Michael P. Klentschy

Designing Professional Development Opportunities for Teachers that Foster Collaboration, Capacity Building and Reflective Practice

A case is made that professional development activities in science, when designed as generic programs, can limit pathways individual teachers may take or even select to meet their specific professional development needs.

The standards movement across the United States has created a real need for teacher learning. This need has created a critical examination of the practices employed by school districts across the country to provide sustained professional development opportunities for teachers. There is a growing belief that professional development should be targeted and directly related to teachers' practice. This belief also focuses on the notion that professional development should be site-based and sustained over time. It should be integrated into the regular practices of teachers. The focus of the professional development should be curriculum-based so that it helps teachers help their students attain higher levels of content understanding and improved performance.

This approach to professional development design is contrary to the current practice of a generic professional development program focusing on curriculum implementation, content, pedagogical strategies or student assessment strategies designed for all teachers within a system or region. The "one-size fits all" approach to professional development limits pathways individual teachers may take or even select to meet their own professional development needs.

An alternative approach to the design of professional development programs for teachers must be considered by policy makers and school districts to meet the growing needs of teachers to move along three distinct professional growth continua described by Berliner (1994), content knowledge, pedagogical knowledge and student learning knowledge. In fact, in a standards based environment, some even suggest that there is a fourth continuum or pathway that must also be considered, pedagogical content knowledge (Marks, 1990).

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Professional development programs for teachers that view the personal professional development needs of teachers as important also recognize that through these efforts a knowledge base for teaching can be created.

There is a growing consensus that professional development can be optimized when it is long-term, school-based, collaborative, focused on student learning, and linked to curricula (Darling-Hammond and Sykes, 1999; Loucks-Horsley, Hewson, Love and Stiles, 1998). Such programs focus teacher activity around the examination of student work, student performance, joint planning, teaching and revising lessons, and individual and group reflection. This paradigm shift from working in isolation to working in a collaborative group is favorably received by teachers (Garet, Porter, Desimone, Birman and Yoon, 2001).

James Stigler in a conversation with Scott Willis (2002) recommends three teacher outcomes from such an approach to teacher professional development:

- they need to learn to analyze practice—both other teachers' practice and their own. In this context analyze means to think about the relationship between teaching and learning;
- they need to be exposed to alternatives; and
- they need situational judgment to know when to employ which method.

These three recommendations are based upon a belief that teaching is a cultural activity rather than as something one learns to do by studying it at school (Gallimore, 1996). Most teachers learn to teach by growing up in a culture watching their own teachers teach, then adapting these methods for their own practice. Changing teaching means changing the culture of teaching to a knowledge-based practice.

In considering the operational characteristics associated with disciplinary expertise as a foundational framework, the notion of knowledge-based practice provides a methodological perspective for approaching curriculum and instruction for teachers. The distinguishing characteristic of knowledge-based instruction models is that all aspects of instruction (e.g., teaching strategies, student activities, assessment) are related explicitly to an overall design that represents the logical structure of the concepts in the subject-matter discipline to be taught, a curricular structure that should parallel the knowledge organization of disciplinary experts. The explicit representation of

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the knowledge to be learned through the standards movement serves as an organizational framework for all elements of instruction, including the deter-mination of learning sequences, the selection of teaching methods, the specific activities required of learners, and the evaluative assessment of student learning success. In considering the implications of knowledge-based instructional practice for education, it is important to recognize that one of the strongest areas of cognitive science meth-odology focuses on explicitly representing and accessing knowledge (Romance, Vitale, and Klentschy, in press).

The research foundations of knowledge-based instruction models are consistent with well-established findings from cognitive science. In particular, Bransford et al. (2000), in the recent National Academy Press report, *How People Learn*, stressed the principle that explicitly focusing on the core concepts and relationships that reflect the logical structure of the discipline and enhancing the development of prior knowledge are of paramount importance for meaningful learning to occur. This prior knowledge can also take the form of prior practitioner knowledge.

In emphasizing the role of prior knowledge in practice, the consensus research findings presented by Bransford et al. (2000) emphasized that both the conceptual understanding and use of knowledge by experts in application tasks (teaching) is primarily a matter of accessing and applying prior knowledge of practice under conditions of automaticity. As characteristics of learning processes, the preceding emphasizes that extensive amounts of varied experiences (alternative methods of teaching) focusing on knowledge in the form of the concept relationships to be learned are critical to the development of the different aspects of automaticity associated with expert mastery in science teaching. Considered together, these findings represent an emerging knowledge-based emphasis on the linkage between the logical structure of what is to be taught with the instructional means to accomplish meaningful learning.

From the 1999 TIMSS Video Studies (Hiebert et al., 2003; Roth et al., in press) three recommendations are made regarding how to change the culture of teaching to improve student achievement through professional development programs for teachers that are focused on developing a professional knowledge base for teachers:

- shift priorities to spend some time daily or weekly to study teaching practices; focus on planning lessons and then reflecting on their effectiveness;
- provide teachers with examples of alternative teaching methods; and
- have teachers learn to analyze students' work and understand their thinking to see how to adjust and improve their thinking.

It is a means for teachers to draw on a shared knowledge base to improve teacher practice. This practitioner knowledge is the foundation of developing a professional knowledge base for teachers (Heibert, Gallimore and Stigler, 2002).

There are three features that make practitioner knowledge useful for teachers: practitioner knowledge is linked with practice; practitioner knowledge is detailed, concrete and specific; and practitioner knowledge is integrated.

Practitioner knowledge is useful for practice because it develops a response to specific problems of practice. In addition to addressing problems of practice, knowledge linked with practice is grounded in the context in which teachers work. These are collaborative practices and involve teachers in the following activities:

- defining the problem and creating a shared language to describe the problem;
- analyzing the classroom practice related to the problem;
- creating alternatives to solve the problem;
- testing the alternatives and reflecting on their effects; and
- recording what is learned in a way that is shareable with other teachers.

This form of knowledge is linked to practice though its creation from the problems of practice and connected to the process of teaching and learning that actually occur in classrooms.

Imperial County, California, has established a sustained program of professional development in science for teachers grounded in the belief that teacher capacity building can be best accomplished through a process that focuses on the power of practitioner knowledge enhanced through the process of lesson study and expanded though a technology supported platform, LessonLab.

The Valle Imperial Project in Science and Imperial County, California

In Imperial County, California, professional development programs focusing on developing teacher capacity and a professional knowledge base in science teaching have been in existence for a decade. In 1995 a pilot program, with assistance from the California Institute of Technology—CAPSI Program, began in the El Centro School District. That pilot effort led to the creation of a countywide consortium in the National Science Foundation funded Valle Imperial Project in Science (VIPS) in 1996. These initial efforts have led to the establishment of a California Science Subject Matter Project from the University of California, Office of the President at the local university, San Diego State University—Imperial Valley Campus. In 2004, this consortium was awarded a California Math—Science Partnership by the California Department of Education. This consortium has long recognized the need to provide systemic approaches for the development of a teacher professional knowledge base for teachers in the 14 school districts in Imperial County, California, that comprise their project. This has led to the sustainability of this professional development effort.

Imperial County, California, is located in the southeast corner of California along the United States border with Mexico and is one of the largest (4597 sq. mi.) and most sparsely populated (142,361) counties in California. Located in the extreme

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southeast corner of the state, the county lacks any large metropolitan area and residents must travel to San Diego (120+ miles) or Los Angeles (200+ miles) to the nearest urban areas.

Many Imperial County residents live in extreme poverty, with household incomes declining in real dollars over the last decade. The county had a 2000 mean per capita income of $17,550, the lowest of all California counties. The county's unemployment rates increased from 17.1% in 1991 to 26.3% in 2000, while statewide unemployment rates remained fewer than 4.9%. Imperial County ranks highest in poverty of all 58 counties in California.

Most Imperial County residents have strong cultural and linguistic ties to Mexico. Of the approximately 36,000 K-12 students in Imperial County, 82% are Hispanic, Caucasian (13%), African-American (2.0%), Asians (1.0%) and Native Americans (2%) make up the rest of the population. A total of 48% of the students in the county are Limited English Proficient. Ten percent of the students are children of migrant farm workers. Nearly all of the county's schools qualify for Title I and 67% of all students are eligible for free and reduced lunches. The need for a systemic approach to teacher capacity building has been acute in this region.

The Valle Imperial Project in Science (VIPS) has served as a catalyst to develop a strong and collaborative partnership between the 14 participating school districts and the local university, San Diego State University—Imperial Valley Campus (SDSU-IVC), modeled after the partner schools associated with the National Network for Educational Renewal (Clark, 1995). A joint research project between SDSU-IVC and the El Centro School District has produced one of the few studies documenting the positive effects of a National Science Foundation funded Science Local Systemic Change Project and has been well documented in the literature (Amaral, Garrison, and Klentschy, 2002; Jorgeson and Vanosdall, 2002; Jorgenson and Smith, 2002; Saul, et al., 2002; Klentschy and Molina-De La Torre, 2004). Through these initiatives, strong alliances have been formed between the local school districts, SDSU-IVC, Imperial Valley College and other university partners such as California Institute of Technology – CAPSI, and the University of California Office of the President with a California Science Subject Matter Project at SDSU-IVC.

Teacher analysis of videos, both of themselves and others, is an essential feature for improving teacher practice and developing a professional knowledge base for teaching.

In 2004, this collaboration for sustained teacher professional development in science has been expanded through a California Math Science Partnership initiative. A critical component of this expansion was the creation of a plan of action to transform practitioner knowledge into a professional knowledge base. The professional development action plan viewed this process as multi-dimensional included two critical elements associated with success in this regard, opportunities to refine instructional delivery through reflection and lesson study groups and applications of technology (Klentschy and Molina—De La Torre, 2002). These critical elements form a strong systemic approach specifically designed to build a strong science education learning community.

Opportunities to refine instructional delivery through reflection and lesson study groups.

Lesson study is a problem-solving process used by Japanese teachers for professional enhancement. This process facilitates systematic examination of teaching-learning processes through initial planning, teaching, observation and reflection of teaching practices. Teachers working in grade level groups, begin by defining a problem that is of interest to the study group and which will lead to some new understanding about teaching, the selected content drawn from the California Science Content Standards, and student learning. The selected problem becomes the goal that will guide the group's investigation. The group collaboratively plans a lesson that will eventually be taught by each of the teachers. Group members observe the lesson, and later, the group meets to evaluate and reflect on the lesson. The group decides to modify the lesson and have another group member teach the revised lesson or accepts the lesson as complete. The final step in lesson study is to share findings with colleagues. Lesson study is continuous and is situated in the school within the context of the individual classrooms. This process or cycle is usually repeated three times within a content unit of study and within a nine to eleven week time frame.

The benefit of lesson study as an effective means for sustained teacher professional development is well documented by Stigler and Hiebert (1999). They state, "the power of Lesson Study is that it facilitates teachers' contribution to the field and to their own professional development. That is, when teachers are able to contribute to the field of education they are simultaneously developing their professional understandings." (p. 122).

Now that teachers have participated in a sustained program of professional development, focusing on both deepening their science content knowledge and strengthening their pedagogical skills, a more intellectually rigorous and self-reflective professional culture is the next step. The challenge is now a second order task, but one that has been deliberately addressed by VIPS and in, which substantial progress has been made. The project offered, for the first time, during the 2000-2001 school year, opportunities for teachers to participate in lesson study groups. Selected lessons may be videotaped and discussed during the following meeting. These lessons will also become a part of a project-wide digital library. These efforts have moved the overall culture toward greater professionalism. (For a detailed description of the lesson study process in Imperial County see Amaral and Garrison, 2004.)

Lesson study is unique in that it has built into its process three very important elements that help sustain professional development overtime, once initial efforts have been successfully instituted. One of these elements is the development of a professional digital library that can be studied overtime by the group or used as a starter for a new group. A second element of lesson study is that it promotes professional community by including sharing and dissemination of results among participants. Teachers become teacher-researchers. Finally, a third, unique element of lesson study is that discussions are data based, and connected to actual lessons. The cycle of improvement is linked integrally to a growing body of classroom data, usually student work.

Lesson study fills gaps left by other professional development programs that expose teachers to new ideas and methodologies, but do not provide support while the teacher is trying to implement these ideas in the classroom. Lesson study has gained favor with teachers because it provides opportunities for teachers to practice, receive feedback, and share with their colleagues. Lesson study groups generate knowledge that shares key features with practitioners' knowledge in that the group members work on a problem that is directly linked to their practice.

The implementation of lesson study required policy makers in Imperial County to address several key issues related to changing the culture of teaching. First, finding time in the weekly or daily schedule was addressed. At the elementary school level, principals, reading coaches and VIPS and IV-CaMSP Science Resource Teachers are utilized to release teachers to conduct the classroom observations. These observations are usually conducted during the last hour of the day. Group debriefing is led by a trained lesson study facilitator, usually a VIPS or IV-CaMSP Science Resource Teacher immediately after the lesson and usually after school. At the middle school level, principals have found creative ways to release science teachers for lesson study observations during the school day and to create a master schedule that allows for the scheduling of the lesson debriefings during a common conference period for the science teachers involved.

Second, VIPS and the IV-CaMSP recognized that teachers must be provided with examples of alternative ways of teaching. Analyzing videos in detail, focusing on the ways teachers implement science content, questioning strategies, problems encountered and student understanding can be useful as lesson study groups plan and revise their own lessons. Teachers actually begin the lesson study process with video analysis as part of their training for lesson observation and providing feedback (Amaral and Garrison, 2004). To this end, a media technician is employed by the project to create videos for this purpose.

Teacher analysis of videos, both of themselves and others, is an essential feature for improving teacher practice and developing a professional knowledge base for teaching.

VIPS and IV-CaMSP also recognized that teachers must have opportunities to study student work in relation to the changes teachers make in the classroom. The best source of student work came in the form of student entries in their science notebooks from the lessons. VIPS has long held the belief that student science notebooks offer the best record of what was actually taught by the teacher and what was actually learned by individual students (Klentschy and Molina-De La Torre, 2004). Learning to analyze student work and to make inferences about student thinking can lead to significant changes in teacher practice and expand their professional knowledge base.

The implementation of these three policy changes regarding teacher professional development: collaborative time, video analysis and analysis of student work are consistent with the recommendations made by Hiebert and Stigler (2004) to change the culture of teaching and to build a professional knowledge base.

The professional development program using lesson study as a core has created a means to use the digital library as a tool to strengthen teaching practices.

Applications of technology

Another catalyst for change in approaches to teacher development emanates from the study of approaches used by teachers in several countries that participated in international mathematics and science assessments (Hiebert et al., 2003, Roth et al., in press). During analyses of videotapes of teachers whose students were particularly successful on these assessments (Stigler and Hiebert, 1999), researchers and teachers were surprised to see that there was a far greater difference in teaching practice across cultures than there was within a culture. They began to see that there are many more ways to teach a lesson then they had ever imagined, and some far more effective.

VIPS began the process of designing teacher professional development programs based upon the belief that Internet accessible digital libraries of lesson videos with teacher commentary could provide tools and resources needed to address two challenges faced by teachers as they transform practitioner knowledge into professional knowledge. The first challenge was to provide teachers with alternatives to current practice. If the professional development design would enable teachers to move from novice to expert in their teaching practice, then alternatives to the current classroom practice were necessary. The second challenge was providing teachers with a means of communicating what they have learned. The creation of an Internet accessible digital video library would address the second challenge.

Teachers in the Imperial County have access to a countywide fiber optic network. There are numerous computers, all equipped with Internet access, found in every classroom. Through the Imperial County Office of Education there are frequent workshops conducted on technology applications for classroom teachers. As a result of the great geographic isolation found in Imperial County, professional development opportunities are conducted over the fiber-optic network, thus reducing the travel time and distance for teachers. Regionalized centers can conduct simultaneous professional development, assisted by teacher leader facilitators. All participants can interact and view the same content simultaneously.

In today's climate of standards, assessment and accountability, a paradigm shift is necessary for systems to improve teaching and learning in their classrooms.

In early 2001, VIPS established a partnership with LessonLab through the California Science Subject Matter Project. Current work with LessonLab has focused on launching a comprehensive software platform to support the development and implementation of innovative, case-based professional learning programs. LessonLab is a video- and Internet-based based teacher professional development learning platform developed to help teachers improve their teaching.

This application of technology consists of an integrated platform for creating and delivering case-based content in an interactive format over the World Wide Web. This technology incorporates a mix of streaming video, user discussions, supplemental materials, and personal learning tools to create an enriching professional development experience. It generally involves teachers viewing videos of classroom teaching practice, reflecting on what they see teachers in the video do, analyzing that teaching in light of their own practice, and working with others to improve their teaching. Videos can be viewed on a CD-Rom for those without Internet access, or online, which allows users to communicate with each other and to access Web-based resources.

Also embedded in the LessonLab platform are resources related to each video lesson, such as samples of student work, a teacher's quiz or lesson plan, learner assessment results and other resources related to teaching the subject, topic or skill in question. In addition, all lessons are keyed to state and district curricular standards. The platform also contains an online notebook where teachers and/or facilitators can take and store notes as they watch a video, and a discussion forum for communicating with facilitators, trainers, experts and teacher peers. LessonLab also is designed to allow groups of teachers to create their own digital libraries of teaching practice, perhaps as they engage in Lesson Study, and to share their work with their colleagues. Course developers also can use LessonLab to create online courses.

The VIPS professional development planners have begun the process of building a digital library of science lessons. Teaching is a performance. It occurs in real time, in a real classrooms, with real students. Video is the best way of representing that process so it can be studied and analyzed. Video extends live classroom observations by providing opportunities to return to the lesson for group discussion, deeper analysis, and reflection. This process combined with analysis of student work generated from the lesson can lead to a deeper understanding of what was learned and what can be improved in the lesson. LessonLab has become a platform where teachers can share their own knowledge of what they have learned about lesson improvement with lesson plans and student work combined with the actual performance.

The professional development program using lesson study as a core has created a means to use the digital library as a tool to strengthen teaching practices. On-line courses are in development. The courses are built around video cases, typically a classroom lesson, and engage teachers in activities designed to promote deep-level analyses of the case. Activities will involve teachers in linking the results of their analyses to their own practice, through planning, trying out and reflecting on their own practice in the classroom. An assessment component will also be available to provide teachers or course facilitators with opportunities to assess teacher learning.

Researchers from San Diego State University—Imperial Valley Campus and from the IV-CaMSP are currently studying the effects of lesson study and LessonLab on teacher practice and student achievement.

Final Thoughts

Teacher professional development programs in science have consistently been designed to address system wide needs. These needs may or may not have been consistent with the needs of individual teachers. In today's climate of standards, assessment and accountability, a paradigm shift is necessary for systems to improve teaching and learning in their classrooms. This paradigm shift must focus to recognize the power of practitioner knowledge and utilize that knowledge base as a starting point for the design of professional development programs. Increasingly, systems must design professional development programs that are site-based, collaborative, focus on the analysis of practice in the context of teaching and learning, and be exposed to alternatives. Lesson study and the use of technology driven platforms are two emerging pathways that should be considered in the design of any professional development program that is to be sustained over time. The transformation of practitioner knowledge through a professional knowledge base is the ultimate goal of such a design and subsequent action plan. The teaching profession then can be one that is defined by a knowledge base, which allows the profession to improve its practices over time.

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Changing Perspectives In Professional Development

This article explores three major shifts in beliefs about professional development that are suggested by the research on teacher learning and shares examples of programs from the National Eisenhower Consortia that demonstrate the importance of the shifts.

Introduction

Over the past two decades teacher professional development has undergone profound changes from a focus on mostly "one size fits all" workshops to more ongoing, subject and need-focused programs, often embedded in the school day, where many belong (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003). When my colleagues and I began our work studying professional development in science, the *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996) had not yet emerged on the education scene. Now, it is hard to imagine a time when educators weren't focused on standards-based education.

Half-way through this first decade of the 21st century, educators are working diligently to ensure that all students learn and schools demonstrate annual yearly progress. Schools are scrambling to find ways to reach students who are struggling. Once again professional development is being seen as a major tool to support improved practice and to assist teachers in meeting goals for student learning. Recently our perspectives about what works in professional development and where to best focus energy and resources have been shifting based on research and lessons from the field. This article explores three major shifts in beliefs about professional development that are suggested by the research on teacher learning and shares examples of programs from the National Eisenhower Consortia that demonstrate the importance of the shifts.

Schooling can make a difference for all students if they have access to quality teaching and are held to high expectations.

When it Comes to Student Learning, Teaching Matters—a Great Deal

There is a growing recognition of the value of a teacher's experience and knowledge with regard to their promoting student learning. Experienced teachers who use effective instructional strategies tend to produce higher student achievement outcomes (Rowan, Correnti & Miller, 2002). Most interesting is research that suggests teachers can make the difference for all students, even those students who come from disadvantaged backgrounds (Wenglinsky, 2002). This research supports the ideas generated in the 1980s that "effective schools" could create conditions for learning for all students and counters research from the 1960s that found that schooling could not overcome the effects of students' backgrounds (Coleman et al., 1966).

Schooling can make a difference for all students if they have access to quality teaching and are held to high expectations. Unfortunately, this is not always the case. Research by Sanders and Rivers (1996) found that children who were taught by several ineffective teachers in a row were highly disadvantaged and performed lower than similar students taught by several more effective teachers in a row. As we make the shift in the field to seeing that teaching makes the difference in student learning, schools and school districts are recognizing the obligation of ensuring that students get access to the best possible teaching. This requires rethinking how schools support teachers to develop and deepen teaching expertise throughout their careers.

New teachers need content-focused mentoring that supports them to teach their specific curriculum and content and inducts them into the profession of teaching.

Effective teaching is complex and involves drawing from a deep knowledge base in the content as well as in instructional strategies for teaching content. Stigler and Hiebert (2004) calls for building a knowledge base for the teaching profession—"teachers need theories, empirical research, and alternative images of what implementation looks like"(p. 16).

Understanding the subject matter is essential for effective teaching. Research studies that examined the relationship between teacher qualifications and background and student achievement in mathematics and science found that high school math and science teachers with a standard certification in their field of instruction (usually indicating coursework in both subject matter and education methods) had higher achieving students than teachers teaching without certification in their subject area (Goldhaber & Brewer, 2000; Darling-Hammond, 2000; Monk, 1994).

For beginning teachers, there is a growing recognition of the need for a different kind of induction program that goes beyond tips for classroom management, directions to the supply closet, and general teaching strategies. New teachers need content-focused mentoring that supports them to teach their specific curriculum and content and inducts them into the profession of teaching. The content-focused mentoring model assigns beginning teachers or teachers who wish to improve their teaching to an accomplished teacher mentor who teaches the same subject matter. The focus of the work between the mentor and mentee is on teaching the content and ensuring student understanding of important scientific or mathematical ideas. The mentor and mentee work on lessons together, observe one another teach and study the local, state and national standards in their subject area. Together, they get to know the research on how children learn the content and the alternative conceptions students bring to their learning. For example, the Northern New England Co-Mentoring Network Project (www.nnecn.org), supported by a National Science Foundation grant awarded to the Maine Mathematics and Science Alliance, developed a model for content-focused mentoring and teacher leadership to support beginning teachers in Maine, New Hampshire, and Vermont. Novice teachers or teachers new to teaching science or mathematics are paired with accomplished veteran teachers who provide coaching and mentoring on standards and research-based teaching of the content. When novice teachers encounter material they find difficult to teach or hard for students to learn, the mentor teacher helps them examine the research on learning science and mathematics and deepen their understanding of the ideas students find confusing and reflect on how to adjust their instructional strategies based on the research (Keeley, 2005). By focusing on quality teaching of the content, informed by standards and research, this program is building the next generation of effective science and mathematics teachers.

Since teaching matters so much to student learning, veteran teachers, too, must continue to deepen their knowledge and skills throughout their careers. They need opportunities to collaborate with others, reflect on practice, learn from data and results and see what does and does not work in their classrooms, recognizing that strategies that work one year with one class, may need to be adjusted for new students. Especially in the science field where there are discoveries and new developments, teachers need to continue to expand their content knowledge through courses, reading and other professional development.

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Professional developers at the Northwest Regional Education Laboratory (NWREL) facilitate the use of lesson study with teachers in Oregon and Washington to build communities of practice characterized by teachers working together on lesson designs, talking with one another about student learning and observing teaching in the classroom. According to Eric Blackford, Unit Director for the Mathematics and Science Education Center in the Center for Classroom Teaching and Learning, lesson study is a way to shift teacher learning from one time "outside learning" to learning as part of teachers' "ongoing professional life." NWREL works with partner school sites that involve the faculty and administration in examining lessons to enhance teaching. The approach involves participating faculty in examining their practice on an ongoing basis. At one of the partner site schools, the principal and assistant principal actively engage in learning with the teachers to enhance the teaching of subject matter.

As teachers develop their teaching expertise, professional development can shift to activities that support them to assume roles as instructional leaders, supporting others in their buildings to use quality teaching methods. Schools, like other organizations, need leadership at all levels embedded in the school as a whole (Lambert, 1998; Fullan, 2001). This becomes critically important when the school is trying to make changes in its practices because leaders are needed to support the changes and model effective practice. As Lambert writes, "Without broad based leadership the ability of a school to grow and become better for children is limited." (p. 93). Blackford points out that using strategies such as lesson study "deepens teachers' content knowledge and prepares them to work in a professional community focused on ensuring quality teaching."

Professional Development Needs to be About the Content and How to Teach it

This idea may seem obvious, yet there are still too many professional development resources used for programs that have little to do with learning to teach the subject matter. Some focus only on learning content, others only on teaching techniques and still others on extra curricula topics.

What we have discovered from research is the importance of professional development that is focused squarely on increasing teachers' content and pedagogical content knowledge and teaching skills. Greater positive effects on student learning are seen from inservice programs that focus on content knowledge and on how students learn subject matter (Kennedy, 1999; Weiss, Pasley, Smith, Banilower & Heck, 2003). Teachers apply their professional development learning more often when the professional development programs they attend have direct links to the teachers' curriculum, they are afforded time to try out new ideas and practices with colleagues, and there is ongoing support (Loucks-Horsley et al. 2003). Professional developers are seeing a much higher pay off in the classroom when teacher learning is based on what the teachers teach and teachers are part of a professional learning community that focuses on teaching practice and the ultimate goal of enhanced student learning (Sparks, 2002).

Research evidence suggests that professional development that is most closely linked to improved student learning deepens teachers understanding of the content and how to teach it (Cohen & Hill, 2000; Wiley and Yoon, 1995; Brown, Smith and Stein, 1996; and Kennedy, 1999). Mary Kennedy (1999) examined studies of professional development in mathematics and science that included evidence of student learning. She concluded that "the content of in-service programs does indeed make a difference and that programs that focus on subject-matter knowledge and on student learning of particular subject matter are likely to have larger positive effects on student learning than are programs that focus mainly on teaching behaviors" (p. 25). The programs she examined with the greatest effects were not focused purely on teaching the subject matter, but also on teaching the subject matter in the context of how students learn it. Further evidence comes from the *Inside the Classroom* study (Weiss et al., 2003) that found that it is necessary, but not sufficient, for teachers to have content knowledge. This study reports that: "[Teachers] also must be skilled in helping students develop an understanding of the content, meaning that they need to know how students typically think about particular concepts, how to determine what a particular student or group of students thinks

What we have discovered from research is the importance of professional development that is focused squarely on increasing teachers' content and pedagogical content knowledge and teaching skills.

about those ideas, and how to help students deepen their understanding" (p. 28).

Knowledge of content also helps teachers to develop an essential ingredient for effective teaching, their specialized professional knowledge, called pedagogical content knowledge. Pedagogical content knowledge is an understanding of what makes the learning of specific topics easy or difficult for learners and knowledge of ways of representing and formulating subject matter to make it comprehensible to different learners (Shulman, 1986; Cochran, DeRuiter, & King, 1993; Fern ndez-Balboa & Stiehl, 1995; Grossman, 1990; van Driel, Verloop, & De Vos, 1998). Studies suggest that teachers' development of pedagogical content knowledge is contingent on having subject matter knowledge (Clermont, Krajcik, & Borko, 1993). With limited content understanding, teachers' ability to develop their understanding of how to teach the content is restricted. The National Science Education Standards (National Research Council, 1996) suggest that pedagogical content knowledge is an essential part of effective teaching.

> "Effective teaching requires that teachers know what students of certain ages are likely to know, understand, and be able to do; what they will learn quickly; and what will be a struggle. Teachers of science need to anticipate typical misunderstandings and to judge the appropriateness of concepts for the developmental level of their students. In addition, teachers of science must develop understanding of how students with different learning styles, abilities, and interests learn science. Teachers use all of that knowledge to make effective decisions about learning objectives, teaching strategies, assessment tasks, and curriculum materials" (NRC, 1996, p. 62).

The Department of Education at Rhode Island College in collaboration with the East Bay Educational Collaborative, the Eisenhower Regional Alliance at TERC and participating school districts joined forces to develop a model for increasing teachers' content and

"Effective teaching requires that teachers know what students of certain ages are likely to know, understand, and be able to do; what they will learn quickly; and what will be a struggle."

pedagogical content knowledge. They combined the use of lesson study—a process by which groups of teachers meet regularly over long periods of time (several months to a year) to work on the design, implementation, testing, and improvement of one or several lessons—with a content-based institute. Teacher and administrator teams work together in a science inquiry experience to deepen understanding of science topics. They use their experience to inform their lesson study and incorporate the use of science notebooks to reinforce the inquiry process and enhance student literacy. The integration of the content institute with the ongoing lesson study process leads the teacher and administrator teams to learn the content and focus on how to best teach it to meet student learning goals. In a recent interview, Joyce Tugel, professional developer for science at the Regional Alliance at TERC stated that through this design "the teams develop a common understanding of what inquiry science is, what it looks like in the classroom and how to do it." She says the program is designed to be "relevant and grounded in the teachers' own practice rather than an isolated professional development strategy."

In another example, the Far West Eisenhower Regional Consortium for Science and Mathematics supports the use of cases of science learning to integrate content and pedagogical content learning for teachers. Teachers who collaborated in examining practice through case discussions of content learning in science showed gains in students' science test scores whereas there were no gains among comparable students of non-participating teachers (Daehler & Shinohara, 2001). Case discussions and examination of student work have been shown to develop teachers' content knowledge and pedagogical reasoning skills and to increase student achievement (Barnett & Tyson, 1993).

In a recent interview, Mayumi Shinohara, one of the authors of the science cases stated that:

> "Teachers engage in doing the science in the cases and as they do they are thinking really hard about the learning of that science … they see there is real logic behind the common wrong ideas kids have and see the diversity of ideas kids have about

science concepts. It leads the teachers to very different ways of thinking about students' ideas and how they would work with the kids to help them understand the concepts." She went on to say that "the value of professional development focused on content and pedagogical content knowledge is that it allows for going deeper to better understand student learning and student thinking. While knowing the curriculum materials and how to use the science kits is important, we must create opportunities for professional development to focus on the harder things teacher must do—such as developing the habits of mind to be always wondering how children will respond to the lesson. Professional development that only deals with the basics leaves teachers with the hardest work to tackle later on their own."

The Purpose of Professional Development is to Enhance Learning of Challenging Content for All Students

Another significant positive change we are witnessing in the field is the shift to seeing and believing that the purpose of professional development is to enhance learning of challenging content for all students. This has led to increased accountability and responsibility for professional development programs to better equip teachers to teach a rigorous curriculum to all students and to ensure that students have every opportunity to meet the highest standards. Educators are now recognizing professional development as a tool focused on building the knowledge and skills of teachers to enhance student outcomes.

Teachers can examine student work and other artifacts to see changes in the type of work and thinking students are doing, as well as their level of understanding.

The research demonstrates that students of all races, cultures, and genders are capable of learning science. "All learners from very young ages come to school with conceptions about the world, are curious about phenomena, and can inquire into them and make meaning of them. When all children have access to quality teaching and high expectations, they are able to meet standards for content learning" (Campbell, 1995). Through its use of lesson study mentioned earlier, the Northwest Regional Education Laboratory is increasing teachers' use of inquiry in the classroom and enhancing knowledge of how children learn science. Teachers engage in lesson study to redesign their science instruction to increase the use of inquiry-based learning. One district using a kit-based science curriculum worked together to revise the lessons so that they were more inquiry focused and met specific state standards and learning expectations for grade levels. This professional development program plays a key role in helping teachers develop a wide variety of teaching strategies to meet the needs of all learners.

There are significant differences in the professional development schools choose to implement when they see its purpose to be the enhancement of student learning. They think about what kind of professional development program they need based on student learning needs. They dig into data to find out where their students are not meeting proficiency goals and develop professional development plans related to enhancing teaching and learning in those areas and on building stronger school communities to support that learning. Later, classroom observations and teacher surveys can provide data on whether and how teachers are using new practices.

Teachers can examine student work and other artifacts to see changes in the type of work and thinking students are doing, as well as their level of understanding. With evidence of change in teacher practice and student learning outcomes, the school can begin to build a case for the effectiveness of its professional development program.

Looking Ahead

While the standards have raised the quality of teaching in many places, a study investigating over 350 science and mathematics lessons found that "fewer than one in five lessons were intellectually rigorous—schools in rural settings and those with high percentage of minority students tended to be rated as lacking intellectual rigor" (Weiss et al., 2003). It seems our nation is still at risk when it comes to science learning. A May 2004 article in the *New York Times* warned that the U.S. has started to lose its worldwide dominance in science and innovation as evidenced by fewer patents being issued, fewer Nobel Prizes, and fewer scientific papers published by people from the United States. Recent international studies show that U.S. students still lag behind their counterparts in other developed nations.

The implications are that educators need to continue efforts to build the capacity of teachers to provide a challenging science education that prepares all students for the world they live in. The three shifts discussed in this article must inform decision making about the structure, form and focus of teacher professional development. Policy makers and practitioners must recognize the importance of quality teaching to student learning and create permanent mechanisms and structures, embedded in the school culture, that support teachers to develop deep knowledge of teaching throughout their careers. This includes providing professional development with a strong content and pedagogical content focus tied to student learning goals and situated in teacher practice. Teachers are enriched by studying teaching, examining student learning, and using knowledge from research. Educators must abandon outmoded approaches to staff development and invest in these more "practice-based" approaches to professional learning for teachers.

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Robert E. Yager

Achieving The Staff Development Model Advocated In the National Standards

An argument is made that more actions are needed by more professionals in more schools if the visions of the National Science Education Standards are going to succeed in accomplishing the illusive reforms for which the science education community has so often strived.

The early drafts of the National Science Education Standards (NSES) did not include any mention of staff development; it was not considered as part of the needed visions for changing school science. There was never any intention that the Standards would indicate minimum competencies that would be required of all. Instead, the focus was on visions of how teaching, assessment, and content should be changed. It was a matter of choice that elaboration of content would follow considerations of changes in teaching and assessment strategies. First of all, there was fear that everyone would look first (and perhaps only) at content—and ignore all else. Too often reform and improvement is defined as new organization of materials for teachers to use. Even though suggestions for content inclusion were not placed first in the NSES, they still resulted in the most discussion, concern, and debate among those responsible for preparing the Standards. It is almost as if what one teaches, and when, and for how long it is taught, are all that is really important.

The final draft of the Standards appeared in 1996 after four years of debate and an expenditure of nearly $7 million. Several early drafts were circulated widely with invitations to comment, suggest, debate, and assist with attaining a consensus document. A director of consensus provided leadership and assistance as final drafts were assembled. Early on, programs and systems were added as follow-ups of teaching, assessment, and content. But, as indicated, professional development standards were offered as a sixth area and placed after teaching and before assessment in the final draft of the Standards. It was when the final draft was offered to the leadership in the National Academy of Sciences that a section on Staff Development was added in response to the argument that such visions for the continued education of teachers would be needed if any significant use of the Standards, any improvement of existing teachers, and any improved ways of preparing teachers were to be realized. In many respects these standards for encouraging teacher development and growth were vital to implementing the Standards; and yet they were non-controversial while being viewed by many as the most important part of the Standards for achieving the visions which the other parts suggested.

Too often reform and improvement is defined as new organization of materials for teachers to use.

The NSES and Professional Development

There are fourteen features of Professional Development (PD) included in the NSES; all are considered vital if the Standards are to result in progress for assuring continued growth and development of all in-service teachers. They also provide suggestions for the features needed for programs designed to prepare new teachers. Figure 1 provides a listing of conditions suggested in the National Standards as needed if such programs are to succeed to the fullest.

Figure 1. The National Science Education Standards envision change throughout the system.
The professional development standards encompass the following changes in emphases:

Less Emphasis On	***More Emphasis On***
• Transmission of teaching knowledge and skills by lectures	• Inquiry into teaching and learning
• Learning science by lecture and reading	• Learning science through investigation and inquiry
• Separation of science and teaching knowledge	• Integration of science and teaching knowledge
• Separation of theory and practice	• Integration of theory and practice in school settings
• Individual learning	• Collegial and collaborative learning
• Fragmented, one-shot sessions	• Long-term coherent plans
• Courses and workshops	• A variety of professional development activities
• Reliance on external enterprise	• Mix of internal and external expertise
• Staff developers as educators	• Staff developers as facilitators, consultants, and planners
• Teacher as technician	• Teacher as intellectual, reflective practitioner
• Teacher as consumer of knowledge about teaching	• Teacher as producer of knowledge about teaching
• Teacher as follower	• Teacher as leader
• Teacher as an individual based in a classroom	• Teacher as member of a collegial professional community
• Teacher as target of change	• Teacher as source and facilitator of change

(NRC, 1996, p 72)

The first change suggested for improving PD programs is *less emphasis* on transmitting teaching knowledge and skills by lecture (a feature of most staff development initiatives of school funded programs and for typical college/university teaching). Instead the Standards call for the focus to be one of inquiry into teaching and learning. This, of course, emphasizes the use of questions that leads to learning and the identification of possible answers that could be tested as a means of collecting evidence that the explanations and ideas are valid.

The Standards continue to de-emphasize lecture and reading as models for instruction in favor of learning through investigation and inquiry. Again, they de-emphasize the transmission of information and skills directly by teachers to students. This departs 180° from the way learning is portrayed and modeled in traditional collegiate settings.

Another feature of the PD Standards consists of dropping the idea that science and teaching knowledge can or should be separated in PD efforts, instead ensuring that they are approached in an integrated fashion. Similarly, the Standards suggest less emphasis on separating theory from practice, and *more emphasis* on their integration, especially when in school settings.

One could argue that "real" science is seldom encountered or experienced in most science classrooms.

The Standards emphasize that individual learning needs to change to more collegial and collaborative learning. The Standards identify fragmented, one-shot sessions as problems to be replaced with long-term, coherent plans (probably taking place over several years). Project 2061, the major reform suggestions advanced by the American Association for the Advancement of Science (AAAS), suggests such a plan should coincide with the life span of a human being, perhaps 75 years (Rutherford and Ahlgren, 1990).

The Standards suggest that current workshops should not describe and outline visionary PD models; instead, a great variety of activities and approaches should be used. And, these should be models for the enrollees to experience directly and to prompt discussion and debate among all concerned—something to be used in K-12 science classrooms.

The Standards also de-emphasize the reliance on external expertise; they suggest the importance of the involvement of local teachers and consultants as well as outside persons with specific expertise and experience. The Standards suggest that there be *less emphasis* on staff development seen as efforts on the part of "experts" and more of an emphasis on them serving as facilitators, consultants, planners, and questioners. Teachers are portrayed less as technicians (factory workers) and more as intellectual, reflective practitioners (professionals). Teachers are viewed (by the Standards) less as *consumers* and more as *providers* of knowledge concerning teaching. Teachers are portrayed less as *followers* and more as *leaders*. They are seen less as persons housed in a classroom and more as a member of a professional community. The teacher is not seen as "the target" for change, but as a source and facilitator of change.

How Teachers Must Change

Professional Development is about ensuring that teachers continue to grow and improve. It forces us to look at the acts of teaching and to discuss the effects of these acts on student learning. We have to be sure that learning does result—and that it is learning with understanding and potential use after students leave the school classrooms and laboratories—and not merely an indication of attention, remembering, repeating, reciting, duplicating words, definitions, skills, activities, and verbiage.

Again, the NSES clearly state nine ways teaching should change to result in more and better student learning and to move toward meeting the stated goals. These changes are summarized in the NSES as contrasts between *less emphasis* conditions (which are commonly used strategies by most teachers) and the *more emphasis* conditions which are needed for science teachers to be successful in producing students who have learned with understanding. These contrasts are indicated in Figure 2.

The teaching standards are first in the 1996 publication because of their importance in realizing the goals and because they were the least controversial of all the visions contained in the NSES. These changes in teaching are the targets for improving in-service teaching and the needed skills for science teacher preparation.

The nine *more emphasis* conditions provide another way to measure the success of PD efforts. Do we get teachers who exhibit the *more emphasis* conditions? How much improvement has been found? What else should be emphasized and modeled as part of an exemplary PD program? A new monograph prepared by the leadership of the National Science Teacher Association (NSTA) will be published in 2005 and featured at the March 31 Conference in Dallas. It includes sixteen exemplary programs that illustrate where we are with respect to successful implementations of the Professional Development Standards elaborated in the NSES.

Education has become *training*; i.e., getting students to accept and be able to recall explanations others have offered.

Figure 2. The Ways Teaching Must Change if the NSES Visions for Reform are to Occur

Less Emphasis On

- Treating all students alike and responding to the group as a whole
- Rigidly following the curriculum
- Focusing on student acquisition of information
- Presenting scientific knowledge through lecture, text, and demonstration
- Asking for recitation of acquired knowledge
- Testing students for factual information at the end of the unit or chapter
- Maintaining responsibility and authority
- Supporting competition
- Working alone

More Emphasis On

- Understanding and responding to individual student's interests, strengths, experiences, and needs
- Selecting and adapting curriculum
- Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
- Guiding students in active and extended scientific inquiry
- Providing opportunities for scientific discussion and debate among students
- Continuously assessing student understanding
- Sharing responsibility for learning with students
- Supporting a classroom community with cooperation, shared responsibility, and respect
- Working with other teachers, local experts and school and community leaders to enhance the science program

(NRC, 1996, p 52)

A New NSTA Monograph High-Lighting P.D. Models

The National Science Education Standards (NSES) clearly articulate four goals (justifications) for requiring science in K-12 schools. These four goals illustrate the major focus for producing students who can:

1) experience the richness and excitement of knowing about and understanding the natural world;
2) use appropriate scientific processes and principles making personal decisions;
3) engage intelligently in public discourse and debate about matters of scientific and technological concern; and
4) increase their economic productivity through the use of the knowledge and understanding, and skills of the scientifically literate person in their careers

(NRC, 1996, p.13)

For many the first goal is the most important since it ensures the every student will have a firsthand personal experience with the whole scientific enterprise. This means exploring nature with a natural curiosity which all humans enjoy. It means asking questions, identifying the unknown, proceeding to knowing—even if it is a personally constructed answer or explanation (but wrong in terms of current science academy notions) of the original question arising from personal curiosity. Again, all humans do this in different ways. Artists see beauty, poets express feelings, dancers dance. In science the exploration of natural phenomena must include evidence produced by some manipulation of nature, and others must accept the evidence before science is done.

What Is Basic Science?

Science educators tend to define science as the information found in textbooks for K-12 and college courses or the content outlined in state frameworks and standards. Such definitions omit most of what George Gaylord Simpson (1963) described as the essence of science; Simpson's five *activities* which define science are:

1) asking questions about the natural universe; i.e., being curious about the objects and events in nature;
2) trying to answer one's own questions; i.e., proposing possible explanations;
3) designing experiments to determine the validity of the explanation offered;
4) collecting evidence from observations of nature, mathematics calculations, and, whenever possible, experiments carried out to establish the validity of the original explanations;
5) communicating the evidence to others who must agree with the interpretation of the evidence in order for the explanation to become accepted by the broader community (of scientists).

(Simpson, 1963, p. 3)

The elements of science identified by Simpson are rarely studied in schools. For example, science students seldom determine their own questions for study; they are not expected to be curious; they rarely are asked to propose possible answers; they seldom are asked to design experiments, and they rarely share their results with others as evidence for the validity of their own explanations (Weiss et al., 1994). In fact typical school science treats science concepts as givens—something to be transmitted to students via textbooks and teacher lectures often following closely State Standards which have all too often negated the National Standards.

One could argue that "real" science is seldom encountered or experienced in most science classrooms. The typical focus is almost wholly on what current scientists accept as explanations (Harms & Yager, 1981; Weiss et al., 1994). Competent science students only need to remember what teachers or textbooks say. Most laboratories are but verification activities of what teachers and/or textbooks have indicated as truths about the natural world. There is seldom time for students to design experiments that could improve human existence.

Science education should be about drawing people out in terms of engaging their minds. Instead, most science programs focus on directing students to what they should learn—i.e., the explanations of objects and events that scientists have accepted as truths or explanations of the natural world and/or technological achievements (e.g., automobiles, airplanes, air conditioners) (AAAS, 1990a).

NSELA members need to become the conscience for society by insisting on a more precise definition of science and what this means for school programs and, more importantly, for teaching science in schools.

Education has become *training*; i.e., getting students to accept and be able to recall explanations others have offered. This is often done under the pretext that specific concepts and process skills are necessary prerequisites for understanding, even though it is now apparent that such approaches are useless and that understanding is rarely accomplished until students see the importance of those concepts and skills, and the need for them (Resnick, 1987; NRC, 1999; Greeno, 1992).

Realizing the NSES Visions

What we now know about effective Professional Development for science teachers should provide the framework for all the efforts of members of the National Science Education Leadership Association (NSELA). NSELA members are the leaders who will determine what goes on in K-12 schools with respect to science programs. Leaders should not blindly follow what others mandate or direct. Too often such attempts at reform are alien to what good leadership suggests and certainly do what science itself entails.

NSELA members need to become the conscience for society by insisting on a more precise definition of science and what this means for school programs and, more importantly, for teaching science in schools. Too often teachers as well as the general public are too willing to ignore the essence of science and to relegate its teaching to the topics too often characterizing curriculum frameworks, textbook chapters, the "agreed upon" concepts too often packaged in discrete disciplines.

Paul DeHart Hurd often reminded us that the traditional disciplines are no longer useful and only exist as designations for college departments and secondary school courses. All current research now is blurred in terms of discipline structure. And, instead of science leading to technology (often called applied science), now scientific research is completely dependent upon new technologies. The future of science education is rooted in its alignment with technology (and mathematics research and structure). It will take time for all the reforms to succeed and to be successful. But, NSELA members must assume the needed leadership if it is to proceed in meaningful ways in these tumultuous times.

School science is rarely seen as an experience that enriches and excites students about their knowledge and understanding of the objects and events found in the natural world.

The first and overarching goal for science education for the decade following the 1996 publication of the NSES is to provide a direction for our field and is listed first in the NSES narrative (NRC, p. 13). All science educators (and especially NSELA members) must internalize and work diligently toward meeting this important goal and justification of science in K-12 schools. It should be the goal that unifies us all. But it will be the most difficult to achieve! School science is rarely seen as an experience that enriches and excites students about their knowledge and understanding of the objects and events found in the natural world.

Reconsidering Scientific Literacy

Paul Brandwein once said that science literacy would begin to be realized if every student had even one full experience with science as it is defined by Simpson (1963). Brandwein contended that most high school graduates complete their schooling without even one experience with real science. Many within NSTA have argued that we should aim for more than one science experience in thirteen years—instead, a better goal would be at least one for each year of the thirteen-year continuum of a general education for all. Even then, most teachers would argue that thirteen such experiences are but "a drop in the bucket." In the early 80s, a quarter of a century ago, NSTA called for science to be offered "every day for every year that a student is enrolled in school." Earlier NSTA had proclaimed that producing scientifically literate graduates was the primary aim of science education. Many worried as to what this meant; some felt that it was a call to focus more on learning "about" science. Some looked at the failure that a focus on curriculum changes caused and the fact that few real changes emerged that improved student learning. It should be remembered that change is dependent on leadership and change in education is indeed slow. Effective leadership can make it happen sooner!

The other three goals from the NSES (in addition to ensuring that all students experience the essence of the whole sequence that characterizes science) focus upon experiences in school science which will affect the daily lives of students that can help them make better scientific and societal decisions and lead them to increase economic productivity. These are seen as a way to achieve a fuller scientific literacy. These three NSES goals are rarely approached, realized, or assessed in typical classrooms by typical teachers. Information that would help in realizing these goals are not offered in texts, teacher preparation efforts, or programs for in-service teachers. If we want science concepts and skills to be used in making personal decisions, we are going to have to deal with ideas of how these can be achieved. In *Backward Design,* Wiggins & McTighe, (1998) provide ideas about what needs to be done—what evidence we need to be sure we have met Goal 2 (i.e., using appropriate scientific methods and principles for making personal decisions) must be practiced in the classroom and beyond. Efforts are needed to collect evidence to indicate that each goal is met. We cannot stop with the idea that students seem to know certain concepts and can perform certain skills. We need to expect evidence for learning to include practice with the concepts and skills in actually making decisions in daily living.

Taking Actions as a Result of School Science

Another focus for school science must be on involving students in public discourse and debate in school, and in the outside community, beyond life for any given year. Perhaps the best evidence that this goal had been met is in the involvement of students in their school and community affairs. Where do they actually use what is in the curriculum and what teachers teach? A whole new way of viewing content, instruction, and assessment is needed if this goal is to be realized as one of those proposed in the NSES.

It is probably important to remind ourselves that learning is something that the brain is designed to do.

The fourth goal may be the most difficult to achieve and to assess. In some ways it is even further from daily life and the immediate community. It focuses on economic productivity, possible career choices, and the use of the typical concepts and processes which often provide only a two-dimensional view of science. This could be construed as taking long range actions arising from school science study.

Where We Are with Implementing NSES Visions

We have had eight years to reach the visions advanced for Science Education for the decade following the publication of the NSES. The NSTA series dealing with exemplary programs will be available shortly to highlight the most successful schools and teachers in meeting these visions. Some are already planning to develop new Standards—perhaps to chart new pathways. Some worry, however, that these are so few instances where substantial progress has been made. Nonetheless, it is generally agreed that ten years is a targeted time to take assessment of progress and to find new ways to reach these goals. More actions are needed by more professionals in more schools if the NSES visions are going to succeed with accomplishing the illusive reforms for which we have so often strived.

Features of a Model PD Program

One effort in the staff development arena which continues to grow and change based on experience is the Iowa Chautauqua Model (ICM). It was initiated in 1983 as one of seventeen projects funded by NSF and coordinated by NSTA. It was initiated after NSF decided not to support further the long time AAAS project to provide summer workshops and follow-up meetings for college faculty (mainly faculty from four-year colleges and community colleges). It was designed to use noted researchers and making them available to enthuse and involve science faculty who no longer have engaged in major research efforts. This annual sequence seemed ideal as a way to engage K-12 teachers in similar efforts over the course of a full year in accomplishing needed reforms. The Iowa Chautauqua was initially funded for three years as a program for middle school teachers and attracted further support from industry and a new National Science Foundation (NSF) grant after the NSTA effort (3 years) terminated. Later Iowa Chautauqua was the vehicle for involving teachers and schools in the NSTA Scope, Sequence, and Coordination (SS&C) project which enjoyed major funding and support for a seven year period (1990-97).

Iowa Chautauqua and later Iowa SS&C were approved by the Program Effectiveness Panel (PEP) of the U.S. Department of Education, funded by the National Diffusion Network, validated the Northwest Regional Laboratory and the Middle School Research Association as a professional development model which embodies the professional development needs as identified in the HRI (Horizon Research Institute) study of such programs (Weiss, 2002).

Iowa Chautauqua continues work in Iowa (through National Diffusion Network (NDN) work in 12 other states) but over a period of one to three years for K-12 teachers. Basically, the Iowa Chautauqua Program is at least a whole year-long staff development sequence designed to help K-12 science teachers align their curricula, instruction, and assessments with the visions embodied in the National Science Education Standards. The standards establish eight content areas for science education: unifying concepts and processes, science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and societal perspectives, and history and nature of science.

The program prepares teachers to pilot test short teaching units during the fall based on content standards in these areas. After additional collaboration and training (including action research projects), teachers working in teams develop and pilot longer instructional modules adapting curricular materials developed nationally (often with federal support). The eventual goal is the creation of a unified school-wide curriculum and assessment plan.

Figure 3. A View of the Sequence of Activities Describing the Iowa Chautauqua Model

LEADERSHIP CONFERENCE

A Week Long Conference Designed To

1. Prepare staff team for conducting a workshop series which follows for 30 new teachers.
   a) One lead teacher for no more than ten new teachers
   b) Scientists from a variety of disciplines
   c) Scientists from industry
   d) Administrators
   e) Science Supervisors/Coordinators as chair of staff teams
2. Organization and scheduling for each workshop
3. Publicity and reporting
4. Assessment strategies
   a) Six domains
   b) Use of student reports
   c) Teacher journals/notebooks, new research plans for Lead Teachers

THREE WEEK SUMMER WORKSHOP

Teaching and Learning as Outlined in the NSES

1. Includes special activities and field experiences that relate specific content within the disciplines of biology, chemistry, earth science, and physics—all related to the four goals of teaching science in the NSES.
2. Makes connections between science, technology, society within the context of real world issues.
3. Issues such as air quality, water quality, land use/management provide context for concept development.

Figure 3. continues on page 23

Figure 3. continued

ACADEMIC YEAR WORKSHOP SERIES		
Fall Short Course ➪	Interim Project ➪	Spring Short Course
Awareness Workshop	Three Month Interim Project	Final Workshop
20 hr. Instructional Block (Thursday p.m. Friday, & Saturday)	**The STS Module**	**20 hr. Instructional Block** (Thursday p.m. Friday & Saturday)
Activities Include: 1. Reviewing problems with traditional views of science and science teaching 2. Outlining essence of the broader definition of science. 3. Defining techniques for developing new modules and assessing their effectiveness 4. Selecting a tentative module topic 5. Practicing with specific data collection assessment tools in each assessment Domain.	Activities Include: 1. Developing instructional plans for minimum of twenty days 2. Administering pretests in six domains 3. Teaching the module utilizing student ideas and prior experiences. 4. Collecting posttest information 5. Communicating with regional staff, Lead Teachers and central Chautauqua staff	Activities Include: 1. Reporting on the teaching and learning experiences 2. Reporting on multiple assessment efforts 3. Interactions concerning new information arising from the action research in the classrooms of all participants 4. Planning for involvement in professional meetings 5. Planning for next-step initiatives

Establishing Successful P.D. Programs

The Chautauqua program prepares teachers to use constructivist instructional strategies in the classroom. This means less emphasis on lecture, demonstration, memor-ization, and rigid adherence to curriculum. It means more emphasis on discussion, teacher collaboration, active inquiry, cooperative learning, continuous assessment of student understanding, and use of student experience and local issues as vehicles for learning.

The Iowa Chautauqua program and its successor, the Iowa Scope, Sequence, and Coordination project, have been evaluated by outside evaluator teams, doctoral candidates, annual assessment reports, and studies in 10 states and 6 international settings. Most of these studies have focused on changes in teacher practice and attitude. Several, however, have examined student achievement in six domains of science learning: concepts, process skills, applications, creativity, world view, and attitude. In one study, for example, 15 lead teachers each taught one science class using the Chautauqua approach and another using a traditional textbook approach. Students (a total of 722) were randomly assigned to treatments and traditional classes. Pre-tests were given to students in September and post-tests in April. The type of test used varied from domain to domain. For example, the concept domain was assessed with multiple choice tests available from textbook publishers, the process domain with 13 skills identified by the American Association for the Advancement of Science, and the application domain by multiple choice items generated by program developers. The results revealed no difference between Chautauqua and control students in the concept domain (traditional science content); in the other five domains, however, Chautauqua students demonstrated significantly more growth than control students.

Other studies have found that female students in classrooms taught by Chautauqua teachers have more positive attitudes towards science than counterparts in traditional science classes. Studies have also demonstrated numerous positive effects on teachers, including better understanding of the nature of science and greater ability in ability to teach it. Figure 3 is an outline of the features of Iowa Chautauqua Model.

A Broader View of Science

It is probably important to remind ourselves that learning is something that the brain is designed to do. Perhaps of even more importance is the fact that real learning is occurring even when it seems that many students do not succeed in school because they do not seem to learn what teachers teach or what is in the curriculum. The assumption is too often that they have not learned at all.

Frank Smith in his book "The Book of Learning and Forgetting" (see Figure 4) distinguishes between what learning is classically and what it has become officially in institutions called schools (Smith, 1998).

Learning about Professional Development is just like learning in school. But the official theory is not the one that the NSELA leaders should follow; it is time to renew use of what Smith calls the classical theory of learning and in so doing revise the official view of learning which exists in most schools. We should be pushing for use of the classical theory in our work with teachers for change and ignore the so-called official theory which is the root of most of our failures for reforms in science education in schools.

Figure 4: Views of Learning (From the book Learning and Forgetting).

The classic view (of how humans learn) indicates that real learning is	*The official theory (which governs schools) results in learning that is*
continual	occasional
effortless	hard work
inconspicuous	obvious
boundless	limited
unpremeditated	intentional
independent of rewards and punishment	dependent on rewards and punishment
based on self-image	based on effort
vicarious	individualistic
never forgotten	easily forgotten
inhibited by testing	assured by testing
a social activity	an intellectual activity
growth	memorization

(Smith, 1998, p. 5)

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Putting the Puzzle Together: Scientists' Metaphors for Scientific Inquiry

This study describes specific metaphors commonly used by scientists to articulate aspects of their conception of scientific inquiry.

Metaphors are used as a typical way to negotiate and to describe our everyday experience. In the classroom, teachers commonly employ metaphors to engage students and to make abstract ideas appear more concrete (Ogborn & Martins, 1996; Thagard, 1992). In particular, metaphors provide an effective means to help visualize abstract ideas (Davidson, 1976; Miller, 1979). We feel that understanding the metaphors scientists use will assist teachers in crafting classroom discourse that will guide students' developing understanding of scientific inquiry. Lemke (2003) argues that the languages of science are complex and that teachers rarely teach about how to converse in ways that are like scientists. Our study describes and characterizes metaphors used by academic research scientists as they described their experiences with authentic scientific inquiry.

Theoretical Framework

Lakoff and Johnson (1980) articulated metaphors as based in a shared experience and containing links between the form of the metaphor and the real idea that the metaphor seeks to describe. Pugh, *et al.* (1992) extend Lakoff and Johnson's model and describe *grounding* as the need for a metaphor to be based in a shared experience. *Form* refers to the commonality of imagery between the two concepts that is essential if a metaphor is to be successful. For example, in comparing the structure of the atom to the solar system, the form is an image of objects orbiting around a center. *Correspondences* are the multiple points of comparison between the two concepts within the form. The more correspondences there are, the more complete and potentially persuasive is the metaphor. Finally, *connotation* addresses the extent to which a metaphor defines a particular experience. That is, how much has the metaphor entered the culture?

This metaphor reminds us that scientific inquiry is not set of proscribed steps with a known outcome.

Methodology

Interviews with 52 science faculty members at a large midwestern academic research institution were conducted using a semi-structured interview protocol designed to probe the subject's conceptions of scientific inquiry (Harwood, Reiff, & Phillipson, 2002). Interviews were tape-recorded and interviewers took field notes during the interview. Together, the transcripts and field notes represent our data. The scientists interviewed were disbursed across nine science departments (anthropology, biology, chemistry, geography, geology, medical sciences, physics, applied health, and environmental affairs) and a wide variety of specific research fields.

After conducting the interviews, we independently analyzed the science faculty members' responses to each of the eight interview questions. Potential metaphors were identified. Following a constant comparison methodology, we compared our independent lists of metaphors and agreed on a consistent understanding regarding how to classify items (Bogdan & Biklen, 2003). The result was a list of metaphors and another list of what we defined as, "every day life examples." These every day experiences were not classified as metaphors. As an example of how inquiry plays a role in a person's every day business, a medical science researcher gave the following response:

> "teaching, interviewing, fixing a car, cooking, business. Let me put it this way, I can't think of many things that scientific inquiry doesn't, one way or the other, play a role in a person's life. They are doing it but they don't know it's scientific inquiry. They just ask the question, search for an answer, and then make improvements next time. That is essentially what is happening in their thinking."

We then independently read through the interviews a second time to double-check for a complete list of metaphors and to collect the metaphors into initial categories. When a discrepancy between our individual categorizations occurred, the results were discussed until a mutual agreement could be made (Tobin, 2000).

Results and Discussion

The scientists' metaphors provided powerful images to complement descriptions of important aspects of scientific inquiry. Scientists used metaphors to describe the process of connecting data, the importance of knowing how and when to use resources or tools, the ability to remain open minded, the relationship between problem solving and scientific inquiry, and the necessity of enhancing scientific knowledge by adding creativity and individuality to an investigation.

Often the metaphor used by a scientist filled multiple purposes and contained a rich set of correspondences. Five key characteristics associated with scientists or with aspects of the processes associated with doing scientific inquiry emerged where the scientists tended to use metaphors. These were: *open-mindedness*, *putting yourself in your work*, *utilizing resources*, *problem solving*, and *making connections*. Below we look at each of these characteristics and describe the metaphors used.

Open-mindedness

An important characteristic of a scientists engaged in a study is the ability to remain open-minded regarding the results of the study. Scientists who are overly concerned with proving a hypothesis may overlook data in the rush to communicate findings to peers. This open-minded realism (Harding & Hare, 2000) encapsulates the investigator's challenging task of being willing to be wrong in their expectations regarding their scientific inquiry.

The image of the emotion-less scientist may encourage non-scientists, including children, in believing that science is boring enterprise devoid of passion.

Remaining open-minded during the process of scientific inquiry allows the investigator to consider that their expectations or their understanding of other aspects of the study may not be correct. Thus, an investigator can be more open to discoveries or to data that is contradictory to what was expected. A physicist used the metaphor of the SCIENTIST AS ARTIST,

> It's like an artist. An artist does not know the answer. An artist in the process of creating something lets the process lead them to whatever they are doing. They experiment and that's kind of what you do in science.

The correspondence of this metaphor to the experience of being a scientist requires that we understand that authentic scientific investigations do not progress in a linear way where one step invariably leads to the next. Scientists may not know exactly how their investigation will progress and so must be open to the process of scientific inquiry in the same way an artist is open to their muse.

This metaphor reminds us that scientific inquiry is not set of proscribed steps with a known outcome. Rather, it is an exploration into the unknown, but knowable world. A nice description of this type of exploration in a high school setting is given in Crawford's (2000) case study. In one instance (p. 923), the teacher indicates that he doesn't really know what will be discovered as they begin analyzing data from a nearby river. He conveys both his excitement for discovery and his open-mindedness toward the results they may find. In this way, the teacher provides an example for his students of this characteristic of a good scientist.

Putting yourself in your work

Lemke (2003) and others understand that science is not a dispassionate search for objective truth. The image of the emotion-less scientist may encourage non-scientists, including children, in believing that science is boring enterprise devoid of passion. Scientists in our study, however, described doing science as a much more creative endeavor where they design methods and look at data in many different ways. To develop new knowledge about the world entails putting a little of yourself into your work.

A medical scientist compared coming up with something new in science to cooking. In this view of SCIENCE AS COOKING, the scientist does not suggest just following a recipe. To do so will not lead to a new dish or concoction. Adding a spice here and there, however, or substituting items can create a recipe unlike the original. Similarly, scientific progress can result from trying out different variations of an idea. The correspondence of this metaphor with the experience of a research scientist is in feeling that the investigation is their own. An anthropologist compared doing scientific inquiry to PLAYING A CELLO.

> Yo Yo Ma, who is a cello player, says that interpretation is not passive. It's not just playing the notes as they are written; it's putting something of your own, yourself there.

Other metaphors that scientists used that have similar correspondences regarding ownership of the process of scientific inquiry include SCIENCE AS FARMING and SCIENCE AS GARDENING.

> Farmers do that today in determination of when to plant, what to utilize in the fields. They use the available evidence of what they're told and they fit that in with their experience and what their father or their grandfather did

If further studies are needed, the farmer or gardener may repeat appropriate stages of inquiry and redesign the experiment using different controls. The farmer guides the process according to their own goals and purpose much as a scientist guides the process of scientific inquiry to gain a deeper understanding of their questions.

> Let's say somebody is a gardener. Maybe they tried growing tomatoes in different locations or different amounts of sun or the soggy part of the garden as opposed to the dry part of the garden.

Scientific inquiry was also compared to the creative act of WRITING POETRY. The construction and selection of styles of poems is similar to the process of designing and choosing methods to form and shape a study. Writing poetry and designing a study are creative endeavors that involve the self in producing a unique creative work within a structural frame. Interestingly, Watts (2001) has recently argued for explicit connections between science and poetry in school curricula.

Teaching science in ways that do not engage students in the process of inquiry reinforces an image of science and scientists as lacking creativity (Moravcsik, 1981).

Scientific inquiry is not an unemotional, detached, and uninvolved activity where results are known and nothing out of the ordinary ever happens. A scientist from applied health described contrast between teaching that emphasized reciting facts found in a science textbook and the importance of involving yourself in your work.

> That was a big realization for me—you don't actually just learn the book and spit it back; it's like you are making the book.

Utilizing Resources

Scientific inquiry investigations involve the use of resources or tools that will help bring a study to a fruitful resolution of the investigator's question. How a scientist chooses to use the available resources impacts the results of the study. Thus, scientists need to be skilled in selection of the appropriate tool for the investigation and must be able to use the tool in a proficient manner.

Scientific inquiry is not an unemotional, detached, and uninvolved activity where results are known and nothing out of the ordinary ever happens.

A geographer used the metaphor of teaching someone to fish to explain the importance of knowing how to use the tools in an inquiry investigation. If someone wants to feed him/herself, one does not just give that person the fish. To teach a person how to fish, you give them a rod or the tools necessary to fish then assist them in developing skills and techniques in fishing. This is similar to carrying out scientific inquiry investigations—the investigator must know how to conduct the research and not just be focused on getting the fish or the "right answer."

Several scientists mentioned the role of a metaphorical TOOL BAG in an inquiry investigation. Each tool bag contains methods, instruments, questions, techniques, and it is up to the scientist to decide which tool to use, and when, in an investigation.

> and then I think the other thing that you need is a kind of tool bag and you gotta have a lot of different tools because typically one tool isn't going to get you what you wanted.

Knowing how to make effective use of resources equips scientists to conduct successful investigations. A chemist compared competency with the tools used in inquiry investigations with the skills used in PAINTING. A painter must know how to use the brush, the paints, and the canvass to construct a painting, just as a scientist must be proficient at using available tools to enhance investigations.

The ability to "make connections" between the data was most frequently cited as the most important characteristic of doing scientific inquiry.

Problem-solving

In the course of conducting a scientific inquiry any number of problems may be encountered. Indeed, this experienced reality is often summed up humorously as "Murphy's Law" stating that if anything can go wrong, it will (and usually at the worst possible moment). Solving these unexpected problems can be a major use of investigators energy. The need to address vexing problems in daily life led some scientists to relate problem solving in a scientific inquiry to solving problems in their everyday lives. In these scientists' view, non-scientists can benefit by approaching and solving everyday life problems in the same way scientists approach solving scientific problems.

A common metaphor form for problem solving strategies is one we call "the lawnmower metaphor." The Lawnmower metaphor refers to a set of metaphors that take the form of repairing a complex machine (SCIENCE AS ENGINE REPAIR). The metaphor is used to describe the systematic process that scientists use as part of the problem solving strategy within an inquiry. This metaphor also contains within it the need of scientists to use failure to inform the progress of their inquiry.

> [You] take your lawnmower you pull the cord and it starts. You went in with certain assumptions. You're going to have clean gas, you're going to have a full level of oil. Well, you go one day and you pull the cord and it doesn't work. You begin questioning those things you assumed are in place. You think about it. You check the gas. You check the oil level. You check all these things basically you assumed at the outset when you walked up to the lawnmower. Then you find out where you went wrong. And you hope it's one you know and can control. You hope that it's not some working part that you don't have knowledge of. You really think about what you're doing. At least the way I do. It all comes down to solving problems and understanding whenever you get an unexpected result the first thing you have to do is assume—assuming everything in the experiment was done correctly—assume that you made an erroneous assumption. And you've got to locate that and fix it and retry.

Notice that the process of problem solving described by this scientists moves from simple solutions to more complicated solutions—a commonly identified characteristic of the nature of science.

Making Connections

The ability to "make connections" between the data was most frequently cited as the most important characteristic of doing scientific inquiry (Harwood, Reiff, & Phillipson, 2002). This skill in making connections involves the use of analytical and critical thinking skills to identify patterns and inconsistencies across the data. Scientists recognized the importance of individual pieces of data but also how the data can be connected to provide a pattern, model, or theme.

For example, a geologist used the metaphor of SCIENCE AS A BRICK BUILDING to represent the significance of each piece of data (a brick) in the analysis of the larger set of data corresponding to the overall stucture.

> I think science has a very big building of bricks, not always a capstone. Everybody puts their brick here and there and not all bricks are superior important ones like a capstone or something but every brick counts.

Even data from separate investigations can be connected to enhance an understanding of a scientific concept.

Another part of making connections is to be able to focus on current investigations, but also to have insights into implications of the study and further possibilities for research. A biologist articulated this process with the metaphor of SCIENCE AS A CHESS GAME in that one needs to be able to "recognize the important questions but be able to look ahead 5-6 moves." Connections also need to be made with the existing body of literature on a topic. A chemist used the metaphor of SCIENTIFIC INQUIRY AS LEARNING A FOREIGN LANGUAGE to describe the process of connecting the body of known information to the new information arising from the current study.

> "this ability to think abstractly about a problem is absolutely crucial. It's also crucial to have a lot of facts at your disposal it's very vaguely like learning a foreign language. You have to learn syntax and grammar and that's the thinking abstractly part, how things were generally put together. But, also to learn a foreign language you have to learn vocabulary. In science you must know a set of a reasonably large number of facts."

A scientist needs to be fully aware of details, but not lose sight of how these might fit into the "Big Picture". A geologist used the metaphor of SCIENTIFIC INQUIRY AS BUILDING A MOSAIC ARTWORK in just this way. They point out that in making a mosaic, the artist had to decide how the pieces would be placed and arranged in the picture. The important part is not to loose track of the individual pieces. At first the artist might just have a pile of yellow, purple, and brown mosaic tiles but how these are placed together or connected will determine how the picture will look.

A geographer used the metaphor of being able to see the forest through the trees as an essential characteristic of an investigator in scientific inquiry. Scientists who are so focused on the details of an investigation (the trees) may not be able to take a step back and see how the data are connected (the forest).

Explicit use in the classroom of metaphors that focus on the five characteristics we identified may provide students with a clearer understanding of the nature of science and scientific inquiry.

> Being able to synthesize the big picture but also at the same time concentrate on the details—not losing sight of the forest from the trees, but also looking at the tree itself.

This ability to make connections is an essential characteristic of conducting scientific inquiry investigations. This skill requires the ability to synthesize large amounts of data and to see the patterns that exist between the data so that the meaning can be given.

Conclusion

> 'When it comes to atoms, language can only be used as in poetry. The poet, too, is not so concerned with describing facts as with creating images' (Niels Bohr, quoted in Mashhadi, 1997).

The metaphors used by scientists to articulate aspects of their conception of scientific inquiry identified five broad characteristics of scientists engaged in scientific investigations:
open-mindedness, putting yourself in your work, utilizing resources, problem solving, and making connections. Specific metaphors such as lawnmower repair, painting, musical performance, cooking, and the tool bag elucidate aspects of the process of scientific inquiry and the characteristics of good science.

These metaphors help us to understand the conceptual approaches and experiences that the community of scientists values. Explicit use in the classroom of metaphors that focus on the five characteristics we identified may provide students with a clearer understanding of the nature of science and scientific inquiry. Teachers of science can choose activities that reinforce these perspectives and develop the skills most valued by active research scientists. The use of metaphors helps to describe scientific inquiry in such a way that relates scientific practices with experiences to which people are familiar. In this way, perhaps, students may begin to perceive themselves as modeling scientific inquiry when doing normal activities such as fixing a car or gathering evidence to make an informed decision.

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Pre-Service Teacher Self-Efficacy Beliefs Regarding Science Teaching: A Comparison of Pre-Service Teachers in Turkey and the USA

Results from a study to compare preservice elementary teachers' efficacy beliefs at a large Turkish university and at a large American Mid-Western university indicate that the preservice elementary teachers in these two countries may have different science teaching efficacy beliefs.

The issue of teachers' efficacy is of importance as teacher preparation programs throughout the world attempt to address shortages of qualified, competent teachers. In the field of science education, monitoring and reacting to the issue of efficacy seems to be one way in which teacher preparation programs are evaluating the structure of programs. In developing countries there is an immediate need for qualified and innovative science instruction as governments attempt to insure that a pool of scientists, engineers and computer specialists are trained for business and academic research and citizens are provided with (and retain) some understanding of science. This study provides a comparison of the self-efficacy of future science teachers in two countries (one developed and one rapidly developing). Analysis suggests what might be learned to aid teacher preparation programs in many settings.

Teachers' sense of efficacy is a construct derived from Bandura's (1977) theory of self-efficacy in which the generalized behavior of an individual is based upon two factors, (a) a belief about action and outcome; and (b) a personal belief about one's ability to cope with a task. Tschannen-Moran and Woolfolk Hoy (2001) defined teacher efficacy as a teacher's "judgment of his or her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated." (p.783)

Teacher efficacy has been found to be one of the important variables consistently related to positive teaching behavior and student outcomes (Gibson & Dembo, 1984; Ashton & Webb; 1986, Enochs et al., 1995; Woolfolk & Hoy, 1990; Henson, 2001). Research on the efficacy of teachers suggests that behaviors such as persistence at a task, risk taking, and the use of innovations are related to degrees of efficacy (Ashton & Webb, 1986). For example, highly efficacious teachers are more likely to use open-ended, inquiry, student-directed teaching strategies, while teachers with a low sense of efficacy were more likely to use teacher-directed teaching strategies such as lecture or reading from the textbook. Research indicates

In developing countries there is an immediate need for qualified and innovative science instruction as governments attempt to insure that a pool of scientists, engineers and computer specialists are trained for business and academic research and citizens are provided with (and retain) some understanding of science.

that students generally learn more from teachers with high self-efficacy than those same students would learn from those teachers whose self-efficacy is low (Ashton & Webb). Woolfolk and Hoy argue that teacher efficacy is one of the few constructs about teachers that is related to “the behavior of learning of students.”

The construct of teacher efficacy has been explored by a number of researchers in recent years. For example, Tschannen-Moran et al. (1998) proposed a model of efficacy that integrates several important components of social cognitive (Bandura, 1997) and locus of control theories (Rotter, 1966). Within this model, teacher’s efficacy judgments are the result of the interaction between a personal judgment of the relative importance of factors that make teaching difficult and a personal assessment of his or her personal teaching competence or skill.

Bandura (1986) argues that teacher efficacy is a situation-specific and even subject-specific construct. For example, a teacher’s self-efficacy may be low while teaching science, but high while teaching language arts. For this fictitious teacher they may devote more time to language arts instruction in comparison to science. Furthermore this teacher might have more personal interest in participating in professional development activities related to language arts as opposed to science.

Enochs and Riggs (1990) claimed that a teacher’s belief system is important in elementary science teaching. They suggest that two types of beliefs seemed relevant, belief that student learning can be influenced by effective teaching (outcome expectancy beliefs) and confidence or belief in one’s own teaching ability (self-efficacy belief; Gibson & Dembo, 1984). Having one belief being high, for instance outcome expectancy, does not mean a strong belief with respect to the other measure. Riggs (1991) reported that elementary school teachers with low science teaching efficacy beliefs avoided science teaching even though their outcome expectancy beliefs regarding teaching generally were high.

Studies evaluating cross-cultural comparisons of teacher efficacy suggest that preservice teachers in different cultures vary in the degree to which they believe themselves to be efficacious in their teaching (Campbell, 1996; Gorrell & Hwang, 1995; Lin & Gorrell 2001; Rich, Lev & Fischer, 1996; Yeung & Watkins, 2000). These studies suggested that the concept of teacher efficacy may be influenced by the unique features of cultures (Gorrell, Hazareesingh, Carlson, & Stenmalm-Sjoblom, 1993; Gorrell & Hwang; Lin & Gorrell; Lin, Gorrell and Taylor, 2002). For example, using a modified version of a teacher efficacy scale developed by Gibson and Dembo (1984), Lin and Gorrell suggested the existence of a different factor structure compared with the original scale developed with a sample of Taiwanese preservice teachers. They concluded that the concept of teacher efficacy may be culturally oriented and needs to be carefully examined when applied to teachers in different countries. Similarly, Lin et al. examined the influence of culture and education on U.S. and Taiwan preservice teachers’ efficacy beliefs, they found that preservice teachers in these two countries may have conceptually different expectations of teaching (e.g. parental support, social awareness, individual efforts). They suggested that in both countries, preservice teachers’ efficacy beliefs may be influenced by the context of their academic programs, by their increasing competence and experience as teachers, and by cultural perspectives. In another study, Rich et al. (1996) conducted a study to examine the validity of the Gibson and Dembo teacher efficacy scale. When translated to Hebrew and administered to Israeli teachers, results indicated a factorial structure of this particular teacher efficacy scale similar to that observed with an American sample of students. Gorrell et al. (1993) compared American, Swedish, and Sri Lankan preservice teachers and found that American preservice teachers had more positive general efficacy of teaching beliefs compared to Swedish and Sri Lankan teachers. However, Sri Lankan teachers’ personal efficacy beliefs were found to be higher than that of American preservice teachers. In another study, Campbell (1996) compared teacher efficacy beliefs of preservice and inservice teachers in Scotland and America and found no significant difference between the two countries with regard to teacher efficacy.

Research indicates that students generally learn more from teachers with high self-efficacy than those same students would learn from those teachers whose self-efficacy is low .

Gorrell & Hwang (1995, p. 101) have argued that there is a research trend towards "understanding teaching and teacher education in terms of development of teaching and personal efficacy beliefs." They suggested that teacher efficacy is an important topic for comparative studies between the United States and other nations. "Studies with preservice and inservice teachers both in the United States of America and in other countries would profit from examining closely the growth of teaching and personal efficacy as teachers expand their teaching orientations and their experiences" (Gorrell & Hwang, p. 104).

A Brief Comparison of Two Teacher Education Institutions-One Turkish, One American

The American and Turkish systems of teacher education have many similarities and differences. The Turkish system of teacher preparation, for example, is currently very centralized when compared with the American system. In Turkey, elementary school teachers are educated through undergraduate programs of four years in duration. All of the teacher education programs throughout Turkey are required to offer core coursework for preservice elementary teachers that is suggested by the Higher Education Council (YÖK, 1998). All of the teacher education programs in Turkey are intended to educate prospective teachers for the schools of the Ministry of National Education, which has centralized the curricula throughout the country (Çakiroglu & Çakiroglu, 2003). The students attending teacher education programs in Turkey are selected through a nation-wide university entrance examination that is used to identify students for all university programs. Elementary education programs in Turkey presently use a curriculum which has resulted from teacher education reform efforts which have been taking place in the country since 1998. As a result of these reforms, more emphasis has been placed upon improved field experiences, fostering technology literacy, and providing teaching methods for subject matter courses (Simsek & Yildirim, 2001).

The students attending teacher education programs in Turkey are selected through a nation-wide university entrance examination that is used to identify students for all university programs.

During the 4 year preservice elementary teacher education program in Turkey, students are required to complete coursework that concerns both general education and subject matter areas. Students must also satisfy a practice teaching requirement. The four years of coursework is a total of 152 credits hours (YÖK, 1998). The list of science related courses required of Turkish students is provided in Table 1, for the authors believe the number of science courses preservice teachers complete is relevant information with regard to science teaching efficacy.

Quite contrary to the Turkish system, teacher certification requirements in the USA are determined by each state and as a result, colleges and universities must develop curricula and related experiences to comply with these varied, state by state, regulations. In the United States there are no national requirements for teacher preparation, quite contrary to that observed in Turkey.

During the 4 year American program evaluated in this study, preservice elementary teachers complete a total of 128 credits

Table 1
Science related courses the sample of preservice teachers were required to complete in Turkey and USA

Courses	Turkey Credit Hours	USA Credit Hours
Scientific Inquiry	–	3
Biology	3	3
Earth Science	6	3
Chemistry	3	–
Physics	3	3
Ecology	3	3
Science Teaching Methods	6	5[a]

[a] *Includes a 2 credit hour field experience. In the methods courses of the Turkish students, there is no accompanying field experience.*

In general, USA preservice teachers have stronger personal science teaching efficacy beliefs than Turkish preservice elementary teachers.

from four different areas—general education, an area of concentration (e.g. science, math, social studies), electives and professional education. The general education component includes courses in numerous subject areas such as language arts, fine arts, mathematics, science, and social studies. The area of concentration enables students to gain an in-depth knowledge in a subject of their choice. The professional component includes a series of subject-specific methods courses (work within the field of psychology/learning, applying technology in education settings, multicultural courses, the history of American education, an examination of the purpose of schooling in America) field experiences, seminars, and a final semester-long student teaching experience.

Purpose

The purpose of this study is to compare preservice elementary teachers' efficacy in a Turkish university, and in at a major American university located in the Midwest. While researchers have examined preservice teachers' efficacy extensively in United States, there is little work which has been carried out concerning preservice teachers' efficacy beliefs regarding science teaching in Turkey, and perhaps not surprisingly no research has been done comparing how Turkish students' self-efficacy in science teaching might compare to their peers at an American institution. The information provided by this study may not only help one to better understand Turkish preservice elementary teachers' efficacy beliefs regarding science teaching, but also reveal possible differences and similarities between students of these two different countries with respect to teacher efficacy beliefs. Knowledge of preservice teachers' efficacy beliefs is an important step if positive educational experiences are to be designed for preservice teachers in teacher education programs in Turkey. Knowledge of how students of these two countries compare will help one see how students might be similar and dissimilar. This might help one revisit assumptions one might have about a particular program of study for preservice science teachers.

Instrument and Data Collection

The data for this study were collected by utilizing Enochs and Riggs' (1990) Science Teaching Efficacy Belief Instrument (STEBI-B). The STEBI-B is comprised of two subscales; personal science teaching efficacy beliefs (PSTE, 13 items) and science teaching outcome expectancy (STOE, 10 items). High scores on the first scale, relative to other respondents, indicate a strong personal belief in one's own efficacy as a science teacher, and high scores on the second scale indicate high expectations of the outcomes of science teaching—for instance confidence in how students will do in science.

In order to develop a Turkish language version of the STEBI-B the original instrument was translated into Turkish by the researchers. The next step involved an independent back translation of the Turkish version into English by two qualified, bilingual Turkish graduate students who were not involved in the original translation. Then the Turkish researchers checked the back translations and, for some items, necessary modifications in the Turkish translation were carried out. Turkish pilot test results produced alpha coefficient of 0.86 for PSTE subscale and 0.79 for STOE subscale. A factor analysis suggests the factorial structure of the STEBI-B developed by Enochs and Riggs (1990) with their American sample of students was the same structure as that observed for this sample of Turkish students.

All of the Turkish participants were enrolled in a four year teacher education program. In the Turkish sample there were 100 preservice elementary teachers (48 female and 52 male) and in the American sample there were 79 preservice elementary teachers (65 female and 14 male). The data were collected by convenient sampling and all preservice teachers from both countries participated voluntarily in the answering of questionnaires.

Data Analysis

The stochastic Rasch model was used to evaluate the survey data. One important benefit of the model is that it can provide estimates of item difficulty and person ability and/or attitude that are relatively invariant over different samples (Green, 1996). The Rasch model converts non-linear raw scores of person and items to measures on a linear logit scale. It is critical to point out that parametric tests assume the use of a linear scale. Thus, the utilization of raw scores from survey instruments potentially

Table 2
Descriptive statistics based upon raw scores

	Turkish Students		USA Students	
	PSTE	STOE	PSTE	STOE
N	100	100	79	79
Minimum	3.0	3.30	3.38	2.70
Maximum	5.54	5.85	5.85	5.40
Mean	4.25	4.37	4.65	4.19
SD	0.57	0.59	0.58	0.56

Note. Values were based on the raw score average of all subscale items. Maximum possible score was 6 and the minimum possible score was 1. A higher score indicates stronger positive PSTE and STOE beliefs. In the questionnaire judgments were made on 6-point scales (1 = strongly disagree, 6 = strongly agree)

violates measurement assumptions. Wright and Linacre (1991) also mention a number of additional advantages of utilizing the Rash model: (1) an evaluation is allowed when respondents do not answer every item, (2) measurement errors of survey items and respondents are reported; and (3) idiosyncratic responses of students can be easily detected. Survey data were calibrated by using the BIGSTEPS computer program (Wright & Linacre). Much of the data presented in this study is reported in Rasch log odds units (so called logits), which take into consideration issues of non-linearity. The authors provide appropriate guidance later with regard to the relative meaning of differences between comparison groups expressed in logits. In some tables the raw score is provided to ease understanding for those unfamiliar with logits, but all statistical tests were carried out using the logit measures (as opposed to raw scores) calculated for each respondent.

Results

A descriptive analysis of student data indicates generally positive self-efficacy beliefs regarding science teaching in both countries (Table 2). Overall preservice teachers generally had high science teaching outcome expectancy scores, which meant in general, that participants had expectations that their science teaching would influence student science learning.

An initial raw score analysis suggested that about 89% of the participants in USA and 78% of the participants in Turkey had confidence in their ability to teach science effectively. In both countries only about 45% of the participants felt they knew the steps necessary to teach science concepts effectively. Similarly, about 59% of preservice teachers in both countries claimed to understand science concepts well enough to be effective in teaching elementary science.

Respondents also seemed generally willing to assume that student learning in the content area of science is the responsibility of the teacher. About 77 % of the participants in the USA sample indicated that good teaching could overcome the inadequacy of a student's science background. On the other hand, 94% of the Turkish participants agreed with this statement. While more than half of the Turkish participants (64%) believed that the teacher is generally responsible for the achievement of students in science, this percentage was slightly lower in USA sample (46%).

To compare both the PSTE and STOE views of the students, Rasch measures for the two student samples were calculated. This meant that a set of items defining self-efficacy was used to calculate an overall attitudinal measure, and that measure was provided in linear (non raw score units). Also the set of items defining outcome expectancy was used to calculate an overall attitudinal measure, and that measure also was provided in linear units. Then those linear measures (two for each person) were used for parametric tests. First, ANOVA procedures were utilized. First, a 2x2 ANOVA was run on the data using gender and country

It is conceivable that the successful implementation of science education programs may depend on teachers' self-efficacy beliefs, that is, their personal beliefs regarding their ability to teach science and their ability to produce positive outcomes in science for students.

as independent variables, and the students' PSTE measures were used as the dependent variables. ANOVA results indicated that preservice elementary teachers of the American sample had a significantly higher personal science teaching efficacy measure than the preservice teachers in Turkey, $F(1,175) = 7.19, p < 0.05$. This means that these preservice elementary teachers in the United States had significantly more positive beliefs in their own ability to influence student learning in science than their peers in Turkey. Although the difference was statistically significant, the effect size was found to be small (eta squared = .04) There were no significant differences between PSTE scores of female and male preservice teachers neither in the overall data set, $F(1,175) = 1.11, p = 0.293$, nor when compared as a function of country, $F(1,175) = 1.23, p = 0.353$.

A second 2x2 ANOVA was run with the same independent variables and the logit measures of STOE (Outcome expectancy) as the dependent variable. This analysis indicated that science teaching outcome expectancy measures of the preservice teachers from the two countries did not differ significantly $F(1,175) = 0.002$, $p = .965$. In other words, the degree to which these preservice teachers' believed that their teaching can influence student learning were not significantly different in the two compared countries. The ANOVA results suggest that among these two groups of preservice elementary teachers gender was not a significant factor which could predict the magnitude of one's science teaching outcome expectancy belief $F(1,175) = 0.264$, $p = 0.608$.

To investigate the responses of preservice teachers to each survey item, logit measure of each item in the questionnaire were computed. Tables 3 and 4 provide the logit measures of the items comprising the PSTE and STOE scales. In these tables, lower logit measures indicate items which were easier to agree with by the surveyed preservice elementary teachers, and the higher logit measures indicate items which were harder to agree with. The differences in the functioning of items in two countries were also tested. In testing the significance of the difference in item functioning, the alpha level was set to be .004 for PSTE scale items and .005 for STOE scale items, in order to reduce the probability of type one error. There were several items in PSTE scale that demonstrate statistically significant difference in terms of functioning between the two samples (Table 3).

In the PSTE scale the item which was most easy to agree with in the USA sample involved believing to

Table 3
Responses of preservice teachers to personal science teaching efficacy items.

Items	USA Measures (logit)	Turkey Measures (logit)	t
Be at lost in helping students with difficulties in understanding science[a]	-2.87	-0.05	-9.78*
Not able to effectively monitor science experiments[a]	-1.10	-0.21	-3.47*
Not willing to be observed by supervisor while teaching science[a]	-0.27	0.49	-3.35*
Know steps to effectively teach science	0.12	0.77	-3.06*
Will not likely have necessary skills to teach science[a]	0.45	0.47	-0.10
Understand science well enough to be effective in teaching	0.50	0.17	1.55
Will not be able to teach science as well as most subjects[a]	0.52	-0.01	2.49
Will generally teach science ineffectively[a]	0.30	-0.25	2.51
Find it difficult to explain why science experiments work[a]	0.45	-0.12	2.68
Welcome students' questions about science	-0.03	-0.86	3.56*
Will find better ways to teach science	0.28	-0.56	3.71*
Able to answer students' science questions	1.65	-0.30	9.46*

Note. Statements of the items were abbreviated for presentation purposes. Higher logit measure indicates the statement's being relatively less easy to agree with. The items are ordered based on t values. Statements relatively easier to agree with in USA sample than the Turkish sample are presented at the top of the table and the statements relatively easier to agree with in Turkish sample than the USA sample are presented towards the bottom part of the table.
[a] Items reversed before scoring
*p < .004

Table 4
Responses of preservice teachers to science teaching outcome expectancy items.

Items	USA Measure (logit)	Turkey Measure (logit)	t
If parents note an increase in the interest in science, it is due to the teacher's performance.	-0.34	0.24	-2.73
When a student does better than usual in science, it is due to teacher's extra effort.	-0.15	0.41	-2.63
Teacher is responsible for student's science achievement.	-0.01	0.51	-2.62
Improved science grades of students are due to teachers' effective teaching approach.	-0.78	-0.43	-1.50
The inadequacy of a student's science background can be overcome by good teaching.	-1.02	-1.01	-0.04
Low science achievement cannot be blamed on teacher. [a]	1.15	1.14	0.05
When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	0.11	-0.34	2.18
Increased effort in science teaching produces little change in students' science achievement. [a]	0.53	0.09	2.20
Underachievement is due to ineffective science teaching.	0.53	0.00	2.65
Science achievement of a student is directly related to teacher's effectiveness in teaching.	-0.01	-0.60	2.76

Note. Statements of the items were abbreviated for presentation purposes. Higher logit measure indicates the statement's being relatively less easy to agree with. The items are ordered based on t values. Statements relatively easier to agree with in USA sample than the Turkish sample appears at the top part of the table and the statements relatively easier to agree with in Turkish sample than the USA sample are presented towards the bottom part of the table.
[a] Items reversed before scoring

have "the ability to help students having difficulties in understanding science" (Table 3). This statement had significantly different degrees of agreement in two countries. Preservice teachers in USA agreed with this statement more than their peers in Turkey (Table 3). On the other hand, the statement about being "able to answer students' science questions" was significantly easier to agree in Turkey than USA.

With respect to the STOE scale, the most easy to agree with and the least agree to with items in both countries were the same. The most agreed item involved whether the inadequacy of a student's science background can be overcome by good teaching. The least agreed to item, in both countries, was that the low science achievements of students can be blamed on their teachers. In addition, none of the items in STOE scale had significantly different functioning in two samples (Table 4).

Discussion

Results from this study indicate that there were differences in personal teaching efficacy beliefs of the USA and Turkish samples of preservice teachers.

In general, USA preservice teachers have stronger personal science teaching efficacy beliefs than Turkish preservice elementary teachers. There were also significant differences on the responses to several individual items in the personal science teaching efficacy scale. For example, preservice teachers in Turkey had significantly higher beliefs on themselves for welcoming student questions about science or being able to answer students' science questions. Preservice teachers in USA, on the other hand, had stronger beliefs in themselves to be able to help students with difficulties in understanding science.

There may be various reasons for this difference. Since the instrument was created utilizing samples in USA, it is possible that some statements in the questionnaire are not suitable when applied to differing cultural perspectives. Similarly, Lin and Gorell (2001) suggested that the concept of teacher efficacy may be culturally oriented and thus need to be carefully examined when applied in different cultures. Another reason of such a difference may be the coursework that preservice teachers in both countries are required to complete. In terms of the amount and the type of courses, there are not clear differences between the two programs. However, pedagogical courses in the teacher education program of the USA may have some differences in terms of the goals and the learning experiences they provide. For example, the pedagogical courses in the Turkish teacher education programs rely generally on the international knowledge base and mostly on the sources are originated from English speaking countries (Çakiroglu & Çakiroglu, 2003). This may result in less relevant understanding of the science teaching issues by the preservice teachers in Turkey, which in turn may bring about lower personal science teaching efficacy beliefs.

Preservice teachers' conceptions of their workplace may also contribute to their personal efficacy beliefs. These beliefs are partly formed through student teaching experiences. Some researchers have suggested that fieldwork may influence preservice teachers' sense of efficacy towards science (Huniker and Madison, 1997; Ramey-Gassert et al., 1996, Crowther & Cannon, 1998). Both of the samples we investigated in this study had not completed the student teaching experiences. However, the preservice teachers in USA completed a field study accompanied with a science teaching methods course. Due to having more student teaching hours, the American preservice teachers may develop a better understanding of the workplace and spend more time on understanding the issues within the education system. This may also help preservice teachers in USA to develop a better sense of efficacy in teaching science.

Another reason of the difference might be the characteristics of the sample of preservice teachers in both countries. Students in both countries enter the teacher education program in a different way. For example, in Turkey students are placed in undergraduate teacher education programs through a nationwide university entrance examination. After taking the exam, students must submit a list of programs which they would like to study in the order of preference. It is sometimes the case that the candidates are placed to teacher education programs as their last choices of profession to study. There is a shared concern among teacher educators in Turkey that some of the candidates of teacher education programs make their decisions by thinking the well-known saying in Turkey: "if you cannot be anything you can at least be a teacher" (Altan, 1998). For that reason, preservice teachers in USA might begin their teacher education program with more specific and determined aims, which in turn may result in different levels of science personal teaching efficacy beliefs.

Interestingly, the science teaching outcome expectancy beliefs of the preservice teachers of both countries were similar. Analysis of Variance suggested no statistically significant difference in the STOE measures of preservice teachers in the two countries. In addition, a comparison based on individual items indicated no significant differences in their functioning between USA and Turkey. In both samples preservice teachers generally disagreed with the idea that low science achievement can be blamed on teachers. Again both groups of preservice teachers generally agreed with the idea that the inadequacy of a student's science background can be overcome by good teaching. Data collected with this sample of students suggest that the survey items which emphasize a connection between underachievement of students and their teachers' performance, tended to be harder to agree with than the other survey items. The items which emphasized a connection between improvement in student achievement and teacher performance tended to be relatively easier to agree with than the other items in the STOE scale.

While researchers from different cultures practice approaches inherent in their own context, each culture has much to learn from the other.

It is conceivable that the successful implementation of science education programs may depend on teachers' self-efficacy beliefs, that is, their personal beliefs regarding their ability to teach science and their ability to produce positive outcomes in science for students. Therefore, efficacy beliefs give a measure of the sense of how the preservice teachers perceived their strengths and preparedness as potential science teachers. Due to the vital role preservice teachers will play in educating younger generation, teacher education programs need to evaluate efficacy levels of their teacher education students and begin to find ways to enhance their efficacy beliefs regarding science teaching. Then these teacher education programs can begin to launch future teachers who are ready, willing, and able to meet the needs of their students.

Educational research that crosses national boundaries offers much promise for generating new insights because the familiar educational practices, beliefs and attitudes in one country can be exposed and questioned when researchers from two countries collaborate on studies involving teaching and learning (Albridge et al., 1999). While researchers from different cultures practice approaches inherent in their own context, each culture has much to learn from the other. The current study suggested that there may be common experiences and similar self-efficacy beliefs among national and cultural boundaries. Similarities and differences should be explored if we want to expand our knowledge about the development of teachers throughout the world. In such cross cultural comparisons of science teaching efficacy, future research should consider beliefs about science teaching, for an understanding of science teaching—e.g. whether being committed to a more "teacher-centered approached" or "student centered approached" is related to teachers' belief regarding their effectiveness in science teaching. In addition, parallel longitudinal studies may help one better understand the influence of preservice teacher education programs to prospective teachers across cultures.

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Early Recruitment of Science Teachers: Promising or Problematic Strategy

This study examines the experiences and knowledge of students who are participating in a recruitment course in a secondary science, mathematics, and computer science teacher education program.

The United States currently faces a shortage of mathematics and science teachers, and the problem is getting worse. In response to this concern, several reports have been issued discussing the shortage of teachers and suggesting potential reform and policy measures (e.g., National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Commission on Teaching & America's Future, 1996). Among the recommendations that have been made, several pertain to the preparation of science and mathematics teachers at universities and colleges. As a result, institutions preparing teachers now offer different pathways for certification, such as one-year programs that offer certification and a graduate degree, or programs that allow a content expert to receive on-the-job pedagogical training. Another effort, which has not been discussed much in the literature, involves the recruitment of students into the educational pipeline. Recruitment programs precede formal teacher education programs as a means of increasing the pool of applicants.

This study looks at students who are participating in a recruitment course in a secondary science, mathematics, and computer science teacher education program at a large university. By examining the experiences and knowledge of students in such a program, it is possible to understand the disposition of students who elect to participate in these courses, and the curricular and instructional aspects that impact students who are considering the teaching profession. The findings provide an additional data source from which to draw conclusions, and thus have direct implications for those affiliated with similar courses.

Ideally, by understanding how teachers develop and why they remain in the profession, we can design recruitment programs to target students with potential for longevity and impact in the educational environment.

In addition, our findings can assist those who are contemplating the development of such courses to consider course goals, the content and process of the course, and the means by which students are recruited into the course. While our intent is to inform other science teacher educators about our examination of this unique period in teacher development, we also hope to demonstrate the importance of examining the recruitment phase of the teacher education process, and to purposefully contribute to the limited literature in this area.

Background

Research regarding recruitment courses is notably absent in the teacher education literature. However, studies pertaining to teacher persistence and teacher development exist, and can inform those seeking to understand issues related to recruitment. Ideally, by understanding how teachers develop and why they remain in the profession, we can design recruitment programs to target students with potential for longevity and impact in the educational environment.

The literature about teacher persistence suggests that a commitment to teaching and positive field experiences may contribute to one's decision to have a career in education. In a study of graduates from a secondary science teaching program, Eick (2002) compared their autobiographies that were written over time in order to determine trends related to persistence. Teachers still in the classroom (more than three years since graduation) expressed interest in science and teaching and/or recognition about the rewards of working with students. A study conducted by Marso and Pigge (1997) followed potential K-12 teachers in order to explore factors that led to persistence in the field. After seven years only 51% of the population had made the transition to the teaching profession. Those making the transition at the secondary level were very or almost certain about becoming teachers early in their teacher preparation program and they decided to pursue teaching prior to graduating from high school. Neither their academic aptitude nor their perceived effectiveness as a teacher was related to their transition to teaching. An earlier study by Chapman (1984), which collected data from teacher education graduates, sought to determine how administrators could deter the attrition of new teachers. While the data revealed a limited impact by administrators in terms of retaining teachers, it was found that persistence was linked with an early commitment towards teaching and positive field experiences during the preservice program.

The research literature is rich with discussions of the many aspects of the professional development of teachers, including the knowledge base and beliefs of teachers. For secondary science teachers, the knowledge base that one holds is important in terms of learning to implement reform-based practices. This knowledge base should consist of an understanding of the prominent concepts in one's discipline (Carlsen, 1993; Hashweh, 1987) and an understanding of the processes and nature of science (Duschl, 1987). Furthermore, this knowledge should be connected and accessible to the science teacher (Gess-Newsome, 1999).

Beliefs guide instructional decisions, influence classroom management, and provide a lens through which to understand classroom events.

Ultimately, science teachers need to understand both the structure and the nature of their discipline, as well as have the ability to select and translate content into learning activities. But a sound knowledge base is not enough; the beliefs that a teacher holds directly impact his/her classroom practices (Pajares, 1992). Beliefs guide instructional decisions, influence classroom management, and provide a lens through which to understand classroom events. In fact, beliefs may be more important than knowledge when considering a teacher's classroom practice (Pajares). For example, Ernest (1989) found that two teachers with similar knowledge but different beliefs taught in different ways. Ultimately, he suggested that an understanding of teaching beliefs rather than knowledge was more useful in predicting teachers' classroom decisions.

The UTeach Program

The UTeach program at the University of Texas is a joint effort of faculty and staff from the Colleges of Education (COE) and Natural Sciences (CNS), along with local teachers, to prepare secondary science, mathematics and computer science teachers for the state of Texas. As a program that draws upon different knowledge bases, the program coursework consists of content and pedagogical courses at the University of Texas and field experiences in surrounding school districts. Collectively, the different components of the program provide students with content courses that support their degree majors, classroom and field experiences in various forms of instruction, and opportunities to learn about different knowledge bases in teaching. During each of these experiences students explore issues related to equity, technology, inquiry, and translating theory into practice.

The recruitment courses, which are referred to as *Step 1* and *Step 2*, are unique parts of the UTeach program. These one-credit courses focus primarily on recruitment, but they also provide field experiences in which students teach science in a reform-based manner. In *Step 1*, students learn how to teach three different elementary science lessons from a popular kit. In *Step 2*, students again draw upon the lessons in a science kit and learn to teach three different reform-based middle school science lessons. During their field experiences, the cooperating teacher gives feedback to the students on their instruction.

Freshmen, sophomores, juniors, seniors, and post-baccalaureate students are informed about these courses though written invitations, orientation booths, announcements, brochures, and COE and CNS advisors. Students who complete *Step 1* or *Step 2* can be reimbursed for the tuition associated with these courses, and they can apply these credits to their degree plan. Typically, more than half of the students who complete *Step 1* and *Step 2* continue in the UTeach program.

Study Context

The findings that are reported here represent one aspect of a larger study, which is being conducted at the University of Texas. The larger study looks at the development of beliefs, practices, and various knowledge bases of secondary science teachers throughout their teacher preparation program and during their first years in the classroom. This study is following 17 students in the UTeach program from *Step 1* through their second year in the classroom.

This first examination of the study data specifically explores the first semester of the UTeach students, focusing on 1) the circumstance of their recruitment, 2) their belief and knowledge profiles as related to teaching, and 3) their salient experiences in a UTeach recruitment course.

Methods

Participants

Randomly selected students in *Step 1* courses, who indicated that they were science majors, were contacted through e-mail about participating in the longitudinal study of secondary science teachers at the University of Texas. Of the students who were contacted, 17 indicated a willingness to participate in the study. Table 1 gives a brief overview of the students who comprise this study.

In addition to the typical presentation of demographic data, information is also provided that pertains to the student's reason for considering a career in education. Students who indicated in their first interview that the teaching profession was a primary interest are noted as "primary." Students who are participating in the *Step 1* courses for reasons other than being a teacher are listed as "secondary." This will be discussed further in the Findings section.

Data Collection and Analysis

Interviews – To collect background and experiential information from the students participating in this study, semi-standardized interviews were conducted twice. The first interview occurred during *Step 1* and the second interview took place in the following semester. Berg (1998) states that a semi-standardized interview involves a number of predetermined questions that address the research goals and

Table 1.
Students in Step 1

Student	Gender	Year in school	Major	Current status after Step 1 course	Reason for teaching
1.	Male	Junior	Biology	Dropped	Secondary
2.	Female	Senior	Physics		Primary
3.	Male	Freshman	Biology		Secondary
4.	Female	Junior	Chemistry		Primary
5.	Male	Junior	Biology		Secondary
6.	Male	Sophomore	Bio/Pre-med.	Dropped	Secondary
7.	Female	Sophomore	Biology		Secondary
8.	Male	Junior	Chemistry		Primary
9.	Female	Sophomore	Biology		Primary
10.	Female	Junior	Biology		Primary
11.	Male	Freshman	Biology		Primary
12.	Female	Senior	Biology	Moved to elementary program	Primary
13.	Male	Junior	Geology		Secondary
14.	Female	Senior	Chemistry		Primary
15.	Female	Junior	Biology		Secondary
16.	Male	Junior	Chemistry		Primary
17.	Male	Senior	Chemistry		Primary

that are presented in an order and language appropriate for the people in the study. The interviewer can digress or probe beyond the predeveloped questions in order to gain a further understanding of the topic discussed. We included questions beyond typical demographic data. For example: How did you decide to enroll in the UTeach program? How is the UTeach program helping you become a secondary science teacher? What has led you to believe that you may want to be a teacher?

The students' reasons for considering the education profession ranged from finding a degree that allowed them to work with people and science, to dissatisfaction with the courses and instructors in their current science or engineering program.

The responses of the students were examined and categorized in order to determine trends that existed among the participants. Points in the data that represented salient findings are shared in the Findings section.

Belief interviews – Teacher beliefs were captured using an interview with eight open-ended questions. Students were interviewed during the *Step 1* semester and the following semester. The wording of the interview protocol sought to elicit how the students participating in this study viewed teaching and learning in a secondary classroom, as well as what underlying beliefs impacted their instructional decisions. Questions used to capture the UTeach students' beliefs, for example, included: How do you think your students will learn best? How do you think you will know when your students understand? How will you adapt your teaching to best represent the discipline of science? All of the interviews lasted 45 to 90 minutes, were audiotaped, and were conducted by one of the authors of this paper.

The audiotaped interviews were coded by faculty and graduate students familiar with the coding process (see Luft & Roehrig, accepted). Each coded interview resulted in the eight questions being categorized as traditional, instructive, transitional, responsive, or reform-based. Traditional and instructive responses represent teacher-centered beliefs, while responsive and reform-based responses represent student-centered beliefs. Transitional responses indicate beliefs that are teacher or student-centered, as they can be focused on conceptual knowledge or aspects of relationships between a teacher and his/her students.

Views of the nature of science interviews – During the *Step 1* semester, participants in the study completed the Views on the Nature of Science—version C questionnaire (VNOS-C) (Abd-El-Khalick, Bell, & Lederman, 1998). Questions in the VNOS-C were designed to elicit views about the tentative and subjective nature of science, the role of society and culture in science, the difference between observation and inference, the role of theories and laws in science, and the role of creativity and imagination in science. The VNOS-C responses were examined by one of the authors and coded to depict the participating students' views of the nature of science as contemporary (i.e., science as tentative and a human construct) or traditional (i.e., science as procedure that accurately depicts the natural world). We added a third category called naïve, which means that the views of students straddle both or neither domains. Details about the coding process for contemporary and traditional views of science can be found in Abd-El-Khalick, Bell, & Lederman.

Artifacts – Artifacts were collected from the UTeach students to capture their experiences during *Step 1*. The students were specifically asked to share documents that best represented their development as a teacher. The documents were copied and placed in the student's file, while the originals were returned to the student. These documents were integrated appropriately and accordingly into the findings.

Findings

The findings from this initial analysis of the data address three areas, which ultimately provide some insight into the recruitment of students into teacher preparation programs.

Recruitment circumstances

Students looking for alternatives enrolled in Step 1. The UTeach program uses a variety of methods to inform students about the *Step 1* courses. Students receive letters or brochures, are referred by academic advisors, are contacted in high school, or find out about the program through the web or a fellow student (Dodson, 2002). The students in this study elected to participate in the program after talking to a friend, seeing an advertisement, or talking to an advisor. These recruitment events came at a time when the student was interested in looking at other career options, which takes us to our second point regarding recruitment.

Students were more advanced in their coursework. The *Step 1* course was developed with the goal of providing freshmen or sophomores with classroom experiences. However, the program is configured so that students can participate in *Step 1* at any in time in their university career. In our study, most of the students were more advanced in their coursework and were actively considering another major. They did not plan to pursue a degree in education initially, but it was now an option for a variety of reasons. The students' reasons for considering the education profession ranged from finding a degree that allowed them to work with people and science, to dissatisfaction with the courses and instructors in their current science or engineering program.

Participants in the program

Students were involved in education for different reasons. The students in our study were categorized as either having a primary or secondary interest in education (Table 1), and there was clearly a mix of both. Students who were classified as having a primary interest in education wanted a career in education in order to work with children and to share their understanding and enjoyment of science. Some of these students had prior experiences as tutors, coaches or teachers, which sparked their interest in education. Students who were classified as having a secondary interest in education were interested in teaching in order to improve the instruction of evolution, live in a town with family members, have a flexible career, or fill the period of time before their entry into another professional program.

Students held primarily teacher-centered and transitional beliefs. The beliefs held by the students were typically teacher-centered and transitional. Based upon the examples provided by students, these beliefs related to their prior experiences in education. For example, when students were asked to discuss their role as a teacher, they spoke about their high school or university instructors and the special attributes of these teachers. This is not surprising, as the UTeach students had not typically experienced or explored student-centered instruction in-depth, nor had their beliefs about teaching been actively and purposefully challenged with the intent of forming student-centered beliefs. Table 2 shows the beliefs data for each student and the overall percentages in each category.

Students expressed limited views of the nature of science. The students in this study revealed traditional views about the nature of science on their VNOS-C and belief interviews. Even though the students enjoyed

Table 2.
Students' beliefs

Student	Traditional	Instructive	Transitional	Responsive	Reform-based
1.		•	••••••		
2.		•••	••••		
3.	•	•••	••	•	
4.	•	••	••••		
5.	•	•••	•••		
6.		•	•••••	•	
7.		•••••	••		
8.	•	•••	•••		
9.	••	••	•••		
10.	•	•••	•••		
11.	•••	••	••		
12		••	•	••	••
13.	•	••	••••		
14.	••	••	••	•	
15.		•••	••••		
16.		•••	••••		
17.	•	•••	•	•	•
Percentage	12%	36%	45%	5%	2%

science, it was clear that their prior experiences in science had not initiated a consideration for a more progressive view of science. Most notably, most students did not view science as tentative, considered science and society to be interactive, nor did they describe scientists as bringing creativity and biases to their research. Table 3 provides an overview of each student's views of selected areas in the nature of science (agreement with a statement aligns with a contemporary view of science).

Experiences related to *Step 1*

Field experiences were a positive feature in the early recruitment course. Each student in Step 1 valued the opportunity to teach different lessons from a science kit in an elementary classroom. In fact, when asked to share an artifact that best represented their development as a teacher, each student provided the evaluation form filled out by his/her cooperating teacher. As students elaborated on these documents, they indicated that the teaching experience was important because it allowed them to experience the enjoyment of helping students learn about an idea in science, share their knowledge with students, and see that younger students were easy to manage. Most of the students considered their initial teaching experiences to be successful and based these conclusions on their own observations and the feedback provided by the cooperating teacher.

Relationships were important to students in their recruitment course. Students in the Step 1 courses valued relationships as they pertained to their educational experience. Some students spoke about the relationships that they found in the program, which consisted of support and encouragement offered by the *Step 1* instructors as well as the advisors of the UTeach program. Others spoke about their relationships with classmates, which allowed them to have peers with whom to discuss their experiences in teaching and in the UTeach program. The relationships the students experienced allowed them to feel connected to the program and to other students. For most of the students this was an important experience.

Discussion & Conclusion

This initial look at the recruitment aspect of a teacher education program provides a unique glimpse at the students who participate in such courses, and the experiences that may be built into such courses. Even though this study is limited in duration and focused on students in one type of program, several points will be useful to those who are contemplating the development of recruitment courses.

Three important topics stand out from our data. First, the students who were juniors and seniors in our

Table 3.
Students' views of the nature of science

Student	Science as tentative and empirical	Experiments are not the only way that scientists build new knowledge	Science as culturally and socially impacted	In following a process, scientists not always have accurate conclusions
1.	N	N	D	D
2.	N	D	A	N
3.	N	A	D	N
4.	N	D	N	N
5.	N	D	N	D
6.	A	D	A	D
7.	N	D	D	N
8.	A	D	D	D
9.	N	D	D	D
10.	N	D	A	D
11.	N	D	D	D
12.	N	N	A	D
13.	N	D	A	D
14.	N	D	N	D
15.	A	D	D	D
16.	N	D	D	D
17.	N	N	D	N

A-Agrees with statement; D-Disagrees with statement; N-Naïve answer program indicated more interest in education as a career and a greater level of commitment than did the freshmen and sophomores in our study. It may be that freshman and sophomores graduated too recently from high school and were not yet ready to consider a career in secondary education, or they may not have had the kind of educational experiences that might influence their interest in the field. This is not to say that freshmen and sophomores should be excluded from recruitment courses. They should be included, but for reasons other than fostering an interest in education. Second, there are clearly two groups of students who were considering a career in science education. At this time it is difficult to describe how either the primary or secondary groups will persist in terms of becoming teachers. However, of these student groups, those with primary interests talked about how prior experiences in education influenced their decision to consider education, while only those with secondary interests in education left after the first course. Third, the field experiences were valued by all students and did not appear to be a factor in their decisions to leave or continue with the program. Students who enjoyed the teaching experiences felt it confirmed their decision to enter education, while those who had a less than satisfying experience were still committed to staying in the program.

In light of these observations, we might place more emphasis on a student's commitment to education, and his/her prior educational experiences, when determining who participates in a recruitment course. Several authors have discussed students' level of commitment as important in terms of persisting as a teacher (Chapman, 1984; Eick, 2002; Marso & Pigge, 1997). Students in our study with a higher level of commitment tended to have prior experiences in education that were sustained over time and that occurred in a variety of settings. Thus, it may be a better approach to recruit certain students early in their academic career, rather than inviting all students to participate in the courses. With more deliberate recruitment measures, those who are currently involved in some form of teaching (e.g., tutoring, coaching) or who had positive educational experiences, can be sought out. Students who are considering education early or later in their educational career will find the program in time.

Clearly, teacher preparation programs—from the first courses to student teaching—need to consider the beliefs and knowledge that students hold.

A more complex issue surrounding recruitment courses pertains to the knowledge and beliefs of entering students. Most of the students in this study held beliefs and knowledge that were not conducive to reform-based teaching. While *Step 1* provided an experience in teaching that was reform-based, the course itself was not designed to impact student knowledge or beliefs. All of the students in this study valued the teaching experience, but none described how it altered their beliefs about teaching or their knowledge in the field. In fact, students felt affirmed as teachers and as part of a community, and were not challenged to consider their current educational ideologies. Studies suggest that beliefs and knowledge are important in learning to teach, and that they are difficult to change (Gess-Newsome, 1999; Pajares, 1992). Clearly, teacher preparation programs—from the first courses to student teaching—need to consider the beliefs and knowledge that students hold. Such programs should be crafted to help the student develop a way of thinking and teaching that reflects current reform-based efforts in science education.

In terms of influencing student beliefs and knowledge, the *Step 1* course described in this study may not have lived up to its potential. Ideally, the *Step 1* course could serve as an initiation point for examining beliefs about teaching and the nature of knowledge. However, those who design recruitment programs should consider whether they have a mission to educate students about the reforms. If this is an objective, then recruitment programs need to stress reform-based instruction by targeting the beliefs and knowledge of these potential teachers. Failure to address these areas may reinforce the traditional and didactic beliefs and knowledge that students bring to the program. Juniors and seniors in the program will have limited time to confront or develop their beliefs or knowledge in regard to reform-based instruction.

Final Comments

As the title of this paper implies, recruitment can be a promising strategy for increasing the pool of teachers in mathematics and science. However, when teachers do not enter or persist in the profession, or when the beliefs and knowledge levels of the students are not fully considered, recruitment can be problematic. Given the financial and personal cost involved in recruitment programs, it is important to consider the population at hand. Recruitment program administrators must strategically recruit teachers and develop programs in a manner that addresses the teachers' entering beliefs and knowledge level. Ultimately, well-designed recruitment programs alone will not solve the shortage, but they do hold out the promise of a bright start in the teacher education process.

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Technology Integration Enhancing Science: Things Take Time

A process is outlined in which a professional development program allows K-8 teachers to make the transition from a traditional classroom to one where technology is imbedded and becomes an integral part of teaching and learning.

Project TIES (Technology Integration Enhancing Science), a four-year Technology Literacy K-8 project, combines technology as a tool for teaching and learning with earth and environmental science education. The project provides K-8 teachers in two school systems in the Central Piedmont area of North Carolina with professional development as well as equipment and materials. The resources enabled teachers to make the transition from a traditional classroom to one where technology is an imbedded and integral part of teaching and learning. During this process, TIES teachers participated in professional development involving science content, the inquiry process, student-centered projects, and the use of technology as a tool for teaching and learning. TIES teachers have taken on leadership roles including presentations at state science teachers and educational technology conferences and provision of professional development within their school systems. The project is being sustained because the expertise and leadership resides within the schools.

Project TIES began as a serendipitous juxtaposition of three seemingly unrelated events. First was the publication of the National Science Education Standards (National Research Council, 1996). Next was the announcement of a request for proposals by the North Carolina Department of Public Instruction for the Technology Literacy Challenge Fund. This was followed by the hiring of a building-level technology specialist and science specialist in one school and a technology director in another school system. These individuals approached a university collaborator and asked her to become the project director. Subsequently, an external evaluator was recruited from another university. Thus began a four-year saga of change and innovation.

"[T]he idea of building new understandings through active engagement in a variety of experiences over time, and doing so with others in supportive learning environments, is critical for effective professional development."

Things Take Time

> "It is clear that, for science and mathematics professional development to be effective, experiences for teachers must occur over time, provide ample time for in-depth investigations and reflection, and incorporate opportunities for continuous learning. [T]he idea of building new understandings through active engagement in a variety of experiences over time, and doing so with others in supportive learning environments, is critical for effective professional development" (Loucks-Horsley, Love, Stiles, Mundry, and Hewson, 2003, p. 81-82).

Although the project was nearing completion as this caveat was published, Project TIES was designed with the precept of providing ten days of professional development over the course of the school year; TIES allowed teachers the time to assimilate new pedagogies and implement them in their classrooms. Change is not easy; for pedagogical change to occur, teachers must be afforded the opportunity to learn new teaching methodologies, incorporate those methodologies into their classroom practices, modify any practices that do not work for them, and retest the modifications.

For this particular technology-based project, it is accurate to add the admonition that “Things Take Materials.” The intention was to provide sufficient resources for teachers to make the transition from traditional practice to a classroom where science and technology are imbedded and become integral parts of teaching and learning. The availability of the equipment and software in sufficient quantity for easy student access, as well as the know-how for using it, permitted students and teachers to use technology on a regular and frequent basis to allow for integrated, project-based instruction. The combination of new knowledge and behaviors as a result of professional development, combined with the needed equipment, helped to provide profound and lasting change.

Project Description

The overarching goal of the TIES Project was to produce a successful, creative, and replicable model for inquiry- and project-based instruction that uses technology to integrate science and other curricula. To attain this, teachers developed long-term inquiry-based science projects appropriate for their K-8 students. Underlying these projects, as well as other classroom instruction, was the seamless blending of technology with science content and project-based instruction. The ensuing professional development not only incorporated project-designed activities, but also a wide array of nationally recognized curriculum materials and activities including The GLOBE Program, Project WET, Streamwatch, GEMS, and AIMS. These programmatic components were phased into the implementation over the project’s first three years, with full implementation achieved in Year 4.

Another goal was the sustainability of this project. This priority was attained by way of five strategies. First, TIES implemented a process of collaborative team efforts utilizing the leadership of experienced TIES teachers. Year-1 and Year-2 teachers became mentors for teachers who entered the project in Years 3 and 4. This allowed experienced teachers time to gain confidence with the pedagogical changes in their classrooms before they were responsible for working with new teachers. Second, experienced teachers assumed leadership roles as they participated in providing professional development sessions in Years 3 and 4. Third, the equipment, including, computers, software, probeware, and a digital camera, was housed in teachers’ classrooms. In this way, technology was available immediately for use as an integral part of the teachers’ repertoire of teaching tools. Fourth, teams of TIES teachers disseminated knowledge gained and lessons learned from the project as they presented TIES at science and technology conferences and at parent and faculty meetings.

The combination of new knowledge and behaviors as a result of professional development, combined with the needed equipment, helped to provide profound and lasting change.

Finally, participating schools have now included TIES in their school-based budgets, thereby ensuring continuation of the project.

Collaborations

The TIES Project was built on the strong collaborations of four schools in two school districts, the Center for Mathematics and Science Education in the University of North Carolina at Chapel Hill (CMSE), the North Carolina Department of the Environment and Natural Resources (DENR), LEARN NC (a statewide technology network), the North Carolina Department of Parks and Recreation, the Eisenhower Consortium at SERVE, and the GLOBE Program. The CMSE staff provided both professional development and project coordination; the other five partners provided professional development for the teachers during one or more years of the project.

TIES Project schools represent a diverse K-8 student population. The schools are located in both suburban and rural communities; two of the schools qualify for Title 1 funding; and minority enrollment varies from 30% to 60%. The CMSE brought strong leadership capabilities in grant administration and professional development, as well as technical guidance in developing and implementing educational models. The DENR brought expertise in assessing and understanding the environmental resources of TIES school sites. Its curriculum projects, including Project WET and Streamwatch, are national programs with outstanding materials that fit well with the K-8 North Carolina Standard Course of Study. LEARN NC, a statewide network of educators using Internet technologies, provided teaching resources, lesson plans keyed to the North Carolina Standard Course of Study, and an online outlet that allowed TIES teachers to share their expertise with other educators. An integral part of the project included The GLOBE Program, a hands-on environmental science education program currently in use in nearly 11,000 U.S. schools and more than 100 countries.

Objectives.

Project TIES had several objectives: providing technology within the context of project goals, acquiring adequate technology for partner schools to insure access; providing opportunities for TIES participants to learn to utilize their school grounds to enhance their instruction in the context of the science curriculum and technology; providing opportunites for TIES leaders to share their expertise with new TIES teachers, as well as other teachers in their school; and forming a colloboration of partner schools to enhance and support each other.

Implementation

Technology can be a powerful entity in classroom instruction when adequate resources are seamlessly incorporated into instructional approaches and strategies. One way to accomplish this is to provide teachers and students with a vehicle for instruction that brings applications to the world beyond the classroom. To implement these real-world projects successfully, teachers must develop skills in integrated instructional strategies, have exposure and experience with specific projects, and be proficient in the appropriate use of technology as a tool for instruction and learning. Administrative support and participation is crucial. Significant commitments of personnel, financial resources, and time are required for a single school to make improvements in these arenas. The need for collaboration is important so teachers, struggling for time to make improvements in their individual classrooms, do not waste time “reinventing the wheel.”

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In the October 1,1998, issue of *Education Week*, Jeff Archer reported on research conducted by Harold Wenglinsky, an associate research scientist at Educational Testing Service. According to Wenglinsky, the positive benefits of technology’s effectiveness depends on how it is used. “One of the positive benefits of technology’s effectiveness depend on how teachers and students relate to each other.” Archer concurs, saying, “... a growing number of education technology advocates argue that the ‘constructivist’ approach toward learning—in which students work in rich environments of information and experience, often in groups, and build their own understandings about them—taps into the computer’s greatest strengths.” Archer further quotes William Fiske, educational technology specialist at Rhode Island’s Department of Education, “Kids learn by doing, by presenting, by displaying, by engaging. Learning happens best when the youngsters are doing the heavy lifting” (pp. 6-10). These remarks speak directly to the impact a project like TIES can have on students.

To build and apply skills for using available infrastructure effectively, each year TIES classroom teachers, project support staff, and administrators participated in ten days of professional development, including two days at the North Carolina Science Teachers Association annual conference and/or the North Carolina Educational Technology Conference. Professional development introduced authoring tools, word processing, databases, spreadsheets, and the effective use of the Internet (including Internet mechanics, Web Quest inquiry projects, various science URLs, and web site evaluation). It also provided hands-on experiences for the understanding of science content—especially in the area of earth science, which successfully blended with the TIES “outdoors as a classroom” focus.

TIES teams implemented projects based on content and integrated instructional strategies developed during professional development sessions in their own classrooms. This implementation strengthened team building, leadership skills, and mentoring opportunities for TIES teachers and administrators. In TIES, the power of technology merges with a constructivist pedagogy in student-centered, project-based classrooms. To support curriculum and standards requirements, TIES project development used instructional approaches as described below. These pedagogies are advocated in the many current publications stemming from recent brain research such as *How People Learn: Mind, Experience, and School* (Bransford, Brown, and Cocking, eds., 1999), *Teaching with the Brain in Mind* (Jensen, 1998), and *A Celebration of Neurons: An Educator's Guide to the Human Brain* (Sylwester, 1995).

- *Constructivist, Student-Centered Learnings*: Students learn best when they construct their own knowledge based on multiple experiences with a concept or skill. Through active, hands-on experiences, they correct their misconceptions, extend what they know, and connect their knowledge to other concepts they understand. Student motivation is enhanced when students pursue answers to questions they have developed.
- *Collaborative Learning*: Most students like to work with their peers and learn more from doing so. Working collaboratively is a required workplace skill for the Information Age. Many everyday activities are collaborative, with students working in small groups to solve a problem.
- *Authentic Learning*: Students learn best when their learning is not artificial—when activities are authentic and connected to the world outside the classroom.
- *Student as Worker, Teacher as Facilitator*: A teacher serves as a facilitator to student learning by arranging the environment so that students will ask important questions and discover ways to answer them.
- *Sustainability*. There are two types of sustainability connected to this project: 1) intra-school sustainability within the school(s), where a project began after external funding was expended; and 2) inter-school sustainability attached to projects that are models able to be transferred to and used by other schools and districts. Project TIES has the ability to promote both types.

Intra-school sustainability requires having key elements of materials, equipment, personnel, and leadership in place in a school(s) so a project can continue after funding expires—to have a "life of its own," so to speak. Continued financial support to update equipment and replenish consumable materials is usually necessary as well. To spread within a school, it may also be necessary to have a project that is adaptable by virtue of scalability and replicability. The project, as it exists in particular classrooms, may need to be modified to be successful in other classrooms. These latter two qualities are discussed below under inter-school sustainability.

Local school district budgets have been modified to accommodate updates and repairs of project hardware and software.

Great efforts were made with Project TIES to ensure it has the support needed to continue in current schools long after the conclusion of the grant period. Hardware, including computers, probeware, and digital cameras, and software are in place, and professional development has been provided to enable teachers to utilize this equipment and materials in an effective manner. Local school district budgets have been modified to accommodate updates and repairs of project hardware and software. In addition, extensive professional development has been provided so participants understand how to implement inquiry- and project-based instruction that uses technology as a tool for instruction. Returning teachers have also emerged as leaders to provide on-going professional development to others in their schools and districts.

In addition to project participants, others in the districts and community have been involved in Project TIES. Area teachers, building and central office administrators, and parents know about and support the project. Presentations about the project have been made to County Commissioners; parent-teacher organizations have been helpful in fundraising for various components of the project; building-level administrators have been involved in the planning and implementation of the project; and other teachers have been included in professional development presentations. These actions have created school-level involvement, as well as community support, which have helped sustain the project.

Since the grant period terminated, partnerships that enhanced the grant have been put in place and continue to influence the schools. Because of the project's successes, others within the schools and beyond have shown a sustained interest in the project. Current project schools have committed financial resources to support the project, and plans are in place for continued funding of additional teachers and classrooms at each school. Experienced TIES teachers are poised to provide continued leadership at their schools. They have shown their leadership by being mentors to new TIES teachers, presenting at conferences, and by developing and presenting technology seminars. We believe TIES teachers will continue to display this leadership.

Inter-school sustainability is attained through adoption by other schools and districts. Sustainable projects must have the qualities of replicability, the ability to be used and modified by others, and scalability, the ability to work within schools of varying size and budget. Project TIES exemplifies both of these qualities. Project TIES is definitely replicable—it can be reproduced in a wide variety of settings. Because of the dedication of TIES participants, as well as the design of the project, TIES is well known within North Carolina. Details of the project are available from individual schools. Web sites describing and explaining TIES have been developed by various teachers and their classes. Information about TIES has been disseminated at state science teachers and educational computing conference sessions.

Project TIES is scalable because it models good teaching and learning using technology as a tool for instruction. It can be implemented in any school setting in schools of varying size, and it can be used at any grade level. While hardware is important, the change process inherent to moving from one type of teaching to another is even more critical. More than just hardware is necessary for change; the change process moved teachers to a different way of using hardware.

Obstacles

While none of the difficulties was monumental, procuring and setting up equipment, allocating teacher and classroom time, and finding a sufficient number of substitutes were obstacles in this project. Existing practices created an additional difficulty.

To many teachers, the idea of student-centered inquiry- and project-based instruction was novel. This new instructional approach differed considerably from their more traditional, textbook-based approach, and the learning curve was sometimes steep. This, along with lack of experience with technology, created consternation for some. When frustrations developed, there was a tendency to revert to traditional modes of instruction rather than implementing inquire- and project-based instruction. While some participants were able to begin their projects quite readily, others needed more guidance and support.

To many teachers, the idea of student-centered inquiry–and project-based instruction was novel.

Each year, one of the most significant and challenging barriers reported by the project team was a difficulty inherent to any change effort—aversion to change or fear of the unknown. The change from a traditional to a technology-based pedagogical approach is very dramatic and met with resistance in some classrooms. Overcoming that resistance through a slow and on-going change process and reaching the levels of enthusiasm now in place in TIES classrooms are certainly two of the most important accomplishments of the project.

Successes

At the beginning of each year, teachers set goals and objectives, planned their projects, and proceeded to develop and implement them with the assistance of project staff. Each year, all TIES teachers met the objective of creating this hands-on technology-based project within their classrooms. In addition, as the project progressed, TIES teachers became instructional leaders who took on responsibility for professional development and mentoring. They also participated in project dissemination as they presented sessions at the state science teachers and educational computing conferences. Other successes that emerged from the evaluation of the project included positive attitudinal changes toward the objectives of the project; development of technology nights for parents; and statewide administrator intern site visits to TIES classrooms, with an eye toward using TIES as a model of technology integration.

Schools in the project have strong technology and science resource support systems in place, including TIES mentors from previous years. In spite of time issues, participants who were in the project during the first two years were very helpful to the new project participants. They helped in the technical aspects of how to use equipment and in the pedagogical aspects of using technology as a tool for effective instruction. Returning teachers were very willing to share classroom management techniques with teachers struggling to adapt their classrooms to a new mode of instruction. Participants have been particularly pleased with their presentations at state technology and science conferences. They report that these presentations have been challenging to prepare but also gave them increased levels of confidence in their abilities as teachers.

Results

The overarching goal of the TIES Project was to produce a successful, creative, and replicable model for inquiry- and project-based instruction that uses technology to integrate science and other curricula. Quantitatively, we saw an increase in competency rankings in technology knowledge and skills, as measured by the *TIES Technology Expertise/Comfort Survey* and on the *Levels of Use of Technology in the Classroom* scale (adapted from the CBAM research, 1987). Other evaluation strategies included site visits, workshop observations, interviews with project personnel, interviews with participants, and comment cards reflecting attitudinal changes from participants. Outcomes anecdotally reported by teachers include shifts in their beliefs and actions from instructionism to constructivism.

TIES Technology Expertise/Comfort Survey was developed to reflect the technologies incorporated into the project and to help participating teachers gauge their own perceptions of their progress in learning to use the technologies effectively. The survey was a self-report instrument, with rankings from 0 to 10 (0 = no expertise, 5 = some expertise, and 10 = a great deal of expertise). Participants showed a gradual increase in their expertise/comfort levels with technology over the course of the project, with the exception of their first year. During the first year, most participants reported a dip in their Expertise/Comfort scores as they came to understand the breadth of the capabilities of the hardware and developed more realistic perceptions of their actual expertise levels.

The *Levels of Use of Technology in the Classroom* self-report scale (adapted from the CBAM research, 1987) was administered to all participants in the third and fourth years of the project. A clear distinction can be made between the levels of use of participants new to the project and those who had been with TIES for one or two years prior to the administration of the instrument. While new participants reported a wide range of levels of use, beginning at Level 0 (Nonuse) and continuing upward through Level IV (Refinement), no returning participant reported a level of use below Level III (Mechanical Use). Also of interest is the rapid movement of Year 3 participants up the Levels of Use scale, as compared to a more gradual movement for teachers who began the project in the first two years. Based on participant comments to a series of open-ended questions and on their interview responses, this is presumed to be a result of mentoring provided by Year 1 and 2 teachers, as well as indirect exposure to the project before actually becoming a part of it. Year 4 participants showed limited growth; however, they were only in the project for one year, which is too short a period to allow for valid, reasonable conclusions to be drawn.

The project team noted some unanticipated beneficial outcomes. The comment cards used for formative evaluation indicated that the internal mentoring, support, and coaching network was much stronger than proposers initially anticipated. Additionally, teachers reported that students wrote about their TIES projects with much less prodding than in traditional writing assignments. The project team was also surprised, not that teacher attitudinal changes occurred, but by the extent of those changes, as evidenced in the comment cards. The magnitude of observed and anecdotally reported changes from a didactic to a student-centered teaching environment was much greater than proposers anticipated at the outset.

Implications

"Fundamental beliefs are formed over time through active engagement with ideas, understandings, and real-life experiences. Deep change occurs only when beliefs are restructured through new understandings and experimentation with new behaviors" (Loucks-Horsley, S., et al., 2003, p. 49). For change to occur, things take time. This study exemplifies these beliefs. Teachers who participated in the project for three or four years showed greater changes than those with only one or two years experience. Only participants who were in the project for more than two years reached Level V (Integration) or VI (Renewal) on the *Levels of Use of Technology* scale; and not all veteran participants ever rose above Level IV (Refine-ment). The change literature, as well as our own experiences with this project, have led us to conclude that significant behavior changes require at least three to four years of implementation and on-going support to become institutionalized within the classroom.

The change from a traditional to a technology-based pedagogical approach is very dramatic and met with resistance in some classrooms.

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Brain Research: Implications to Diverse Learners

A growing understanding of the way the brain functions offers new insights into the minds of students at all stages of development.

This decade marks one of the most productive eras of neurological research, which offers exciting opportunities for the educational enhancement of our classrooms. The latest research is being embraced by progressive educational systems and the necessary means for positive reforms are already beginning to be implemented. A brain-based education uses research in neuroscience on how the brain works to gain an understanding of how students learn and develop in a classroom. Psychology and neuroscience have finally begun to merge to combine how the mind learns, absorbs and thinks with how the brain functions and develops. New research bridges gaps between incomplete conceptions of the brain such as those involving the popular "right brain versus left brain" theory. Current developments in neuroscience allow for a new appreciation of the complexity and individuality with which human beings learn and grow.

Brain-based research deals with classroom-relevant concerns, such as sensory perception, attention, memory, and how emotions affect learning (Goleman, 1995; LeDoux, 1996; Pert, 1997; and Sprenger, 1999). Similar studies describe the brain's "ways of seeing one's self" (Godwin, 2000); perception, attention, and the four theaters of the brain (Ratey, 2002); and a "celebration of neurons—an educator's guide to the human brain" (Sylwester, 2001). The literature on brain-based education is quickly emerging, and several studies make direct connections between the biology of the human brain and teaching and learning (Caine and Caine, 1991, 1997; Greenenough, et al., 1993; Kotulak, 1997; Majoy, 1993; Pinker, 1997; Zadina, 2004; and Zull, 2002). Significant work by Petitto (2003) and other brain researchers led to the discovery of brain tissues related to the biology of language and learning. Indeed, neurolinguistic studies enable educators in a multilingual setting to understand and apply strategies of teaching and learning—for example, in teaching English as a second language (Dehaene, 1999; Dhority and Jensen, 1998; Fabbro, 2001; Genesee (2000); Hernandez, et al., 2000; Kuhl, 1997; and Mack, 2003. According to Zadina (2004), the goals for studying brain research include (1) reaching as many children as possible, (2) teaching to individual differences, (3) diversifying teaching strategies, and (4) maximizing the brain's natural learning processes.

Our brains are fascinating, intricate structures, with unique complexities that continue to marvel researchers and teachers alike.

Diversity in Brain Development

Learning, as a brain function, *is a biological process invented for survival*. It is the organism responding to its environment. Indeed, learning is the formation of new synapses and dentrite branching (Zull, 2002). Moreover, multiple intelligences *guru*, Howard Gardner (1993), describes intelligence as the biopsychological potential to process information in certain ways in order to solve problems or fashion products that are valued in a culture or community. Certainly, intelligence is a brain-body-environment structure and function system. Zull (2002) further adds: "we don't actually know what students will need in the curriculum. Those needs change and are changing more rapidly each decade. But what will not change is biology. The brain becomes the determining factor in thinking about education for this very reason." He concludes: "the curriculum should enable the firing of the right networks and neurons (lesson strategies), create repeated firings (practice) and should make the learner feel good."

Our brains are fascinating, intricate structures, with unique complexities that continue to marvel researchers and teachers alike. Altogether, the human brain contains 100 billion nerve cells that make 1,000 trillion synaptic connection points with one another (D'Arcangelo, 1998). We are constantly organizing and reorganizing our brains, changing both the physical structure of the brain and the knowledge we hold (Bransford and Cocking, eds, 2000). Young minds in particular hold great potential, as new learning windows of opportunity quickly present themselves and children acquire new knowledge at a remarkable rate. Amidst this complexity, researchers have found information on the brain that can bring wonderful new insight to our classrooms.

In children, the stages of learning and development manifest themselves through the ability to make connections and construct patterns. Lawrence Lowery (1990) has explored the ways children seek patterns as a means of explaining how humans develop mentally. He believes that understanding means to know relationships, that the ability to know relationships depends on prior knowledge. As learners construct an understanding of themselves, they advance from viewing a single object and discarding it, grouping two objects with a single attribute, grouping multiple objects, and eventually logically organizing and reorganizing objects based on need and criteria, and using hierarchical standards.

Research on memory and retention is also a vital asset to teachers. Although lecture continues to be

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the most widely used method in the classroom, countless studies indicate that students retain the most by teaching others, practicing by doing, and discussing in groups. Immediate, active use of learning is clearly the best means of retaining information (Sousa, 1995). In addition, students have peak and low times during the day and the course of lessons in which they tend to take in the most information towards the beginning of lessons, and then experience "down time" when retention decreases (Sousa). Therefore, shorter, diverse lessons with different means of instruction may be much more effective than an ongoing lecture environment. As a corollary, sleep (*resting the brain*) is critical in consolidating learning.

Finally, classroom setting and the emotions of students play significant roles in the ability to learn. Experiences generate emotions, which bring relevancy and meaning to students (Jensen, 1998). Teaching tied to positive emotional experiences will lead students to generate new thought and motivation to learn. Teachers can enhance classroom environments in many ways. One important practice is to link the indoors with outdoors for movement to stimulate the uptake of oxygen, which has a positive effect on learning. Another is to create a rich stimulating environment through hands-on activities and classrooms with rich colors, textures, and students' work to indicate "ownership" of knowledge (Lackney, 1998). Earlier studies by Greenenough, et al., (1993) and Karni, et al. (1995), indicated that an enriched (stimulating) environment affects growth in the brain.

Diverse, Experiential Approach to Teaching and Learning

Memory is reassembled from many locations in the brain. The brain seems to sort information in *where* (dorsal) and *what* (ventral) pathways. Zadina (2004) suggests engaging students in multiple pathways by using language, sensory motor activities, metaphor, humor, spatial-temporal activities, music and emotion. Furthermore, using *language*—which, by the way, is *our best form of communication*—activates the frontal lobes. Teachers need to apply multiple strategies and opportunities for oral communication (talking, listening, reading) as well as written ways of communication (reading and writing). Gopnick, et al. (1999), observe that the brain seems "to love to learn from other people!"

Although lecturing continues to be the most widely employed method in classrooms across the country, research on the way we learn indicates that lecturing is not always very effective. Several additional strategies should be employed to maximize the amount students retain. Constructivism encourages learning through interaction to develop a personal understanding of information. The fun-

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damental concept of constructivism is that the basis for all learning is discovery. Piaget (1973) writes: "to understand is to discover, or reconstruct by discovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simple repetition." Student initiated experimentation and invention are encouraged in a diverse, constructivist and experiential classroom. Open-ended questioning is valued because it allows for reflective thought, creative response, and unique commentary. Finally, students are allowed to process and challenge the information they hear or seek though personal discovery. These methods allow students to make "sense" of what they learn in class and to give the new information meaning.

Learning Styles: Teaching to Diversity

Tileston (2000) indicates that the best teaching practices that define teaching competencies relate brain research, learning styles, and standards-based education. A student's Learning Style can be defined as "the way that he or she concentrates on, processes, internal-izes, and remembers new and difficult academic information or skills" (Shaughnessy, 1998).

Recent research in learning styles examines the different ways in which individuals learn and process information and acquire new skills. Clearly, the concepts of right and left hemisphere processing are also relevant to these theories of learning. Moreover, Perini, et al. (1997), advocate integrating learning styles and multiple intelligences. In addition, learning styles may be influenced by such factors as age, gender and cultural background. Evidence shows students achieve more in a shorter amount of time when teachers know how to teach to the students' individual learning styles. Teachers must cater to the learning styles and diversity of learners. This requires constant attention to elements such as noise and music, light, social structure, mobility, and the design of the classroom. The presence of different learning styles indicates the need to create opportunities for diverse learning experiences. It is evident that sensory information and the classroom atmosphere significantly contribute to the way students learn.

Reflective Teaching and Learning and the Concept of "Wait Time"

Another concept, the idea of reflective teaching and learning, maintains that students learn by reviewing and reflecting on their work, not simply by just completing a task or listening to a lecture. Techniques including keeping journals and preparing portfolios reveal the progress of a student while allowing the student to develop a sense of pride in his or her work. A new method involving videotaping classes, especially group situations, devotes time to a student's personal reflection. Reflective learning methods provide a valuable opportunity for self-examination and a greater overall understanding of a student's individual role in his or her learning process.

The closely related theory of "Wait Time" is based on the idea that students need time to individually process what they have learned. Teachers must encourage this "processing" time instead of automatically asking their students to repeat back information they have just covered or heard in lecture. Recent studies also indicate that the brain seems to exhibit *plasticity* (Gage, et al., 1999)—and one way this is demonstrated is through "experiential learning." This means that the brain has the ability to change as a result of rich experience through active, personal and engaging learning activities.

Evidence shows students achieve more in a shorter amount of time when teachers know how to teach to the students' individual learning styles.

Conclusion

A growing understanding of the way the brain functions offers new insights into the minds of students at all stages of development. Unfortunately, curriculum often mismatches content and teaching practices with the thinking and learning processes of students. Teachers must promote active learning through incorporation of research on brain-based education and the corresponding academic needs of the student. "The teacher is a reflective practitioner and decision maker. Teachers must understand the theories, continue to study them, reflect upon them, and make appropriate applications for their own students and their own situations" (Guild, 1997). Advancements in neurological science and the growing understanding of the interconnectedness of the brain and mind present new possibilities that can lead to the enhancement of the quality of instruction for all students. The knowledge of how students pay attention, take in new information, process that information, and then store knowledge in memory is crucial for teachers. In addition, practices using areas such as Learning Styles, Constructivism, and Reflective Teaching (Wait-time) are all valuable applications of the research and practice of brain-compatible learning.

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