realize how much of the computations required in the science laboratory are actually taught at the middle-school level. Ratios, proportions, percent by weight, and parts per million are used every day in mixing chemicals needed to carry out the projects at the Wetlands Research Laboratory. Other areas in which I observed and assisted involving mathematics were in finding an MPN from a formula and interpolating MPNs from the standards book.

Enjoying the Field Trip

Probably the most exciting part of this research experience was the collection of water samples. We took along bottles to store the samples, a depth sampler, and an instrument that recorded water temperature, oxygen levels, and the pH of the water. We prepared all the bottles necessary for the sampling prior to the trip. On the morning of the trip, I loaded the bottles into ice chests according to the order of sample sites. I was also placed in charge of the sample bottles during the trip. Five of us launched an 18-foot boat into the Pensacola Bay. It took us about 20 minutes to reach the first sampling position. The boat captain used a portable GPS direction finder to locate the exact sampling spot. The GPS[7] uses satellites to coordinate the exact position of latitude and longitude anywhere on the globe. As with any scientific experiment, the results must be replicated from the same position as previous sampling. With the GPS, the boat captain could anchor within ten feet of the desired location.


Ron's students design their "hurricane-proof" house.

We collected samples at four locations from three depths: bottom, middle, and top. Margo was in charge of lowering and raising the instrument that measured the temperature and oxygen levels. After collecting data at the first site, I began recording the measurements that Margo gave me and took care of the sample bottles. As soon as we returned to the Wetlands Research Laboratory, we began the testing procedure that I described earlier. The trip was educational and fun, but very hot on that summer day. Such is the life of a research scientist! This field trip opened my eyes to the importance of getting out of the classroom every once in a while.

Teamwork in Science and Mathematics Education

Based on her own research experiences and later classroom applications, Hahn[8] states that teacher preparation programs should involve more activities in the laboratory to enhance student learning in science. Hahn asserts those teachers of other disciplines benefit from experiential activities, as well. For instance, art teachers experience art as artists before they become teachers, and music teachers generally know how to play three or four instruments before teaching. However, science teachers (especially new ones like me) often have not experienced scientific research first-hand, as I did that summer. If teachers are to teach inquiry, they need to experience it first-hand.

Jan planned all the samplings and test schedules. She showed Margo and me how to set up and run the tests for fecal coliform. From the beginning of the project, Margo and I had planned how we would apply what we were learning in this summer research experience during the semester in which I would undertake a teaching practicum with her as part of my undergraduate teaching program. I planned to co-teach an integrated, interdisciplinary lesson on ratios and proportions. I would review and teach the mathematics necessary to complete the science projects that Margo would have her students do. We scheduled this science investigation for the following spring semester.

I conducted a lesson on ratios and proportions and related how I had used it during the summer research program with the Wetlands Research Laboratory. The students were interested in hearing about my experiences as a "scientist" and wanted to know more about fecal coliforms in the waters. This is a good example of bringing students closer to science and helping to establish a connection between mathematics and science. Once the students began to see how science and mathematics affected their lives, the topics became more interesting to them.

Classroom Applications

Making Lemonade

As a student teacher the following fall, I taught Pre-Algebra and Algebra to eighth graders. The Pre-Algebra course called for ratios and proportions. My favorite ratios and proportions lesson to use in the classroom involves making lemonade. A 29-ounce canister of lemonade mix will make 48 servings. Assuming everyone drinks two servings and 100 people are expected to be there, I asked how many canisters of lemonade are needed. I did not tell them that this related to science, but I do feel that it is a very good real-life example.

Making Houses for the "Hurricane Project"

After being hired as a middle-school mathematics teacher, I have taught ratios and proportions similar to what I used in my research that summer. Last year as a first-year mathematics teacher at the middle-school level, I used these lessons to help prepare students for the Florida Comprehensive Assessment (FCAT) test.[9] The FCAT test results are used to help grade each school in the state of Florida and to determine the level of individual students.

A student makes "final cuts" to perfect his house.

I also used a lesson in ratios and proportions for the last project of the school year. The project involved students designing and building model houses that could withstand hurricanes. Living in Florida, this is certainly applicable and relevant to these students' lives. The Hurricane House project lasted two weeks. I divided the students into groups of five and gave them exact standards that were to be met. Each group had to design and build a house that they thought would withstand a hurricane. The main criterion was that the house had to have a floor area of 400 cm². Most of the groups chose to go with a square house, as it did not require a great deal of mathematics to lay it out. However, there was at least one group every class period of the school day that designed and built a round house. The round house required the students to use formulas for the circumference and area of circles. One group designed and built a six-sided or hexagonal "star" house, and another group designed and built an eight-sided or octagonal house.

The first two days of lessons involved the drawing of floor plans for a hurricane-proof house. The students had to use scales and ratios to draw their houses to fit on the paper. Doing ratios was fairly easy for the students because we had learned that process earlier in the year. Establishing what a scale was and how to use it was a little more difficult for some of the students. The students had fun drawing either their own homes or a house that they wanted to live in.

Girls in Ron's class carefully construct their "hurricane-proof" house.

This project was hands-on at its best. The students were given exact directions for what to use, but the groups had to decide what they would build. The other seventh-grade mathematics teacher and I collaborated on the project. We answered student questions and posed others on how they could possibly improve on what they had, but we never told the students how to construct their houses or what to do next. The last day of building construction was a flurry of activity. At the beginning of the day, only one or two houses were complete in each period. By the end of the day, all the houses were prepared. The anticipation was building.

Students Calling, "Over! Over!"

The last day of the project was the actual hurricane day. All the houses were built on stilts and were blown with a leaf blower to see if they would fall over or collapse. The houses were graded on the following criteria:

- If they had all their shingles or not
- If they had a door on each side
- If there were windows on all four sides of the house
- If the house was six inches off the ground

A parent volunteer prepared the leaf blower so that the wind velocity out of the blower was just over 100 miles per hour. He would then aim it at all sides of the house. The house had to withstand a total of four minutes of the hurricane force winds. Each house would lose points for shingles that were blown off and any other part of the house that went flying.

The students became so excited every time a house was put to the test. If a house started to shake, the class would begin chanting, "Over! Over!" The more the house shook or came apart, the louder the chant would get. The students were very motivated by this project and were seldom off task. This was an exciting end to the school year.

What Did I Learn from the Summer Research Experience?

This hands-on experience made learning fun and also raised the following question: Do my students have fun in class learning just from books? Every once in a while, teachers need to step back into the role of student to remind themselves that learning needs to be fun. Learning also needs to be hands-on and pertinent to students' everyday lives. The CO-LEARNERS Program provided me with this experience.

One of Ron's students working on her project

The relationships that teachers and scientific researchers develop in a project like CO-LEARNERS should promote the students' learning of science and mathematics, as well. Hopefully, either the student can visit the research facility and see a real life laboratory, and/or the researchers can visit the classroom and enhance the teacher's lesson.

Should all teachers do research in their own field? Absolutely! The only way that a teacher can truly know what is happening in his or her field is to experience it first-hand. Add a student teacher, and all areas of the community are covered. Because of my own experience, as well as the trend in education today to incor-porate more interdisciplinary teaching, I believe that teachers and students should be paired with experts in other fields.

Endnotes

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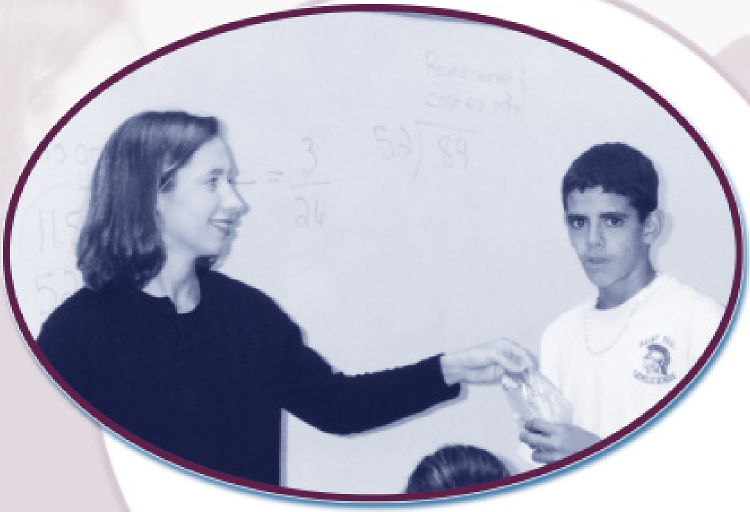


Christy Tarter with one of her students

CHAPTER 9

Science: Not Your Typical Textbook and Lecture-Based Class Anymore

Christy Tarter

Introduction

A CO-LEARNERS Participant Over Two Summers

As a participant in CO-LEARNERS Program for two summers, I would like to address each summer as a distinct research project. While both experiences were educational and valuable during my teaching education, each was unique and presented various challenges. In this chapter, I will discuss each research experience, then compare the two by discussing the benefits, and finally make recommendations for improvement.

Prior to my first summer with the CO-LEARNERS Program, the only research experiences I had were in college laboratory classes. So, when the opportunity arose to work with real-life scientists, I jumped at the opportunity. In the first summer, I worked at the State of Florida Department of Environmental Protection (DEP) laboratory on the cloning of various sea grasses. My experience working in the laboratory and in the field with the DEP was wonderful. I learned quickly how much work and detail goes into restoring the environment. In the laboratory, I worked in a sterile environment making sure to follow procedures correctly. In the field, I participated in rebuilding areas with sea grasses grown in the laboratory. Much emphasis was placed on detail and procedure. It was a little tedious sometimes, but fun.

"The culture of science in the classroom differs from my experiences because most teachers rely on textbooks to teach students what is science."

During the second summer of research, I worked at the Wetlands Research Laboratory located at the University of West Florida. The project involved researching the benefits and concerns of the use of fluoride in local drinking water. My practicing teacher/partner was Sandra Porras. She and I conducted several water collections at various sites, performed several laboratory tests, and contributed to a report on the safety of adding fluoride to the county drinking supply. The Wetlands Research Laboratory prepared the report for the Escambia County Utilities Authority (ECUA). The report targeted the community's concerns relative to the addition of fluoride to the county's water supply.

Summer One—Cloning Sea Grass

Perceptions of the Scientist

When students picture what a scientist looks like, they usually envision a man with black-rimmed glasses, lab coat, pocket protector, and crazy white hair. I, too, imagined the same type of individual before working on the summer research projects. I expected the people at the DEP to be boring and nerdy. However, this was not the case. Both Chips Kirschenfeld and Rick Harter were far from that image. In fact, everyone that I met from DEP was excited about their work and explained their research enthusiastically. In turn, I became excited about the work I was doing. I had expected the work to be boring, but I changed my mind quickly.

"Cloning" Around

During my summer with the DEP, I learned how to clone sea grasses that would one day be planted in the local environment. Sea grasses are flowering plants that live underwater. Like land plants, sea grasses produce oxygen. The depths at which sea grasses are found are limited by water clarity, which determines the amount of light reaching the plant. Although sea grasses naturally occur throughout the coastal waters of Florida, they are most abundant from Tarpon Springs northward to Apalachee Bay. Sea grasses also grow in protected bays and lagoons, as well as along the continental shelf in the Gulf of Mexico.

Florida's estimated 502,000 acres of sea grass meadows are important natural resources that perform many significant functions including

Why major in science education and go into the classroom just to teach out of a textbook that most students have trouble comprehending?

- Maintaining water clarity by trapping fine sediments and other particles in their leaves
- Stabilizing the bottom with their roots and rhizomes in much the same way as land grasses retard soil erosion
- Providing habitat for many fish, crustaceans, and shellfish
- Providing food for many marine mammals as well as the smaller organisms that live on their leaves
- Providing a nursery area for much of Florida's recreationally and commercially important marine life

Sea grass leaves provide excellent protection for young marine animals from larger open water predators. Some animals, including manatees, eat the sea grass blades. Still others derive nutrition from eating algae and small animals that colonize the sea grass leaves. The colonizing organisms provide an additional link in the marine food chain.[1]

My lead teacher and partner was Paige Bowron. She and I gathered various sea grasses in the area from local state parks and bayous and brought them back to the laboratory to begin the cloning process. Gloved, Paige and I worked under a sterile hood to separate the sea grasses into many smaller parts that were then placed in test tubes containing a saltwater solution. The test tubes were dated, labeled, and placed under artificial light for about six weeks. Once the sea grasses matured, they were split again and placed in test tubes again. When enough sea grasses were cloned, they were transported to a tank containing a mesh-like material where they would continue growing. Once the sea grasses were large enough, they were taken to the greenhouse. At the greenhouse, Paige and I continued our work of separating the sea grasses into smaller plants for continuous growth and reproduction. The process of cloning and growing sea grasses is long and takes a lot of work. However, when I was able to take the sea grasses I had worked with and plant them back into the environment where they were needed, I felt a great sense of accomplishment and pride. Today, two years after planting the sea grasses, the impact from my efforts to help the environment is still seen. In fact, the DEP has begun a huge sea grass restoration project based on our initial research.

Here I am with Paige in the laboratory at the Department of Environmental Protection.

Textbooks Have Their Place, But...

The culture of science in the classroom differs from my experiences because most teachers rely on textbooks to teach students what is science. Students have little opportunity to work in laboratory settings where they can apply what they learn in the classroom to real-life experiments. Many teachers lack laboratory skills, do not have or do not know how to obtain resources, or do not think their students are capable of performing in a laboratory setting. There are many reasons why it is convenient to use a textbook. One reason is that it takes time to develop and implement hands-on projects and laboratories. What incentive is there for teachers to spend a lot of time developing curriculum? Well, most of what a student reads or tries to read in a science textbook is incomprehensible because of students' reading level and interest in reading. Someone who has ever tried to put something together, like a child's bicycle, by relying on an instruction manual, understands the difficulty of reading unfamiliar information. Students who lack prior knowledge face such difficulties with textbooks.

Teachers should use textbooks as only one of many resources. Student involvement in planning activities could make students feel more ownership of their learning. Allowing students to work in groups for research and laboratory activities enables students to change previously held science misconceptions and discover that science exists in the real world outside of a textbook.

If the goal of science education is to promote the learning and interest in science, then we must make what students are learning useful and applicable in their world. Science teachers can do that by planning more laboratory exercises and bringing community scientists into the classroom to answer questions and promote interest.

Out of the Lecture Hall and Into the Laboratory

In a lecture-only science course, topics are condensed in order to cram in as much information as possible, and by the end of the course, most of the information is forgotten. However, by reducing the amount of material covered and focusing on learning for understanding and application of what students are learning, students and teachers benefit.

Paige and I examine samples for growth.

My interest in science began in middle school in the sixth grade. We dissected frogs and worms. I loved it! My science education in middle school was mostly hands-on. This ignited my desire to solve problems and study weird and exciting topics.

As a teacher, I want to make science fun and interesting. I will not have my students read one chapter after another and answer questions at the end of the chapter. I do not learn that way. I encourage students to develop their own questions from science laboratories and activities and discover how things work and grow. Using discovery-based lessons and asking open-ended questions make students think about what they are learning and gives them the opportunity to develop communication, research, and technical skills. I also want students to share with their classmates what they discover and help each other understand and explain various concepts. I hope to make students aware of how much fun science is and that everyone can be a scientist.

Recommendations from Summer One

1. Keep a Journal.

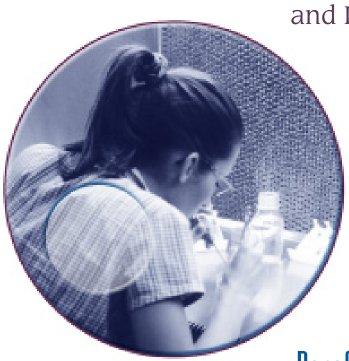
One thing that we concluded from the first summer was that university students should be required to keep a daily log, be evaluated weekly on progress on what is being learned, and have continual contact with the university instructor and research coordinator. This helps when an individual has a question. It is my opinion, too, that when people write something down, they are more likely to remember it.

2. Offer Limited Guidance.

The university coordinator and lead teacher should guide the pre-service teacher to create lesson plans and a research paper. University students need to know beforehand what is expected of them with a syllabus. They should contact the teacher if a problem should arise. This recommendation, too, was met somewhat. It was explained to us later that because the project is constructivist-based, we were not told exactly what to do because we were to "construct" our own learning and develop evidence of this learning.

3. Have a Back-up Researcher.

Because our lead researcher was extremely busy, he did have the foresight to have Rick Harter work with us directly along with an intern. This was a problem in the second summer, as I will address later. This point is extremely important because a science researcher is an integral part of the learning process; therefore, one should be accessible at all times. This was not a problem in the first summer with the DEP, as Rick Harter worked very closely with Paige and me. He answered our questions, helped guide us through our investigations, and gave us necessary feedback. He was also very open to suggestions made by me and Lori Hahn, the graduate researcher and instructor of the course.



Some of the techniques are tedius, but fun.

4. Offer Real Research vs. Labor.

Initially, Paige and I felt as though we were doing "free labor" for the DEP. Since this was the first year with such a project, it was difficult for Rick to know exactly what we were supposed to be doing. He was very agreeable that this project needed to be more research-based. The following summer, while I did not work with the DEP, the group that did was immersed in an actual research investigation from the beginning.

Benefits from Summer One

1. Learning Content

All in all, the first summer was very worthwhile. I learned valuable information that will help me be a better science teacher. The scientists were helpful and excited about helping me learn about their fields of science. Paige, as the experienced teacher on my team, was excited and helpful in suggesting ways to implement various ideas into the classroom. This type of program should be a part of teacher preparation programs for all levels of education so future and current teachers can realize the importance of meaningful science education. Teacher education students need more field and laboratory experiences.

2. Making Contacts in the Science Community

Having contacts in the science community is beneficial for practicing and prospective teachers. During this summer program, I gained several contacts and obtained teaching materials from the people I worked with at the DEP. One gentleman gave me bookmarks, magnets, lesson plans, case studies, and fun activities that I can use with my middle school students no matter what their level. Knowing that people in the community are willing to contribute to science education makes my job easier.

3. Ideas and Encouragement to Provide More Student Involvement

I now know how much fun science education can be for students. During my research experience, I enjoyed learning how to solve problems, how to help the environment, and how interesting environmental science is today. As a teacher, I will be able to explore with my students all areas of science and find ways to promote student involvement. I realize that students and I need to get as much as possible out of what is being learned and taught. Science education needs to be applicable, interesting, and hands-on if teachers and students are to maintain interest and develop a love of learning science.

4. Classroom Applications

What I learned from participating in my first summer research project can easily be implemented in my classroom. The scientists and staff at the DEP were very supportive. I received many lesson plans and materials from the DEP that can be used with all grade levels. Many of the lessons are activity-based where materials are cost-friendly or can be obtained from the DEP. One idea I found is to present groups of students with an environmental problem to solve, while taking into consideration the cost, protection of plants and animals, resources, and time. Many resources and lesson ideas can be found on the Internet. The Florida DEP [www.dep.state.fl.us/enved] and EPA [www.epa.gov/epahome/educational.htm] websites provide lessons, information, and materials to use in the classroom.

Student's in my classroom

DEP scientists were willing to visit my classroom to discuss what they do and to show students how the environment can be improved. I also can take students on a field trip to the DEP laboratories and greenhouse where they could plant their own sea grasses. Students could return months or years later to see their work making a difference in the environment.

Summer Two—To Add or Not to Add Fluoride?

During the summer of 2000, I worked with Dr. Joe Lepo, Dr. Richard Snyder, student Angela Harris, and practicing teacher Sandra Porras researching the impact of fluoridation of the municipal drinking water for Escambia County at the Wetlands Research Laboratory at the University of West Florida. The Escambia County Utilities Authority (ECUA) contracted the Wetlands Research Laboratory to conduct research, which would enable them to answer questions from concerned citizens about the ECUA's decision to add fluoride to the county municipal drinking water at 0.8 mg/L. Several tasks were developed for this project, including assessing the concentration of fluoride and the pH of area waters and ground water wells, analysis of hydrofluosilicic acid to be added for metals contamination, and analysis of the environmental fate of the fluoride ion by laboratory simulations. Though all tasks were not completed during my allotted time on the project, I have learned what water fluoridation means, the pros and cons of water fluoridation, the research findings during that summer, and the importance of applying hands-on science learning in the classroom.

"Learning about science by getting my hands dirty or conducting experiments is how it should be done. My students will need to perform experiments and do research like a scientist in order to understand scientists' work."

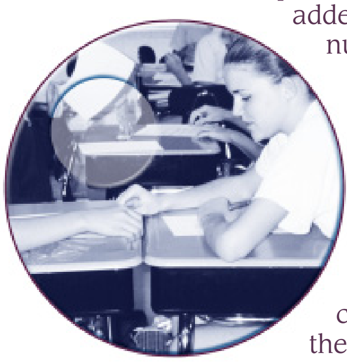
My Initial Research—Learning What Was Known

Fluorine is a halogen. The word halogen comes from a Greek word meaning "salt former." Halogens are nonmetals that combine with metals to form salts. Halogens, such as fluorine, can accept one electron and form an ion with a single negative charge, such as F^{-1}, which is called fluoride. None of the elemental halogens are found as single uncharged atoms but as diatomic molecules, like with fluorine as F_2.

Fluoride helps prevent tooth decay by making teeth resistant to the acids that cause tooth decay. Fluoride "is an essential element for mammals" and "it is toxic to both animals and plants at high concentrations"[2] (p. 1). However, the amount of hydrofluosilicic acid that the ECUA is adding to the municipal drinking water is only 0.8 mg/L, which is between the recommended concentration level of 0.7 to 1.2 mg/L. Water fluoridation "is the process of adjusting the natural level of fluoride to a concentration sufficient to protect against tooth decay"[3]. Water fluoridation began in January 1945 in Grand Rapids, Michigan[4] (p. 20). Since then, water fluoridation has spread across the United States as a way to reduce dental caries and dental costs.

Fluoride is everywhere. It "flows from the continental drainages to the ocean at an estimated rate of 3.7 million metric tons a year"[2] (p. 1). It is in all soils and waters in various amounts. Many water systems in the United States are naturally fluoridated at levels higher than what is recommended. Those cities or communities who have added fluoride to the drinking water systems do so to provide everyone, both rich and poor, a nutrient needed by the body to increase the stability of teeth and bones. The cost to those cities is related to the size of the community, number of wells and treatment plants, amount and type of equipment, amount and type of fluoride chemical, and personnel costs.[5]

In saltwater, "fluoride is naturally present at a concentration around 1.32 parts per million (ppm), [so] anyone who spends a significant amount of time in the Gulf/Ocean, consumes seafood, or uses sea salt for food preparation/consumption...already experiences levels of fluoride near that which will be added to the municipal drinking water supply"[2] (p. 3). Fluoride is a nutrient used by the body. What the human body does not need is excreted in urine. However, like other nutrients, there is a toxic level. A human must consume 2.5g to 5g at one time, which has not occurred from naturally fluoridated water systems or those where fluoride has been added[6] (p. 132).



Student in my classroom display their findings

Even though water fluoridation has been around since 1945 and over 35,000 papers have been written reporting its safety, debates still exist over the issue. However, with this issue, and countless others, people are influenced by what they learn from the media, so-called experts, the Internet, and rumors. It is difficult for most people to read scientific journal articles to understand what water fluoridation is and its impact over the past 45 years.

Water fluoridation has been provided for over 45 years because it prevents and/or reduces dental caries. Dental caries are formed when "oral bacteria in plaque ferment sugars to produce a range of organic acids that promote dissolution of tooth enamel"[2] (p. 9). When water fluoridation began, people were not taking fluoride supplements or using fluoride toothpastes and gels because they were not available. If people could not afford to go to the dentist regularly, they most likely developed dental caries. Water fluoridation became a solution because it is the "most equitable and cost-effective method of delivering fluoride to all members of most communities, regardless of age, educational attainment, or income level".[7]

With regard to all of the research that has been done on water fluoridation, fluoride added to water would not be here today if it were life threatening. The National Cancer Institute "evaluated the relationship between fluoridation and cancer mortality in the U.S. during a 36-year period and a 15-year period. There were 2.2 million cancer death records and 125,000 cancer case records in counties using fluoridated water, but there was no correlation between cancer cases and fluoridated drinking water"[2] (p. 15). Other studies have also proven that water fluoridation does not cause cancer, kidney disease, or heart disease. The American Dental Association has endorsed fluoridation for more than 40 years.[3]

Many communities all over the United States already provide fluoridated water. As of February 1996, the following percentage of communities in states had fluoridated water: North Dakota, 96%; South Dakota, 100%; Iowa, 91%; Minnesota, 93%; Georgia, 92%; Alabama, 83%; South Carolina, 90%; and Kentucky, 100%[4] (p. 20). More than "half the children in the country now live in fluoridated water districts, and most dental health officials say this is why U.S. tooth decay rates have plummeted 50% in the last 20 years"[8] (p. 276). Opponents of water fluoridation argue that adding fluoride is a violation of civil rights. If it works and has worked for so long and no one has been harmed by it, why fight so much?

What I Learned from the Experience

1. Working as a Team

During my research, I wrote this in my journal:

> *I met Sandra Porras today, and she is really nice. Angela showed us how to clean the sample jars with HCl and DI [deionized] water. Everything we do in the lab is very detailed. We learned how to test the jars for pH level after cleaning them and the need to return our wastewater to neutral before discarding it. We also calibrated our stock solutions. Angela has done this before, but she told us that calibrating the stock solution again lets us know if it is still good to use. This process took awhile to complete. Angela explained all the steps clearly, which made it easy. Angela also showed Sandra and me what we would be taking out to the field to collect samples, in case she couldn't come with us. After completing the lab activities, all three of us discussed different school issues, such as discipline, lesson plans, state testing, etc. Sandra informed me of many useful points and ideas. I feel comfortable asking her questions. I also spent two hours looking up fluoridation/fluoride articles to begin my paper.*

Here I am in my classroom.

This passage illustrates the value of teamwork and collaboration in science. Pre-service science teachers, practicing science teachers, and science researchers truly learn from one another. This will ultimately benefit the students in the science classes.

2. Getting Dirty

One of our first tasks was to collect water samples to test for the presence of fluoride as it occurs naturally.

"Teachers should use textbooks as only one of many resources. Student involvement in planning activities could make students feel more ownership of their learning."

From my journal:

> *Angela, Sandra, and I went to the Bayou Marcus Water Reclamation Facility to collect water samples. We collected three jars each of raw sewage, sludge, clarified, and final effluent. The ECUA men at the facility explained the treatment process and walked us through the facility. They also gave us a pamphlet. The information and treatment process was very interesting. We put the jars on ice and carried them back to the lab where they will refrigerate until we begin fluoride testing.*

Teachers need to get their students out of the classroom and get "dirty" sometimes. Students are pretty resilient. There is a lot to be learned from expanding the classroom from the traditional four walls.

3. Gathering our Scientific Findings

Experiments and tests still needed to be conducted so conclusions could be drawn for this project. Because fluoride is a nonmetal, it naturally bonds to metals to form salts. So, reactions with copper and solder piping and the hydrofluosilicic acid will occur, but the amount of change and how quickly were to be determined. We were not able to perform tests with the hydrofluosilicic acid because it was on back order.

The Bayou Marcus Water Reclamation Facility in Pensacola, Florida, uses a state-of-the-art water treatment process to purify wastewater before it is released into surrounding wetlands. Fluoride will remain in the soil. How much is dependent on the type of soil, pH conditions, amount of calcium in the soil, precipitation, and water flow. "Clay soils retain fluoride better than sandy soils"[2] (p. 2). Escambia County has both types of soil, so the amount of fluoride retention will be determined.

With the research conducted for the ECUA by Angela, Sandra, and me, we made the following conclusions:

- There is natural fluoride in our area waters and municipal water wells (see Table I).
- Fluoride does not disappear or go away. It gets recycled and filtered through wastewater treatment processes, soil, precipitation, and water flow.
- Fluoride eventually is released into the environment and back into area waters and the ocean.
- Fluoride will most likely react with copper and solder piping, but the effects will take years to determine.
- The effects of fluoride, when released into our local environment and area waters, will take years to determine.

Table I

Fluoride Concentrations of Water Treatment Facilities (mg/L)

Treatment Site	Sample 1	Sample 2	Sample 3
Main Street (Final Effluent)	1.63	1.55	1.60
Main Street (Clarified)	1.20	1.17	1.18
Bayou Marcus (Final Effluent)	0.0838	0.0365	0.0362

Recommendations from Summer Two

1. Making Researchers and Materials More Accessible

Sandra and I conducted as many experiments as possible during this summer project. One inhibiting factor was the inaccessibility of the researchers. While these researchers were willing to work with us, volunteered their time, and were committed to helping teachers with bringing science into their classrooms, they were very busy researchers. I see this as a possible weakness in this type of program. While another student did work with us, teachers need someone with knowledge of the project with whom to be in direct contact, if the researcher is unavailable at any time.

"A prospective science teacher should be required to perform research and tests in a laboratory setting before graduating."

During my first summer, this was remedied by having Rick Harter work directly with us. Mr. Kirschenfeld knew that he would be busy with many projects and designated Rick to work closely with Paige and me. I see this as an answer to such problems. We also had a few other minor problems such as waiting for materials on order. I suppose this is part of the culture of science, however.

2. Scheduling to Avoid Conflicts

However, sometimes there are scheduling conflicts. It is very important that the pre-service science teacher, the practicing science teacher, and the science researcher work together as much as possible. This can be easily remedied with good planning. This should not be considered as a barrier to establishing such programs to allow pre-service teachers the opportunity to experience science research prior to their classroom teaching assignment.

Benefits from Summer Two

1. Learning Science Content

This project was a good experience because I learned what water fluoridation is and factors for its safety and benefits for communities. I knew very little about fluoride prior to this research. I feel like I learned the content better than if I had read it and then was tested on it in a traditional learning situation, because I actually needed to know the background information before we began running the tests and assisting with the report.

2. Seeing Relevance

My research has helped me realize that I need to keep informed about what is going on in the world and what new things are being done to help our society. I didn't even know that our water would be fluoridated until I started the project. I believe that keeping my students informed about what's going on in the science world and performing relevant experiments will boost their interest in what really goes on around them.

3. Experiencing the Culture of Science

I enjoyed working in the laboratory and in the field. Laboratory work is tedious and time consuming but beneficial because the hands-on experiments and tests, along with my research on the topic, made everything applicable and interesting. From this experience, I was able to better understand what is meant by the "culture of science." The culture of science is very interesting. In contrast, the culture of science in the classroom, as I have experienced, is mostly textbook oriented and not really hands-on. I think the lack of ideas, time, equipment, and desire to make learning science fun and useful inhibit teachers.

My students collaborate on a class project.

Working with people who love what they are doing made me want to bring that feeling back into the classroom. Research, discovery, focus, and love of science make the culture of science exciting. Again, in my experience, the traditional culture of science in the classroom lacks excitement and interest. As a student, I was not motivated to seek answers to questions and research interesting topics.

4. Motivating Students to Make Science Fun

I want to make science fun and interesting. I do not want my students to just read chapter after chapter and answer questions. I want them to develop their own questions and then research the answers. I want them to share with their classmates what they discovered and why that information is important to them. I hope to make students aware of how much fun science can be and that everyone can be a scientist.

5. Developing Classroom Applications

A prospective science teacher should be required to perform research and tests in a laboratory setting before graduating. The information and experiences gained can easily be brought into the classroom to make learning rewarding and interesting. Why major in science education and go into the classroom just to teach out of a textbook that most students have trouble comprehending? A science teacher can give all types of learners a chance to understand and appreciate science because the possibilities are endless in a science classroom.

My research experience will be beneficial to my students. Lesson plans can be developed to help students understand pH, the scientific method, strengths of different solutions, and what the terminology "parts per million" means. Students can bring in water samples from their homes to test the pH, color, smell, and taste. Science and mathematics are better understood through hands-on activities, inquiries, experiments, problem solving, scientific method, and trial-and-error. I will implement as many hands-on science learning activities as possible to help my students better understand what they are learning and how it applies to their world and surroundings.

Endnotes

[1] Florida Keys National Marine Sanctuary: [www.sanctuaries.nos.noaa.gov:80/pgallery/pgflorida/habitats/habitats_6.html].

[2] Lepo, J. E., & Snyder, R. A. (2000). *Impact of Fluoridation of the Municipal Drinking Water Supply: Review of the Literature*. Unpublished report, University of West Florida at Pensacola.

[3] *American Dental Association Statement on Water Fluoridation Efficacy and Safety*. 1999 [www.ada.org/prac/position/fluoride2.html].

[4] Doyle, R. (1996, February). Fluoridation. *Scientific American*, 274, 20.

[5] Public Health Focus: Fluoridation of Community Water Systems. 1992. CDC-MMWR [www.cdc.gov/epo/mmwr/preview/mmwrhtml/00016840.htm].

[6] Richmond, V. L. (1985). Thirty years of fluoridation: A review. *American Journal of Clinical Nutrition*, 41, 129-138.

[7] *Engineering and Administrative Recommendations for Water Fluoridation, 1995*. 1995. CDC-MMWR. [www.cdc.gov/epo/mmwr/preview/mmwrhtml/00039178.htm].

[8] Marshall, E. (1990). The fluoride debate: One more time. *Science, 247*, 276-277.

Christy Tarter teaching
in her classroom

Jan Macauley collecting samples
from Pensacola Bay

CHAPTER 10

Trading Cultures: A Scientist-Teacher Partnership

Janet A. Macauley

A Science Perspective

I am the manager of a small state-certified environmental water-testing laboratory at the University of West Florida. In the summer of 1999, I was asked to be a part of the CO-LEARNERS Program. Lori Livingston Hahn, a doctoral student at Florida State University, was coordinating the project as part of her dissertation research. CO-LEARNERS is an acronym for **C**ollaborative **O**pportunities—**L**earning **E**xperientially **A**nd **R**esearch u**N**iting **E**ducators and **R**esearchers of **S**cience. The project was funded by the National Science Foundation as part of the Florida Collaborative for Excellence in Teacher Preparation (FCETP). Lori was looking for scientists to mentor in-service and pre-service middle school teachers.

Listening to their stories about methods of teaching and sharing science with kids instead of feeding it to them inspired me to look into teaching as a new career path.

The scientists were to involve the teachers in a research project so that they could get experience in "real science." I volunteered to work with a middle school science teacher, Margo King, and a pre-service mathematics teacher, Ron Wark. At the time, my laboratory did primarily environmental water and soil testing for local city, state, and federal agencies. We did this testing in support of permits or monitoring projects (i.e., multiple, long-term measurements of water quality criteria, such as pH, salinity, dissolved oxygen, turbidity, and nutrient concentrations, to assess the environmental health of an area).

The work I chose for them was a monitoring project. A local development group was required to get a permit from the Florida Department of Environmental Protection (DEP) to expand its marina. The group contracted with the Wetlands Research Laboratory (WRL) to do four years of monitoring, that is, taking samples at defined intervals and testing them for certain water quality indicators to show that the marina expansion has had no adverse effect on the quality of the surrounding water. The project involved many techniques, such as taking samples of the water at different depths, ensuring that the samples were representative of the area sampled, carrying them to the laboratory, and analyzing them in a timely manner so that the results would be accurate and acceptable to the DEP.

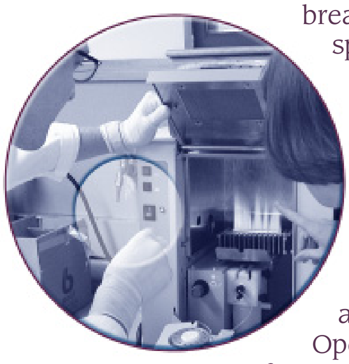
My Science Career

When I started working at the WRL in 1997, I had recently left a large contract environmental testing laboratory. There I had used my science education occasionally, but most of my day was spent running an atomic absorption spectrophotometer, a scientific instrument used to analyze water and soil samples to determine the concentration of metals such as lead in the samples. I began searching for a new position that would allow me to do more with my B.S. in biology than run an analytical instrument all day and produce data for a project I knew nothing about. Acquaintances, who worked at the University of West Florida, told me about a job where I'd be doing work similar to what I had left, analyzing water samples for nutrients like nitrogen and phosphorus on an instrument called an autoanalyzer. However, the job held more interest for me since I was able to see a whole project from start to finish, even if I wasn't involved in the other aspects, like sampling and data management. It made all the difference to me to understand the larger purpose of the work I was doing.

As grants and student employees came and went, I learned more and more of the operation of the laboratory. Eventually, I moved up to laboratory manager. I became well acquainted with the technical support employees at a dozen companies as I learned all the analytical instruments and techniques that the laboratory had available. A state auditor taught me about the rules of quality control that govern the certified laboratory. The state auditor is the person who is responsible for the certification of environmental water-testing laboratories. Our laboratory is a mixture of science and business, and the rules are stricter than in an average research laboratory. Our data have to stand up to public—and sometimes legal—scrutiny. I learned to document every number, every process, and every discrepancy. As the auditor told me, "If you don't document it, you don't do it." I learned what it took to make a laboratory effective and efficient.

Two Kinds of Science

What made my work worthwhile was that I found myself in the midst of real science: researchers pushing back the borders or frontiers of knowledge. One of these researchers, a professor of biology with a Ph.D. in molecular biology, is the director of the WRL. He has graduate students cataloging DNA from dozens of different species of bacteria. Although no area of science stands still, breakthroughs in genetics and molecular biology are moving at the speed of light. New discoveries are literally happening every day, and some of them are happening right around me. Being involved in that kind of discovery is exciting and makes me realize that science is a part of an ever-changing tapestry. As new threads of discovery are woven into the fabric of human knowledge, new connections form, changing the whole picture we have of our universe. It is empowering and humbling.



Here I am with a student while analyzing a sample.

There are really two kinds of science. There is the applied science and the science of research. Applied science utilizes Standard Operating Procedures and accepted protocols that require ten years for methods to move from approval by an expert scientific body (such as the U.S. Environmental Protection Agency) to acceptance by a state bureaucracy. The science of research, however, follows the simpler rules of judgment and common sense, using the latest journal articles and collaboration with others in the same or related field to add new knowledge to the ever-expanding frontier. It is bureaucracy *versus* discovery.

Involvement with Science Educators

Partnering with Pre- and In-Service Teachers

Margo was partnered with Ron to work with me on a research project and create lesson plans based on their experiences in the laboratory. My laboratory did little real research at that time, and I chose a monitoring project that had both a field sampling and laboratory-testing component, the monitoring of a local marina. I wanted them to see the whole process of taking the samples, bringing them into the laboratory to analyze, producing results, and reporting those results to the client, who was required to do this monitoring by a permit from the Florida Department of Environmental Protection. During the course of the summer, we took the boat out to the marina and obtained our monthly samples. With the help of the microbiology technicians, who are UWF students from the WRL, I showed Margo and Ron how to process the samples to discover the number of fecal coliform bacteria in them.

Fecal coliforms are bacteria found in the human digestive tract, as well as that of other warm-blooded animals. The presence of this group of bacteria in a drinking water supply or an environmental body of water can indicate contamination by fecal material. The multiple tube fermentation test for fecal coliforms is a fairly simple test in which a water sample from a body of water (i.e., a local bathing beach) is added to a special broth in a test tube. The broth is designed to help the fecal coliforms grow and to suppress the growth of other bacteria that might be present in the sample. Submerged in the broth is a smaller, inverted tube. The sample/broth mix is placed in an incubator at 44.5°C for 24 hours, the ideal growing temperature for fecal coliforms but too warm for most other bacteria found in the environment. After 24 hours, the inverted tubes are examined for the presence of a gas bubble. Fecal coliforms produce carbon dioxide or sometimes hydrogen gas during metabolism. All tubes showing gas production are positive for fecal coliforms. This test can be used with a single tube to detect the presence of any fecal coliforms (common in drinking water testing) or can be used in multiples with a series of dilutions to statistically estimate the number of fecal coliforms present (used in testing environmental waters). Fecal coliform counts have long been a standard test for the health of a body of water or a drinking water supply. The U.S. Environmental Protection Agency publishes recommended maximum counts of fecal coliforms. If a body of water used in recreation (e.g., bathing beaches) exceeds the maximum count, it is considered to be a potential health hazard to humans because the presence of fecal coliforms can indicate the presence of fecal material in the water, which may carry disease-causing pathogens.

Here I am collecting water samples at a marina with Margo, the practicing teacher.

Margo and Ron worked side-by-side with the microbiologists, processing the samples we took from the marina. They inoculated the samples into the broth tubes using the appropriate dilution series (based on previous knowledge of the sample). They incubated the tubes overnight and counted the number of tubes that turned positive. They recorded all the counting data on the record sheet used for documenting the analysis. Then they used a table in *Standard Methods*: a book of published water-testing methods, to convert the count into a statistical estimate of the number of bacteria present.[1] Ron, the pre-service mathematics teacher, was particularly interested in the procedure for producing the statistical estimate. He planned to use it in his student teaching as a real-world example for his students. Both Ron and Margo were excited about applying the information they learned to their teaching and were looking forward to bringing these examples into the classroom.

Margo worked on another bacteriological test for *Enterococcus* bacteria. *Enterococcus* is also found in the human digestive tract, as well as in other warm-blooded animals. The practical difference between *Enterococcus* and fecal coliforms is that *Enterococcus*, being salt-tolerant, survives better in marine waters. In areas with large bodies of salt water, *Enterococcus* counts can provide a better picture of the contamination of environmental waters by fecal material. However, this test is considerably more labor intensive than the fecal coliform test, as Margo discovered first-hand. It involves multiple-tube inoculation like fecal coliforms. After incubation, growth from any positive tubes (tubes showing turbidity) is transferred onto agar plates. Those plates must be incubated and checked for growth (black colonies with brown circles) at 24 hours and 48 hours after inoculation. Any growth on the agar plates must be transferred to another broth tube. Growth in this final tube indicates a positive test for *Enterococcus*. The entire test takes five days. Any given sample may have 15 to 45 separate inoculations. I am sure Margo would have appreciated the fact that in the next year, the laboratory changed to a new method for *Enterococcus* that only involves one to three plates and 24 hours.

During the time Margo and Ron worked with me, they experienced a range of techniques used to determine the quality of water. They came to understand the importance that attention to detail plays in science. Margo was able to spend a lot of time in the laboratory and became very proficient in the inoculating and counting methods we used. I know they took away a good picture of what we do and why we do it. I hope it has some positive impact on their students.

Sharing Cultures with Two In-Service Teachers

In the summer of 2001, I met Dr. Carol Briscoe, an education professor at the University of West Florida. She was coordinating an extension of the CO-LEARNERS Program, but without the pre-service teachers as in the original project designed by Lori. That summer I worked with two high school science teachers who would change my perspective on science as much as I changed theirs.

Tildon Chavers, a chemistry teacher, and Jo Ann Parsons, a biology teacher, were both from local high schools. They were already involved in hands-on science in their classrooms, using the principle that students learn more by doing and seeking their own answers than by being lectured to. I still had the marina project from two years before, but this time, I arranged it so the teachers could work on it from start to finish. It gave a good overview of what the WRL does and would enable them to see the whole scope of the project.

I am working with a student while setting up an assay.

Tildon was able to start the first week when we took the samples. We went out on our 20-foot Jon boat and anchored outside the marina. The weather was unpleasant that day, and the wind and waves made sampling difficult and wet, at least until we entered the shelter of the marina itself. We were required to take samples at four different sites, one at least 100 yards outside the marina to show a background comparison (away from the impact of the marina), one at the marina entrance, one in the middle of the marina, and one in the far corner. We got some interesting looks while we were cruising around among the yachts in our little workboat.

At each site, we took samples at three depths: at the surface, one foot from the bottom, and at mid-depth. To do this, we used a water sampler, a hollow plastic tube with caps at each end attached by an elastic cord. The samples were taken by hooking the end caps to a trigger so the tube is open, then dropping the sampler into the water to the desired depth, measured by markings made at one-foot intervals on the support rope. When the sampler was at the correct depth, a weight was dropped down the support rope, which released the end caps and sealed the tube. The water from that depth was brought to the surface and poured through a valve near the bottom of the sampler into pre-cleaned sample bottles, one bottle per type of analysis. Some were preserved with acid or other chemicals. The purpose of chemical or cold preservation is to keep bacterial or chemical processes from changing the levels of the analytes in the sample. We took samples at each site and depth for total phosphorus, lead, fecal coliform bacteria, and detergents. The surface at each site was sampled additionally for oil and grease. The samples were stored on ice at 4°C.[2] The boat captain and I were on one team taking the samples. Meanwhile, on the other team, Tildon lowered a Hydrolab datasonde (i.e., a multi-probe water quality monitor) to the same depths that we used for sampling. He recorded the dissolved oxygen, temperature, salinity, and pH of the water on the field data sheet, as well as the times of the Hydrolab and samples readings.

Once all 12 samples were taken, we made sure they were well packed with ice in the cooler, and we headed back to the boat launch. The trip back was not nearly as bumpy, but we arrived at the boat ramp drenched anyway. We hauled all the equipment back to the laboratory and unpacked. Tildon teamed with a college student at the laboratory to count all the samples to be sure we hadn't missed anything. We logged the samples into the laboratory data management system (i.e., a commercially produced database management software package) and labeled them with laboratory identification numbers. All samples, except for fecal coliforms, were stored in the refrigerator at 4°C. The microbiology technicians analyzed the fecal coliform samples by another Standard Method, SM9221E.[1] Tildon observed, but did not participate in, the fecal coliform testing, because the fecal coliform samples must be analyzed within six hours of sampling, and the microbiology technicians have developed a system to handle them efficiently. All samples in the laboratory must be analyzed with accompanying quality control (QC) checks that must give accurate results. Any improper handling can result in inaccurate QC, which invalidates all the associated samples.

The next day, Tildon and I performed the analysis for detergents, called Methylene Blue Active Substances (MBAS) by method SM5540C.[1] One-hundred mL of a sample collected in the field is adjusted to a particular pH, and an indicator dye called methylene blue is added. The indicator dye binds to the detergent molecules, forming a complex that can be extracted from the water with chloroform. The chloroform with its blue complex is read on a spectrophotometer and compared with standards of known detergent concentration. The intensity of the blue color is directly proportional to the amount of detergent in the sample. So, if anyone were washing one's boat and dumping the detergent into the water, we would find out!

The next week, Jo Ann Parsons, the other in-service teacher, joined us. Over the next four weeks, with the help of other laboratory personnel, we analyzed the marina water samples for the following:

- Oil and grease by EPA Method 1664—acidification and extraction with hexane, removal of hexane, then subsequent weighing of material remaining[3]
- Total phosphorus by EPA Method 365.4—heat and acid preparation of the sample, then subsequent analysis by adding a coloring agent and adjusting the pH to form a blue-green colored complex that is read on a spectrophotometer[2]
- Lead by EPA Method 239.2—special chelation extraction to remove salt from the water and then heat and acid preparation, followed by analysis on an atomic absorption spectrophotometer designed to analyze for metals[2]

Being involved in that kind of discovery is exciting and makes me realize that science is a part of an ever-changing tapestry.

During this time, I arranged for Tildon and Jo to attend some research meetings on other projects. Jo, with her greater interest in biology, also spent some time with the graduate students in molecular biology, learning about their research efforts. They were doing the bench work in support of research to use DNA fingerprinting to track the source of certain types of pollution in water bodies. DNA taken from bacteria in water samples is compared to an ever-increasing library of DNA from bacteria taken from the feces of animals and humans. If it can be shown that the groups of bacteria in the feces of a particular animal species are common to all individuals of that species (providing a DNA fingerprint), then water from a polluted waterway can be analyzed for bacterial DNA and compared to a library of known DNA fingerprints from local species. In other words, you could tell if the bacteria in your local bayou are from humans (from sewage or septic tank contamination), raccoons, pet dogs or cats, seagulls, or other sources, and act to limit or prevent the pollution.

Lesson Plans

As part of their involvement in the CO-LEARNERS Program, the teachers had to create lesson plans based on what they had experienced in the laboratory. I had a chance to see the first draft of one plan. It was an ambitious undertaking, an all-inclusive lesson on water quality. The plan incorporated the following parts:

- Group discussions and brainstorming ideas for research (research meetings)
- Background research of local waterways, discussion of issues (the interrelationship of science and society)
- Presentations and sharing of research topics (collaboration)
- Discussion of tools and water quality parameters (project planning)
- A field trip to compare water quality parameters in two areas (testing)

As new threads of discovery are woven into the fabric of human knowledge, new connections form, changing the whole picture we have of our universe.

In addition to the planning and execution of a field survey of water quality, the plan was to design and implement their own individual experiments on water quality in the laboratory/classroom and present their findings and conclusions to the class. Parents will be invited to an open house to see the project posters, and advisors from UWF will attend to discuss the projects with the students. This project could be the beginning of a science fair entry if the student wishes to pursue it. The whole lesson parallels the kind of work the WRL does to a remarkable degree. I look forward to attending the open house.

I did not get a chance to see the other lesson plans, but I offered copies of several chemical methods that were safe enough to be used in the classroom and had enough "gee-whiz" power to get the students' interest. A test for residual chlorine in different types of waters has a direct application to issues like drinking water safety, has calculations that high school students can handle, and has some beautiful color changes, from hot pink to colorless and from colorless to apple green to purple. One teacher told me that he has always prepared all the materials for his students so they can concentrate on the chemistry. Now he realizes that the preparation is half the battle. A student should understand the relationship between the care he uses preparing the materials and the success of the experiment.

What We Learned from Each Other

What I Taught the Teachers

- While working with the teachers both summers, I tried to emphasize certain basic elements of "real science."
- Research science is a process of trial and error. If you prove one thing to be wrong, you know more than you did beforehand, and you start with a new hypothesis and move forward. Usually, you do not find exactly what you set out to find, but with each new hypothesis, you add one discovery to the human database, a discovery that someone else may use to build in another direction.
- The resources you have available to you—materials, time, money, and information—limit real science.
- Success is in the details. Good science is completely dependent on technique. You must take great care in what you do and document everything so if it works once and does not work again, you can go back and find the reasons. Sloppy science is bad science and leads to confusion and inaccurate results.
- Science is about observation. Whether your question is about how something works or how clean the water is, careful observation and measurement is the key to finding answers.

What the Teachers Taught Me

Showing Is Better Than Telling

While working and playing with my own son, I have discovered that showing is better than telling when it comes to learning. We discover things together, and I am constantly amazed at the connections he makes. I had teachers who taught me this way when I was in school, although they were the exception. I still remember the high points in my learning and the consequential changes in my perspective. According to Terrie Kielborn, a practicing teacher who wrote about her experiences in scientific research, this is called the constructivist approach. The approach enables the learner to use prior knowledge for building new knowledge. The combination of new and prior knowledge develops a high level of understanding.[4]

I have always been interested in the idea of teaching, but was intimidated by it as well. My mother taught high school English, which I think is a special challenge. I saw teachers through the eyes of a teacher's daughter—the effort, the love, the homework. I thought teaching must be a wonderful calling, but I never really saw myself as a teacher. I have always loved science, not just the naming systems and the functions and the relationships, but the scientific perspective. Scientists see the universe as a coherent, functional organism, with rules and connections that govern its behavior. A scientist believes that there is an explanation for everything, and accepts that any action she performs has an effect somewhere, at some level. A scientist looks at a problem as something to be solved and has the means to take the problem apart in order to seek the solution. Everyone can benefit from this kind of perspective. It is a valuable life tool and produces more broad-minded adults.

I am supervising a student while collecting samples from a centrifuge.

All the while I was teaching the teachers about science, they taught me about teaching. They have found practical ways to bring this constructivist philosophy into the classroom. Listening to their stories about methods of teaching and sharing science with kids instead of feeding it to them inspired me to look into teaching as a new career path. Given that science is one of the critical areas in teaching, there are many ways to get into the classroom more quickly, and I am told the schools are coming to appreciate the value of a deeper science background in a teacher. The CO-LEARNERS Program and others like it are evidence of this.

Encouraging Students as Scientists

My job as laboratory manager involves teaching of a sort. I always walk a new employee through a method or a technique before having them read the published method. We work side-by-side, and I explain the reasons and potential pitfalls in what we are doing. After they have experienced the technique hands-on, I give them the written procedure to study. I find that they remember all of it better having done it first.

I believe children learn best the same way. My son's pre-school experiences have taught me terms like "manipulatives," which is a technique of learning by working with hands and materials. Children learn mathematics skills and patterns by counting and sorting blocks or pebbles. They learn to compare objects for similarities and differences by using picture cards or toys. The use of touch, as well as sight and hearing, bolsters a child's understanding of a concept. Lori refers to this as "experiential learning," and it is beneficial to both the child student and the adult student. According to Lori, who began the CO-LEARNERS Program at UWF and has herself been both teacher and researcher, teachers should show some empathy when giving students "busy seat work." It is indeed boring. Immersing oneself in an experience—mentally and physically—is far more conducive to true learning.[5]

I have been told by some of the teachers with whom I worked that it is impossible to teach everything "hands-on," and that the sheer resources and preparation involved are major obstacles. But mixing liberal doses of hands-on examples and personal experiences with standard textbook-based learning would help put the subject into context and provide more interest. One of the teachers suggested that with middle and high school students, the "grosser" example is better for getting their attention.

I know a college professor who is well known for peppering his lectures with unexpected examples or descriptions, such as calling a particular type of gelatinous blue-green algal growth "sea snot." That is what sticks with the students. In middle school, I had a biology teacher who brought in an actual cow's head for students to dissect if they finished with their traditional pig's eyeball early. The students were amazed (and disgusted, which was a bonus)! This kind of creativity results in more class involvement and more effective learning.

All the while I was teaching the teachers about science, they taught me about teaching.

In addition to supporting curriculum with hands-on work and interesting examples, a good way to impart knowledge is by asking leading questions. Lecturing and memorizing convey facts—facts that mostly pass through the ear canals without adhering to the brain. Instead, turn the students into investigators. Ask the questions, and let the students make the connections. They will find the answers themselves and learn not only that one answer, but also the questioning process that will help them approach any problem as a scientist. I hope I have given the teachers I partnered with something valuable to take into the classroom. I know they have inspired me to learn about teaching and given me many insights into the joys, traumas, and practicalities of being a teacher. Trading cultures made us all richer for the experience.

Thinking About My Own Future Classroom

Middle school and even late elementary school is the time when students get their first taste of science in school. Like any other subject, when taught effectively, it can interest every child to some extent. When taught poorly, it can ruin a child's chance of ever loving science and may cripple their future aptitude. And while one can live life without science, no one should. My own son already has a general grasp of ecology, the importance of water quality, and genetic inheritance. He wants to be an artist when he grows up, and I know he will be a great one, but he will carry the science perspective with him always.

In the hopes of putting these ideas into practice, I have applied for admission to a teacher education program for middle-grades science. I will call on the teachers I have met during the CO-LEARNERS Program to help me reach my goals, as I hope they will call on me. Someday I hope to stand in front of a group of bored sixth-graders and ask them questions that will light the spark of inquiry in their eyes.

Endnotes

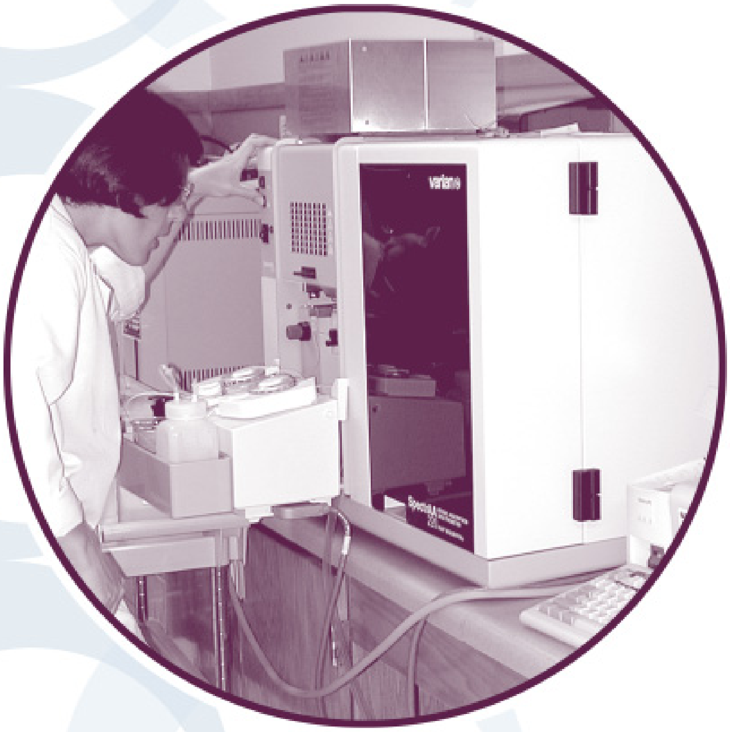
[1] Standard methods for the examination of water and wastewater (1995). 19th edition, Washington, DC: American Public Health Association.

[2] Methods for chemical analysis of water and wastes, EPA/600/4-79/020, March 1983. Washington, DC: United States Environmental Protection Agency, Office of Research and Development.

[3] Method 1664: N-hexane extractable material (HEM) and silica gel treated n-hexane extractable material (SGT-HEM) by extraction and gravimetry (oil and grease and total petroleum hydrocarbons). Washington, DC: Environmental Protection Agency Office of Science and Technology.

[4] Kielborn, T. L. (1999). Blossoming of science involvement through algae research. In T. L. Kielborn & P. J. Gilmer (Eds.), *Meaningful science: Teachers doing inquiry + teaching science* (pp. 67-77). Tallahassee, FL: SERVE.

[5] Hahn, L. L. (1999). Investigating fish mortality: A science teacher's learning experience. In T. L. Kielborn & P. J. Gilmer (Eds.), *Meaningful science: Teachers doing inquiry + teaching science* (pp. 47-55). Tallahassee, FL: SERVE.



Jan is checking her sample
in the autoanalyzer.

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Experiental Learning for Pre-Service Science and Mathematics Teachers: Applications to Secondary Classrooms

There is a growing consensus that it is critical for teachers of science to experience the process of science and scientific inquiry first-hand. This monograph, the fifth in the series, focuses on the voices of pre-service teachers who have chosen to work side-by-side with scientists.

This book *Experiential Learning for Pre-Service Science and Mathematics Teachers: Applications to Secondary Classrooms* includes chapters written by teachers about their experiences conducting action research and/or scientific research. In this monograph, the writers offer the field a significant view of what happens when pre-service teachers, practicing teachers, and practicing scientists work together as co-learners. These co-learning experiences create professional learning communities that stimulate changes and growth for all participants.

When universities embrace this kind of learning experience for pre-service teachers, they begin a significant step in preparing teachers who understand the value of experiential learning—experiencing the culture of science.

Teacher Comments:

> *"If students see teachers excited about [doing science], I think they will get excited about doing it themselves. Neither textbook nor traditional laboratory activities can compare to experiencing science as it occurs outdoors."*
>
> *-Lidia Lanns*

> *"Showing me what they [the scientists] do on a daily basis at work and allowing me to take part not only gives me excellent hands-on experience, but also a substantial amount of confidence in my classroom setting."*
>
> *-Gregory Preston*

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