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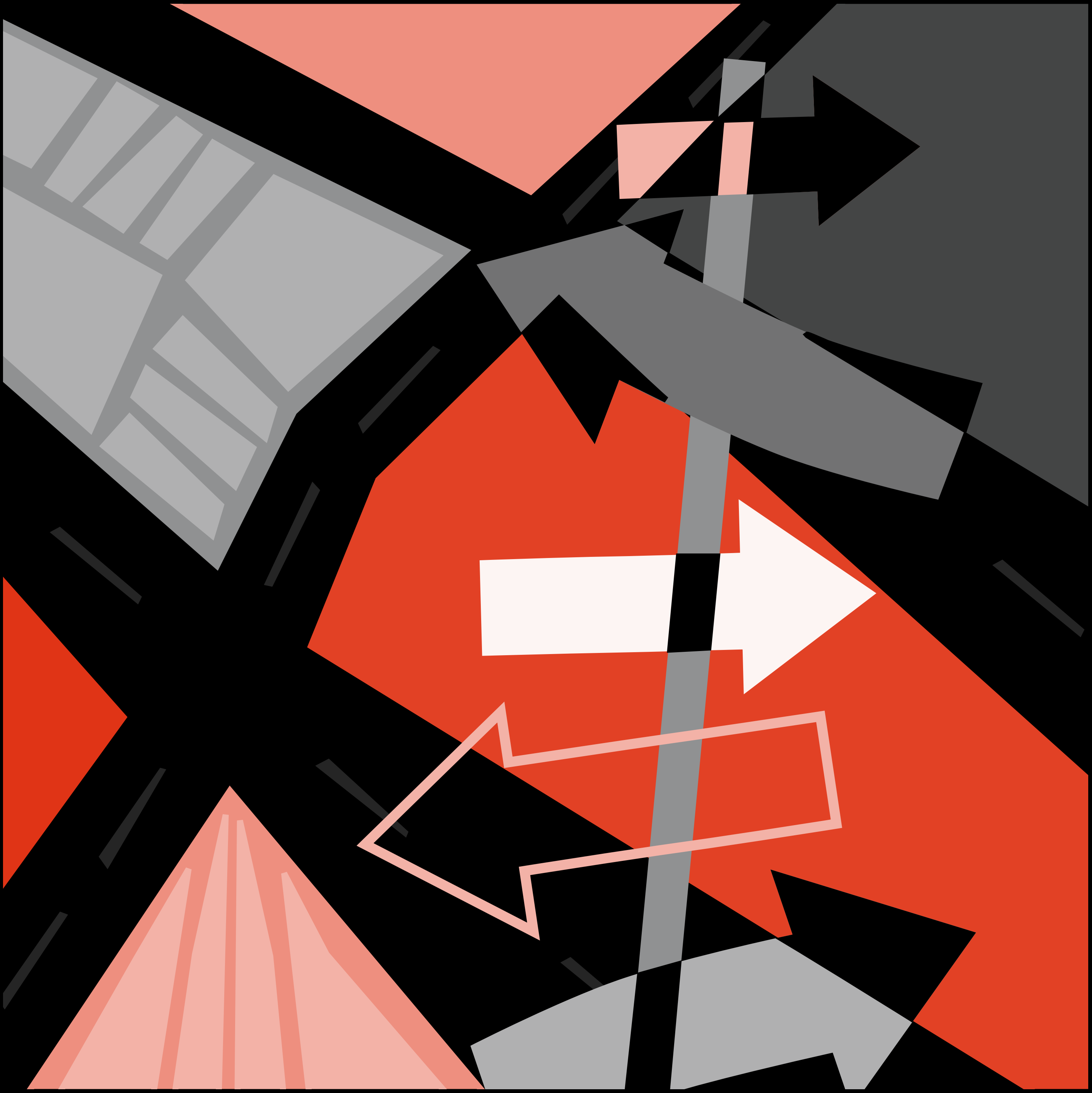

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Models of Providing Science Instruction in the Elementary Grades: A Research Agenda to Inform Decision Makers

This article describes the outgrowth of a recently held invitational conference, supported by the National Science Foundation, to define, describe, and examine existing models for the use of elementary science specialists. The authors explore the educational, policy, and financial issues that affect the use of science specialists as well as offer a research agenda to assess the quality and effectiveness of specialist-managed elementary science programs to ensure that students experience high-quality science teaching.

Introduction

For the past several decades, the Center for Science Education (CSE) at Education Development Center, Inc. (EDC), has worked across the United States with school districts to help them reform their elementary science education programs. Although many school districts employ some model of science specialists to deliver elementary science instruction, there currently is little research about the effectiveness of specialists in enhancing student science learning. What exists in the literature about the role and impact of science specialists is limited and focuses primarily on descriptions of various models and debates their relative merits.

Based on our experience working with school districts and the dearth of current research about the efficacy of science specialists, the CSE proposed an invitational conference to the National Science Foundation to define, describe, and examine existing models for the use of elementary science specialists; explore the educational, policy, and financial issues that affect the use of science specialists; and most importantly, develop a research agenda to assess the quality and effectiveness of specialist-managed elementary science programs on student outcomes. The assumption was that the findings from this conference would begin to add to the existing knowledge about various models of support for science learning at the elementary level and would contribute to the development of a research agenda. Our expectation was that case studies and a research agenda emanating from this conference would lead to more-informed decision making about how best to ensure adequate and appropriate science instruction in the elementary grades.

The goals of the conference were to: describe existing and past science-specialist programs, compare and contrast the elementary science programs provided by specialists vs. regular classroom teachers, identify the specific skills and knowledge that science specialists need to be effective and survey how these are reflected in existing state certification requirements, identify the elements of school culture and administrative support needed for effective science specialist programs, learn about successful training programs for the development of science specialists, and develop research questions and an agenda focused on the impact of elementary science specialists on student science outcomes.

The conference, held in the fall of 2007, brought together state science supervisors; leaders from higher education; district superintendents;

district science coordinators; MSP program coordinators and project directors; science education experts; science education consultants; school principals; literacy, mathematics, and science specialists; mentor teachers; elementary classroom teachers; researchers; and evaluators to share and reflect upon the current use of specialists, their contributions to elementary science teaching, and their effectiveness in supporting students' science learning. Following the conference, manuscripts were analyzed and three products were developed: a research agenda, case studies of different specialist models, and conference proceedings.

Need for Creating a Research Agenda

The 2007-2008 school year marked the beginning of a new era in science education as the federal government, beneath No Child Left Behind, began holding states accountable for student performance in science. Accordingly, states are beginning to ramp up their investment in and attention to science education. The timing is critical; international comparisons of student performance, such as Trends in International Mathematics and Science Study, highlight the fact that American students continue to lag behind other industrialized nations in math and the sciences despite 15 years of education reform (National Center for Education Statistics, 2003). The lack of achievement in science and mathematics education in the United States has resulted in a situation where many students do not have the knowledge and skills to adequately prepare them for the workforce or postsecondary education. In fact, a recent study by the National Science Board (2007) found that 20 percent of entering college students must take remedial science and mathematics courses. Moreover, the ability to respond to major public policy issues, such as global warming and the energy crisis, is dependent upon a "scientifically literate" citizenry being able to understand and evaluate scientific issues (National Research Council, 2007b; 2007a). Thus, it is crucial that American students receive high-quality science instruction and that our scarce energy and resources are directed to the levers that will have the greatest impact on student achievement.

States are beginning to ramp up their investment in and attention to science education.

Despite this new sense of urgency, it is not the first time that national attention has turned to reforming science education. In fact, science education reforms are cyclical, with prior reform efforts, such as the current emphasis on "inquiry," coming in and out of vogue over the years depending upon social and economic factors. National attention is drawn to science education when it is perceived as relevant to the society as a whole, such as after a breakthrough (seen after WWII) or due to a perceived threat (during the Space Race after the Soviet Union launched Sputnik) (NRC 2007b, 2007a; Atkins & Black, 2007; Business Higher Education Forum, 2007). In fact, the post-WWII/Cold War era of the 1950s and 1960s marks the beginning of United States government investment in "modernizing the curriculum" and teacher professional development (Atkins & Black, 2007; NRC, 2007b).

The current period of standards-based reform and testing in science education is no different from prior attempts. It is becoming increasingly clear that the STEM disciplines (science, technology, engineering, and math) will be important for a scientifically literate citizenry and the future economic competitiveness of the nation (NRC, 2007a). Though the vast majority of reform efforts have been directed toward the secondary level, the philosophical approach to the discipline, as well as the significance of the topic, has often trickled down to elementary schools. Most recently, in the 1990s, Project 2061's *Benchmarks for Science Literacy* (American Associate for the Advancement of Science, 1993) and National Research Council's *National Science Education Standards* (1996) promoted national benchmarks for science instruction. Both espoused an inquiry-oriented teaching approach in which students are actively involved in scientific investigations, engaged in hands-on activities, asking questions, and finding answers as opposed to the more traditional approach of learning a random assortment of facts from a textbook (Schwartz, 2000; Jones & Edmunds, 2006; Atkins & Black, 2007).

Despite an emphasis upon raising standards, it is apparent No Child Left Behind has placed science on the backburner in the face of other curricular demands, particularly at the elementary level (Sandler, 2003). Early emphasis upon reading and mathematics skills has resulted in less time, energy, and resources being dedicated to science instruction. In fact, recent reports show that 44 percent of districts across the country have cut the amount of instructional time for science in elementary schools (McMurrer, 2007). Moreover, increasing pressures in other disciplines has also resulted in a wide variation in the quality of the science that *is* taught (McMurrer, 2008).

Prior attempts at science education reform have made it clear that, to be fully effective, reform efforts must begin in elementary school. Evidence indicates that students who start in secondary school, having had limited exposure in the early years, rarely make learning gains equal to those who had a solid science foundation in the elementary years (Nelson & Landel, 2007). Despite the fact that the *National Science Education Standards* recommend the use of inquiry as part of the instructional strategies used to teach science, we also know that elementary teachers are largely unprepared and uncomfortable with teaching in this way, because "this envisioned approach is vastly different from the more traditional teaching approach many elementary teachers experienced themselves …" (Schwartz, 2000, p. 1). Furthermore, the recent focus upon standards and testing has created a tension between the knowledge and skills that are seen as valuable, which are difficult to assess, and what can be easily tested. This makes setting priorities in elementary science instruction with limited resources and time even more difficult to determine (Schwartz, 2000). As a result, inquiry-based science teaching is not the instructional norm at the elementary level.

Despite all of these challenges facing science in elementary schools, the importance of investing in teachers is apparent. Two recent national studies clearly defined the pivotal role teachers—and excellent teaching—play in student achievement. The Business Higher Education Forum found that "the quality of P-12 mathematics and science teaching is the single most important factor in improving student mathematics and science learning" (2007, p. 2). In their report, the National Research Council outlines the hallmarks of teacher excellence as "thorough knowledge of content, solid pedagogical skills, motivational abilities, and career-long opportunities for continuing education" (2007a, p. 113). Thus, investing in teachers and teaching and building teachers' confidence and competence with the discipline will be crucial to improving student achievement at the elementary level.

Compounding this inattention to elementary science is the tendency of elementary teachers to prefer non-science subjects. This has had a number of effects on science teaching that have been consistently documented over many years, including teachers' having limited science content knowledge—particularly in the physical sciences, low confidence to teach science, and the perception that science is a body of facts and knowledge (Abell & Roth, 1992; Australian Foundation for Science, 1991; Department of Education, Employment and Training, 1989; Harlen, 1997).

Though the vast majority of reform efforts have been directed toward the secondary level, the philosophical approach to the discipline, as well as the significance of the topic, has often trickled down to elementary schools.

Constraints to elementary teachers on teaching science include the following: insufficient content knowledge, lack of time, inadequate materials and facilities, competing curricular priorities, lack of support in school (largely from administration), and minimal sense of self-efficacy in science (Schwartz, 2000; Gess-Newsome, 1999; Rhoton, Field, & Prather, 1992):

One can think of these constraints to teaching science in elementary schools as falling into two main categories: school level support and the capacity of teachers. It is clear that any attempt to reform science in elementary school must remove these school-level barriers to effective science instruction and boost the pedagogical skills, content knowledge, and confidence of elementary teachers in the sciences.

Needless to say, accomplishing these goals is easier said than done. One of the biggest obstacles to education reform has been that policy makers have grossly underestimated the investment of time and resources necessary to change practice at scale. A recent study by Nelson and Landel (2007) shows that more than 80 hours of professional development is needed to effectively teach inquiry-based science at the elementary level. Unfortunately, this study also found that few elementary schools invest in professional development to ensure that the curriculum adopted by the school is implemented adequately. As a result, only 18 percent of elementary science and math teachers' lesson plans were found to exhibit "elements of effective science and mathematics instruction" (Weiss, quoted in Nelson & Landel, 2007, p. 73).

Furthermore, data from the Horizon Research, Inc., evaluations of the early Local Systemic Change projects (LSCs) suggest that even with significant teacher professional development (100 plus hours), the quality of instruction is in question. "While limited, our analysis of the data seems to indicate that despite the 100+ hours of sustained and in-depth professional development each teacher received, science instruction delivered by elementary classroom teachers was not adequate" (Weiss, 2001). In addition, the biggest concern of teachers in the LSCs is that they were not getting enough support. While teachers had been trained to use the inquiry-based curriculum materials, they had difficulty translating what they had experienced in professional development sessions to their classrooms. They indicated that they needed more in-classroom help. More specifically, a CPRE report on the results of six years of in-depth professional development with elementary teachers by the Merck Institute for Science Education states that "given the limited effects of the initiative on student achievement to date, the unevenness of science knowledge among elementary science teachers, and the anticipated difficulties in sustaining their participation over time, it makes sense to consider using science specialists to teach science in grades 2-4" (Consortium for Policy Research in Education, 1999, Experimenting with the Use of Science Specialists section, para. 1).

The centrality of providing support to science teachers at all levels to reach NCLB requirements is now being acknowledged. At the recent Massachusetts STEM Summit (October 17, 2005), Congressman Vernon Ehlers of Michigan remarked that good science education should include good support mechanisms and that there should be at least one experienced go-to person in a school building. In the United States, approximately 15 percent of elementary students receive science instruction from a science specialist in addition to their regular teachers, and another 12 percent receive science instruction from a science specialist instead of their regular classroom teachers (Weiss, Banilower, McMahon & Smith, 2001).

Prior attempts at science education reform have made it clear that, to be fully effective, reform efforts must begin in elementary school.

While the use of a specialist model ensures that science is taught, there is little known about the quality of instruction or the impact on students' science learning. Perceived ability to deliver effective science teaching has been shown to be associated with elaborate science content knowledge (Ramsey-Gassert, Shroyer, & Staver, 1996; Shrigley, 1977), successful science teaching experiences (Dickinson, Burns, Hagen, & Locker, 1997; Shrigley, 1977; Tilgner, 1990), and a commitment to elementary science instruction (Ramsey-Gassert et al., 1996).

Given the importance of improving science teaching at the elementary level and the many significant difficulties associated with changing classroom teachers' science instruction, one approach has been to turn to the role of science specialist as a school's primary source of science leadership, teaching, and/or support. Unfortunately, little research exists that indicates whether this approach will have an effect on science instruction and student achievement (Schwartz, 2000). As a consequence, school and district leaders are investing scarce resources in a strategy about which little is known and upon which much depends.

This research agenda will map the territory surrounding the topic of elementary science specialists in a systematic way in order to amass knowledge and to make informed choices to ensure that elementary students experience high-quality science teaching.

Purpose for This Research Agenda

This research agenda is intended to serve decision makers, policy makers, researchers, funders, and practitioners by providing them with an understanding of the areas of research that need to be explored, and within each area, what specific topics should be investigated. This research is becoming increasingly relevant and useful as "specialists" have entered the national- and state-level dialogue for the improvement of science teaching. In individual states, attention has been given to the role of specialist as a way to enhance science leadership at the district and school levels, including a master's degree program for science specialists in Ohio and a certificate of endorsement for teacher leaders in math and science in Kentucky (Education Development Center, Inc., 2008). This agenda provides a map of the issues associated with elementary science teaching and learning that need to be explored and understood, their complexities, and how they are inter-related. It offers a structured research program that is a starting place for further comment and clarification.

Finally, it offers funders of research an overview of the breadth and depth of work that is needed to inform their short- and long-term funding decisions and to provide an overview of how individual studies will build a comprehensive understanding.

This research agenda will not focus on issues related to appropriate methodologies, research designs, and rigor. It will focus on elaborating the depth and breadth of issues relating to the implementation and impact of elementary science specialist models. Conference attendees have identified the issues, highlighted the nature of the questions that they believe must be addressed, and organized them in a framework that will, we hope, enable more reflection and refinement, and, ultimately, advance the progress of relevant research and its utilization by decision makers.

Current Status of Research: What Do We Know About Science Specialists?

Despite a large number of articles addressing the topic of elementary specialists in the literature, there is a dearth of research taking a rigorous approach to studying the efficacy and implementation of science specialists in elementary schools (Gess-Newsome, 1999; Schwartz, 2000). Most of the literature approaches the subject from the philosophical or descriptive level, with little empirical value or in-depth analysis (Jones & Edmunds, 2006). In fact, a literature review of the topic of elementary science specialists found 14 articles that address the topic, but only two studies, Schwartz (2000) and Jones and Edmunds (2006), can be considered rigorous research studies, defined as having a specific research question in which data is collected and analyzed in such a way as to answer the initial research question.

Schwartz (2000) offers the sole empirical evaluation of the effectiveness of specialists compared with classroom teachers. This study compares teachers and students in a district with elementary science specialists to a district following the more traditional, classroom teacher model. The so-called "specialist district" utilizes a model in which the science specialist is responsible for all of the planning and instruction in science. The classroom teacher serves as a facilitator during the lesson and is responsible for follow-up during regular class time. Each class meets for science with the specialist teacher twice a week because the specialist is responsible for teaching all science courses in the elementary school for fourth through sixth grades. The evaluation was based upon (1) a survey of teacher views and opinions regarding science education; (2) sample lesson plans submitted by the teachers to address specific topics at each grade level that were analyzed for the alignment of teaching goals to the National Research Council (1996) and AAAS (1993) standards; (3) student performance on state assessments; and (4) samples of student work from classroom activities.

The evaluation found that specialists held a view of science instruction that was more consistent with the current reform agenda in science education (i.e., emphasis on problem solving and thinking skills vs. traditional textbook-based instruction). Though classroom teachers also claimed to espouse the inquiry approach to science education in the survey, the analysis of lesson plans revealed that classroom teacher beliefs about inquiry captured in the survey did not transfer to classroom plans for instruction. Overall, the lesson plans of the classroom teachers were much more factual and text-book-based with little time for students to creatively explore the answers to problems. On the other hand, the specialists' lesson plans maintained a focus upon building student problem-solving and critical-thinking skills. For example, as noted in the survey by one specialist, "in this student-centered teaching model, independent activities are designed to support the concepts being taught, while students are responsible for constructing their own understanding of the concepts" (Schwartz, 2000, p. 7).

An analysis of student test scores on the state standardized assessments for fourth through sixth grade science found no significant difference in student performance between the specialist district and the traditional district. However, Schwartz (2000) points out an important caveat: standardized exams currently only test student mastery of lower-level knowledge and comprehension. It is for this reason that samples of classroom work were collected and analyzed for evidence of student thinking.[1] Evidence was found in student work to support the fact that higher-order-thinking skills were taught. For instance, students were able to find a relationship between laboratory results and the original research question. Thus, in addition to building the higher-order-thinking and inquiry skills, specialists are still able to prepare students equally well as classroom teachers for the base knowledge targeted in standardized tests.

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[1] These data were only collected in the specialist district due to limitations in access to the control district.

Schwartz concluded that, "students taught by the science specialists (a) were engaged in open-ended, inquiry-oriented, science-based activities of the kind often advocated, but mostly absent, in elementary school, and (b) demonstrated problem solving and higher order and critical thinking skills" (2000, p. 1). This result implies that change/reform is more likely in the hands of specialists; it takes a highly skilled professional—in both content and pedagogy—to make this type of science (inquiry, hands-on) happen in the elementary science classroom.

Though these findings strongly indicate that science specialists are more effective instructors of inquiry-based science, it is important to note that Schwartz emphasizes the context dependence of these findings. The specialist district in this analysis utilized one specific model: the specialist was primarily responsible for classroom instruction with students. Schwartz suggests that the specialist may assume other responsibilities aside from teaching itself, including providing professional development to other teachers. This may be a cost effective in-house alternative for professional development and, in turn, could have a more transformative effect on the instructional methods of classroom teachers and lead to the improvement of the school science program as a whole. However, this was beyond the scope of the analysis, and no evaluations of alternative models were explored.

The second rigorous study by Jones and Edmunds (2006) was based on the variation in the implementation of the specialist model at the school level. Jones and Edmunds found most articles dealing with the topic from the philosophical role alone. Through school and classroom observations, interviews with teachers and administrators, and teacher surveys, they compared the three basic models for science instruction in elementary schools, defined as:

1. *classroom teacher model:* the basic model for instruction in which one teacher is responsible for teaching all subjects in a self-contained classroom
2. *science resource model:* the specialist provides technical assistance to the classroom teacher who maintains primary responsibility for instruction
3. *science instructor model:* one individual is hired specifically to teach science across a variety of grade levels

Similar to the study by Schwartz, Jones and Edmunds (2006) found that the instruction of the specialists is more closely aligned with the new standards for science instruction; students are engaged in more open-ended and "creative" exploration of science concepts and content. Additionally, Jones and Edmunds found that in schools with a science specialist, regardless of the specific model used, more attention was given to science in the school through labs, activities, more materials and resources, or prominently displayed student work. "Specialists in the school, in whatever discipline, may result in an increased physical presence of that discipline in the school" (p. 334). This study also showed that schools with science resource teachers dedicate more instructional time to harder-to-teach topics like physical science. Moreover, teachers displayed a greater interest in science and increased involvement in professional development and improving their own science knowledge and instructional practice. The study concluded that this increased dedication at the school level may alleviate the competing demands made on teachers at the elementary level and facilitate consistent high-quality instruction in science.

Gaps in the Research and Our Understandings

These two aforementioned studies suggest that science specialists are both more comfortable and better able to engage students in open-ended inquiry and problem solving. However, there are many factors that need to be taken into consideration, regarding both the generalizability of these results and their applicability to the school context. The varying models of implementation are largely due to the fact that there are many variations on how science instruction is delivered to students at the elementary level depending on local staffing and budgeting restraints (Jones & Edmunds, 2006). All of the studies, though they provide important initial information, are context dependent. Each school system—and school for that matter—has adapted the role of specialist to their specific context and needs. Thus, there is no consensus on the exact responsibilities a specialist should have with respect to teachers and students, or to the school's science program.

Furthermore, because there is no clear, widely accepted definition of an "elementary science specialist" or the role they should serve in the school, the specific characteristics and, thus, qualifications that will make them most effective are unknown. Jones and Edmunds (2006) and Schwartz (2000) both touch upon this issue. This has implications for the preparation and certification of specialists. Schwartz (2000) noted that science specialists are able to be more innovative and effective because they have a stronger science background than the average classroom science teacher. The importance of content knowledge for inquiry teaching is well documented (Dobey & Shafer, 1984; Ramsey-Gassert, 1996; Shirgley, 1977), and specialists tend to be hired because they have more content knowledge (Gess-Newsome, 1999; Schwartz, 2000). But, in addition to content knowledge, what other skills and knowledge does a specialist need to be qualified for this position? Should leadership be a component of training? This must be worked out before the impact of specialists on teacher practice, student learning, and system of science instruction can be routinely evaluated. At this point, there are more questions than answers. Still, the field knows a lot about science instruction, and this knowledge will have a bearing on the future of elementary science programs and how research on elementary science specialists progresses.

What the Field Believes Is True

According to the National Research Council's *National Science Education Standards* (1996), this new vision of science teaching "requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching" (p. 62). Gess-Newsome (1999) deconstructed this statement and outlined the four teacher attributes that are important to teaching science well: content knowledge and attitudes, pedagogical knowledge, knowledge of students and knowledge of curriculum. Few elementary teachers have high knowledge and skills in each of these areas and, perhaps, it is unreasonable to expect that elementary teachers be experts in all content areas.

While the use of a specialist model ensures that science is taught, there is little known about the quality of instruction or the impact on students' science learning.

The field believes that science specialists possess the attributes identified by Gess-Newsome, and therefore offer a way of providing better science instruction. Aside from the two research studies outlined above, all but one of the remaining articles concerning elementary specialists are descriptive or anecdotal accounts of a specialist-type model in one specific school or district (Century & St. John, n.d.; Nelson & Landel, 2007; Mangiante, 2006; Jacobson, 2004; Rhoton et al.,1992). These articles propose some form of a science specialist, whether it is an individual or a team approach, as a solution to the barriers to providing high-quality science instruction in the elementary grades.

Existing programs for teaching science at the elementary level fall into four categories or models: (1) classroom teachers are responsible for teaching science; (2) classroom-based science specialists with their own regular classrooms provide resources and support for other classroom teachers; (3) school-based science specialists provide direct instruction to students within or across grade levels; and (4) district-based science specialists serve as a resource and support to classroom teachers in several schools. In addition, mentoring, a more and more visible professional development strategy, may take place within several of these categories. With the pressure of NCLB and renewed interest in science, the question of how and to what degree the different models and the programs within them affect student outcomes becomes critical.

Several case studies offer anecdotal descriptions of these models in practice. Jacobson (2004) described how having a science specialist in the school in the role of resource teacher ensured that hands-on science was still able to occur with budget cuts and increasing curricular demands. "Specialists reinforce the science lessons taught by regular teachers by conducting experiments that too often get dropped because of a crowded school day" (p. 15). Mangiante (2006) describes an in-house model for professional development in which the science specialist and classroom teacher are co-teachers. In this model, the classroom teacher learns from the specialist by learning alongside his or her students. Mangiante found that this was "empowering" to classroom teachers attempting to teach science and reduced some of the confidence issues associated with teaching inquiry-based science.

All of these articles acknowledge some of the challenges in implementing a version of the specialist model at the school level, particularly in the resource model. Mangiante (2006) recognizes that oftentimes the specialist serves the role of an "itinerant teacher," providing off periods for classroom teachers. Science educators, such as Karen Worth (quoted in Jacobson, 2004), worries that in this specialist model, science is "falling off the back burner" by being treated as separate;

too often, collaboration does not happen between the classroom teacher and the specialist.

Furthermore, a recurring theme among these anecdotal articles is the importance of context for the effectiveness of the model. Rhoton et al. (1992) outlines the negative effect school-level structures can have on science programs. This article highlights the fact that "teacher initiated change" and teacher ownership of the initiative, which is often touted as a strength of the specialist program, is not enough. Principal involvement is essential for the improvement of any science program and describes an innovative twist on a specialist model, implemented at the district level, in which a classroom teacher and the school principal are trained together in the specialist program to invest in "instructional skills, administrative insights, and content knowledge" (p. 17).

In general, these descriptive articles emphasize several important points:

1. Science specialists can be school-level science experts, and their knowledge and experience can be used in a variety of ways to meet the financial and logistical needs of the school or district.
2. Specialists can be an excellent resource for professional development if school structures are established to facilitate communication and observation.
3. Principal involvement is crucial, and school structures need to be in place to support the work and influence of the teacher-initiated change.
4. Treating science as separate from the rest of the curriculum in the elementary grades may be a mistake, particularly if connections are not made across the curriculum. There is also evidence that classroom teachers (Schwartz, 2000) feel even more inferior and teach even less science than if there were no specialist in the school. It is not a good thing if only one person holds the knowledge; this knowledge must be shared with others and connected to what students are learning in other courses.

But, in a time of competing curricular demands at the elementary level, rising stakes for science, and financial cuts, the field must provide best practices to guide the decision-making efforts of elementary schools to improve their science instruction.

The need for creating a research agenda to assess the impact of the science specialist is long overdue. While there has been a considerable amount of research verifying the need for science specialists, there has been little research that focuses specifically on the role and impact of science specialists in improving student achievement.

Research Questions

In the National Research Council's book *Scientific Research in Education* (2002), Shavelson and Towne identify three basic and interrelated lines of investigation into which most research questions fall: "Description—what is happening? Cause—is there a systematic effect? And process or mechanism—why or how is it happening?" (p. 99). This categorization of research questions offers us a useful framework for the research agenda developed to investigate the nature and impact of the elementary science specialist. Although these lines of investigation explore different questions, Shavelson and Towne note their close relationship to one another, and we echo that observation here. We have divided the investigations that research should undertake into these three categories for the sake of clarity; however, we acknowledge that it is a somewhat artificial separation. The research questions that we raise below can be viewed from different perspectives and investigated in a variety of combinations and designs.

Description— What Is Happening?

Conference attendees acknowledged the wide variation in models for deploying science specialists in elementary schools, and at the same time categorized them into variations of two major groups: teacher mentoring model and student instructional model.

Four case studies of specialist models implemented in diverse U.S. districts were generated from the conference. These are only examples of the variation that exists in the design of a science specialist's role. As conference participants explained, there is considerable variation in the ways these models are implemented. Before we can understand anything about the impact of any given science specialist model, we need to know what these models are. Descriptive studies are needed that systematically document and describe *what* particular models are being implemented within the mentoring and instructional models, their particular components, and how they function.

Conference participants identified three areas that comprise the mentoring or instructional science specialist models: (1) the role of the specialists, (2) the context within which they do their work, and (3) the nature and extent of the support that is provided to them. To understand fully whether, to what extent, and why any variation of the science specialist model is effective, each of these areas needs to be fully explored. The lines of investigation relative to each are described below.

The role of science specialists

There are three primary aspects of the science specialists' work regardless of which model is being deployed: (1) the content and focus of their work; (2) the frequency and duration of their intervention; and (3) the curriculum and materials they work with. In addition there is the experience and training necessary to be successful.

Content and focus. In considering the content and focus of science specialist's work, we need to understand the goals and desired outcomes that guide their work and the tasks and responsibilities they assume in service to those goals. If they are working within a teacher mentoring model, we need to ask what tasks do they perform? These could include lesson demonstrations, lesson observation/debriefing, co- or team-teaching, lesson planning, teaching effective use of materials, teaching science content to classroom teachers, modeling/teaching inquiry instructional strategies, identifying elements of effective lessons, guiding teachers in planning and teaching effective lessons, analyzing student work, and facilitating peer collaboration/mentoring. We also need to ask what other functions specialists perform, and how they carry them out on the ground and under diverse and challenging conditions. What features characterize their interactions with classroom teachers—how frequently and for how long does a specialist work with particular teachers and under what conditions?

At the same time, we need to look at what commitments are required of classroom teachers in the context of specialist-mentor models, what factors influence whether or not they uphold their commitments, and to what degree they are held accountable to fulfill their responsibilities with regard to sustaining the presence of science in their classroom. To what extent are specialists able to adapt their role in response to classroom teachers' needs, capacities, and interests?

If specialists are working within a student instructional model, we need to look at the scope of their instructional responsibilities. Do they teach all students within a school or a subset of students, such as those within a particular grade band? How often do specialists work with students and under what conditions? Do they visit each classroom or have students come to their rooms? To what extent are they able to meet students' particular learning needs, and what structures and supports are provided to specialists in order to ensure that this is possible?

Frequency and duration of the intervention. Regardless of the model, the breadth of specialists' responsibilities varies greatly and must also be understood. For example, are their responsibilities distributed across classrooms within a single school or across schools within a district? Additionally, assuming that specialists must ration the time they have available, to what degree do they prioritize serving teachers (or their students) who are experienced versus inexperienced? inclined to teach science versus less inclined to do so? Just as important, how are those priorities set? Do specialists make these decisions on their own or do they reflect the priorities of their school's or district's instructional leaders?

There is no consensus on the exact responsibilities a specialist should have with respect to teachers and students, or to the school's science program.

Curriculum and materials. Regardless of who is providing science instruction, the curricula and materials used have a significant influence on how the instructional experience unfolds. Therefore, it is important to know what instructional materials science specialists are using, how their materials are selected, what criteria are applied, and what the implications of their use are for specialists or for the classroom teachers they may support. And in addition, what specialists' responsibilities are relative to the acquisition, maintenance, and management of science materials, equipment, and supplies?

Experience and preparation. Finally, it is necessary to understand the experience and preparation that science specialists typically have, and what they need in order to be successful in this role. It is reasonable to expect that there are differences according to the particular model that is in place; so, studies must take these nuances into account. For example, what personal qualities and characteristics, beyond skills and preparation, do science specialists require and how do these vary when the goal is improving classroom teachers' science instruction as compared to improving students' understanding of science concepts? Science specialists arrive at these positions with a variety of prior experiences. Some are simply classroom teachers with an interest in science or teachers needing "coverage." Others have science-specific skills and training. It is worth knowing to what degree classroom experience is called upon in comparison to science content knowledge, and the degree to which this may vary depending on the model. Another important set of questions concerns the continuum of preparation leading to a fully qualified science specialist and, once achieved, the nature of the long-term professional development and support that keeps science specialists engaged and improving their practice. And to what degree do the ongoing professional development supports vary across model types?

Context

Conference participants noted that science specialists do not function in a vacuum, and the context within which they function often dictates the degree to which they are able to realize their intended goals. Policies that identify a vision of effective science instruction and that support specialists' interventions in order to realize that vision have a positive influence on the way science specialists do their work. Also critical in this regard is the degree to which a vision of science instruction is based on common perceptions of students' and teachers' needs, support for the model's implementation from teachers, cost, and school and district accountability. Therefore, an in-depth understanding of the context within which specialists work is critical to understanding whether and how they are able to be effective, however that might be defined.

Rationale for selecting a model. A first step in understanding specialists' work context is to understand why a school or district adopted a science-specialist model at all, and why a particular model was preferred over another. Understanding the specific set of needs, concerns, and conditions that prompted these choices is a crucial component of understanding context. A further question has to do with where the impetus for the specialist model originates? It makes a difference to the success of any model whether it emanated from within a school or district, or from an external funder. Additionally, who makes decisions about what model will be implemented, who contributes to those decisions, and what decision-making process is employed all contribute to the contextual picture and to a specialist's chances of success.

Alignment of expectations. It is most often the case that many different people influence the specialist's work, and therefore it is important to understand the degree to which the vision of the specialist role and the selection process are shared across all stakeholders including classroom teachers, school administrators, and district leaders. When science specialists are working at cross purposes with any of these individuals or groups, their chances for making a positive impact on teaching and learning is reduced. Therefore, research is needed that examines the degree to which specialists' work is aligned to the district's and principal's expectations for science, their expectations for teachers' practice, and their expectations for student learning. Additionally, an understanding of whether and to what extent science specialists have any influence over the attention science receives in their schools and, if so, what strategies they employ to exert that influence will add significantly to our understanding of the role of contextual factors in advancing the work of science specialists.

In a time of competing curricular demands at the elementary level, rising stakes for science, and financial cuts, the field must provide best practices to guide the decision-making efforts of elementary schools to improve their science instruction.

Cost. Calculating the costs of educational programs or interventions is a complex endeavor and one that research has not often taken on. At the same time, when districts or schools are making decisions about how to allocate scarce resources and still maintain the highest level of service to students, understanding the cost of available options is critical. Therefore, studies of the cost of the various science-specialist models would be an invaluable service to the field and to the research literature. Such studies would need to account for such cost categories as personnel; professional development and support; materials, equipment, and supplies; substitutes; space; and transportation.

Accountability. Finally, the degree to which science specialists and their classroom-teacher colleagues are held accountable for carrying out whatever responsibilities the specialist model assigns to them is a critical contextual factor that must be understood. Descriptive studies must examine the formal and informal accountability systems that are in place and the degree to which they are implemented. Therefore, questions that ask to whom specialists report, how they are evaluated, and what criteria are used to determine whether or not they are performing adequately are critical. Just as critical are questions that ask how teachers are evaluated for their science instruction or for their collaboration with their science specialist. In that vein, knowing who conducts such evaluations, how knowledgeable they are about science teaching and learning, and to what extent they can identify/recognize high-quality science instruction is essential.

Value of science learning

Last, and most important, is how the science specialists' context can be characterized with regard to the value placed on science learning. Teaching science in a climate where it has been deemphasized (frequently in order to focus on high-stakes subjects—mathematics and English language arts) is a much different proposition than teaching in a climate where its value has been sustained. When trying to explain the how and why associated with specialists' impact, the importance of this aspect of the instructional context cannot be overestimated. Therefore, a specialist must feel supported if he is to be effective with students.

The supports that influence specialists' ability to do their work and be effective come from four sources: their classroom teacher colleagues, their school administrators, their district, and often institutions of higher education. The questions that research should ask regarding the nature and extent of the support each provides are unique to each source:

Teacher colleagues. It is important to understand the structures that are in place for peer collaboration. For example, are there informal lunch meetings? formal, regular grade-level meetings? inter-visitations? As mentioned above, what are the responsibilities with regard to science teaching that are assigned to classroom teachers, and what characterizes the nature of the interactions between specialists and their classroom teacher colleagues? What is known about a school's culture with regard to its investment in fostering a school-based professional learning community, and what if any, are the structures for including science specialists in that practice?

School administration. We know how important principals' support is with regard to their schools' educational program in general, and it is likewise important to understand the nature and extent of support that principals provide for science in particular. Questions that need to be asked include to what degree principals are knowledgeable about science instruction, to what degree they are provided with training and support regarding leadership for science, and finally, what their personal commitment is to providing their students with high-quality science instruction?

District administration. Because the resources necessary for teaching science emanate from the district, it is important to document the extent to which the resources provided are sufficient. Do science specialists have a ready and adequate supply of the materials, supplies, and equipment they need to implement their instructional programs? What is the nature of the curriculum they are implementing, and to what degree does it represent their districts' planning and investment versus their own? How can the superintendent's support for and commitment to science teaching and learning be characterized and to what extent is he or she able to exercise a positive influence on the presence and strength of a science program?

Institutions of higher education. Institutions of higher education are often important sources of a variety of supports for science programs in general and for science specialists in particular. Thus, it is necessary to understand the role they play, if any, in providing training and certification for science specialists in supporting specialists' instruction via ongoing professional development, faculty involvement in classroom instruction, and/or contributing to program development (e.g. curriculum, student assessment, program evaluation). When such arrangements are in place, it then becomes important to understand the degree to which views on how science should be taught are in alignment.

Cause—
Is There a Systemic Effect?

Understanding the impact of a particular science specialist model and understanding the degree to which these impacts vary across models are, of course, the ultimate goals of this research agenda. With that in mind, the outcome of interest, consistent with the two model types—a teacher mentoring model and a student instructional model—is obviously the impact on the teachers or students they are intended to serve. However, conference attendees also noted that science specialists have an impact on schools and/or districts themselves, and it is important for research to account for those effects if we are to understand the overall consequence of the role of a science specialist.

It is worth noting here that we have separated our discussion of research that would explore the *impact* on teachers, students, and schools from research that would explore the *process or mechanism* by which these impacts would occur. As was mentioned above, we recognize that this separation is a somewhat artificial one, and that it is unlikely and perhaps unwise to examine issues relating to one without considering the other. However, for clarity and ease of discussion, we have approached them separately and trust the reader will recognize the ways in which they are intertwined.

Impact on teachers

The nature of impacts on elementary classroom teachers centers on the ways in which their science instruction has changed as a result of their work with a specialist. Therefore, questions such as, "Are their students receiving *more* science instruction or *better* science instruction as a consequence of the model being implemented?" Of course, quantifying the amount or quality of science instruction is a difficult challenge at best, and one discussed in more detail in the section on Issues and Challenges below.

However, additional teacher outcomes are important as well. These relate to those mediating factors that prevent many classroom teachers from teaching science, such as a sense of inadequacy, or a lack of content knowledge, or an understanding of how teaching science can be integrated with instruction in other subject areas. Increasing teachers' understanding of these issues is not trivial and is often a first step in the process of changing their instruction itself.

Impact on students

The most obvious and important impact on students that conference attendees wanted research to measure and describe was improvement in their understanding of science. Having said that, there is a range of interesting and equally important learning outcomes. For example, has student learning of science concepts improved, has their ability to reason and think scientifically improved, or has their mastery of science skills and command of the scientific process improved as a result of a particular specialist model?

Additionally, just as there are mediating outcomes of interest for teachers, there are also secondary outcomes of interest for students that can be important precursors to improvements in their science achievement. These include their interest in science and their enthusiasm for learning the content; their engagement in the learning process and participation in the work of doing science; and their continued interest in science as evidenced by their involvement in other science-related experiences or their science-course-taking trajectory.

Impact on schools and/or districts

The potential impacts of science specialists on schools or districts were not discussed at length by conference attendees; however, some of the outcomes were raised and deserve mention here because they have systemic implications. For example, science specialists are often ambassadors for science instruction, and their work necessarily requires them to "make the case" convincingly to their colleagues in classrooms or in school or district administrative positions that science should be taught. Therefore, an outcome of interest is the degree to which the understanding of the importance of teaching science has increased as a result of their work. This could be evidenced by, for example, the stabilization of the support structures science specialists require or provide, or the continued provision of the resources necessary for science teaching and learning.

Process or Mechanism— Why or How Is It Happening?

As we have stated previously, the components of the research agenda we are presenting here are inter-related, and it is unlikely that a study would explore any of these questions in isolation. Therefore, the questions below that explore why or how impacts are being achieved (or not) are necessarily related to those questions above in which the nature of the models themselves are defined and described as well as where the impacts might occur. It is expected, then, that we look to the three components of the specialist models (i.e., the specific roles of the specialists, the context within which they work, and the curriculum and materials they work with) to frame investigations that will explain the nature and extent of the impact any of those models have had on teacher or student outcomes.

Asking process questions requires looking within each of those components at their characteristics and complexities as we have outlined them. For example, when considering what it is about the role of the science specialist that might explain their impact on teachers and/or students, we must consider the content and focus of their work, the frequency and duration of their interventions, the curriculum and materials they work with, and their experience and preparation. What can

There is no consistent and commonly accepted language for describing and discussing science-specialist models or their impacts.

we say about each of these aspects of the roles of science specialists, either in comparison to other specialist models or in comparison to other modes of providing elementary science instruction to students, which is a significant predictor of improved outcomes?

Similarly, estimating the importance of context in achieving teacher and student outcomes is a complicated endeavor. Studies must take into account the reason why a particular model was chosen; the alignment of expectations among specialists, teachers, principals, and districts; model costs; and the accountability measures that are applied to ensure the model is implemented as intended. Here, too, we are interested in understanding the relative importance of each of these aspects of context, as well as their significance with respect to one model's impact compared with another's and/or compared with other modes of teaching elementary science.

Finally, to capture the relative importance of the support provided to specialists' to the nature and extent of the impacts they achieve, researchers must account for all of the aspects of support that are described above. These include the nature and extent of teacher collaboration, the role the school and district administration play in supporting their work, and the nature and extent of support provided by institutions of higher education.

Challenges that Research Must Address

The purpose of this research agenda is to make explicit the need for research in general, and the kinds of research questions that must be asked in order to contribute to the advancement of elementary science teaching and learning. Given the complexity of the topic, it is clear that pursuing research on any of the questions raised above will be a complex task characterized by a variety of challenges. We present them here in summary form in order to acquaint researchers, funders, and decision makers with the difficulties of this work, and to provide them with a framework for designing, funding, or applying the knowledge they generate. At the same time, we acknowledge that each of these topics covers a large territory in itself, and any study, if it is to be rigorous and useful, must address them all more thoroughly than we have done here.

Research methods and designs

The research questions raised above are varied in their nature and intent; as a result, the methods and designs that researchers employ to answer them must be varied as well. Raudenbush (2005), in his discussion of research methods and study designs, recognized this and his comments are relevant here, and reiterate much of what we have discussed already.

> … Causal questions—questions about the impact of alternative policies and practices—have emerged as priorities in education research. Questions drive methodological choices, and randomized experiments provide the clearest answers to causal questions arising in social science. … the question before us now is not whether to employ mixed methods in education research generally; rather, the question is how to employ them in the service of a newly dominant research agenda that seeks to evaluate claims about the causal effects of interventions aimed to improve teaching and learning in the nation's classrooms (p. 25).

In addition,

> … experimentation, although necessary, is far from sufficient to achieve the goal of learning about "what works." Research using a variety of methods is essential and should include:
>
> 1. Defining the student outcomes that we seek, so that we can change, build, and validate assessments of those outcomes;
> 2. Supporting novel thinking about how best to intervene, to support preliminary studies of those interventions, and to enable educators to test the feasibility of implementing those interventions in ordinary school settings;
> 3. Clarifying the subsets of children who are in greatest need of intervention or who are most likely to benefit from new ideas about teaching and learning; and
> 4. Studying how resource constraints affect the outcomes of interventions, with the aim of ensuring that new approaches are cost effective.
>
> A final goal is to study why an intervention works, why

> it works for some children and not others, or why it fails. A variety of methodological strategies, including studies of implementation, interviews of teachers and children, and observations of practice, can produce plausible explanations, new hypotheses, and ideas for refining interventions. Descriptions of practice in "settings of origin" (i.e., settings in which a new intervention is initially found effective) can be compared with descriptions of practice when the intervention is implemented on a broader scale (p. 30).

Clarity and definitions of terms

As the conference attendees attested and the existing literature demonstrates, the terms that are used by researchers and their practitioner colleagues are varied and sometimes even confusing. There is no consistent and commonly accepted language for describing and discussing science-specialist models or their impacts. For example, different terms are used to refer to a science specialist such as "resource teacher," "coach," or "teacher leader." Conversely, the term "science specialist" itself may also refer to a wide variety or combination of roles and responsibilities, including, but not limited to, school-level science coaches (Mangiante, 2006), dedicated science resource teachers (Jacobson, 2004), laboratory aides providing technical assistance to classroom teachers (Century and St. John, n.d.), and teachers assigned to teach science because of departmentalization by content at grade level (Gess-Newsome, 1999).

If research is to be usefully applied in the field, the language researchers use needs to be consistent and well understood by decision makers and practitioners.. In fact, Schwartz (2000) specifically cautions that the results of her analysis, though rigorous and empirical, are context dependent and have specific implications for a specific model of specialist in the school system in question.

Measurement

Issues relating to measurement are considerable. Most fundamental is the fact that we have no explicit, observable, and well-accepted definition of effective elementary science instruction, and as a consequence, there are no rigorous and well-accepted instruments designed to measure it. That does not mean that rigorous instruments do not exist; some do, and more are being developed in recognition of this deficit. But in the absence of commonly accepted, observable attributes of high-quality science instruction, they are being created based on operationalized definitions that are unique to each instrument's purpose and the perspective of its designers. While this will enable rigorous studies to be conducted independently, it will not necessarily further our ability to accumulate knowledge across studies, which is our ultimate aim.

Current status of observational instruments relevant to scientific inquiry instruction.

Instrument development is not often the focus of research endeavors; most researchers are interested in the substance that these instruments are designed to assist in measuring. Thus, there are few studies that focus exclusively on instrument development and, as a result, instruments are often tailored to the specific needs of a project with less generalized utility for other projects. The process of developing instruments with evidence of both reliability and validity across projects requires a significant investment. Fields other than education, especially psychology and human development, have seen the utility of this work and, consequently, have produced a number of standardized instruments to measure a range of constructs of key relevance to numerous research and evaluation questions. For example, the Child Behavior Checklist (Achenbach & Edelbrock, 1983), which assesses in a standardized format the behavioral problems and social competencies of children as reported by parents, and the Beck Depression Inventory (Beck, Steer, & Garbin, 1988), which assesses self-reported manifestations of depression are just two commonly used standardized instruments (Plake & Impara, 2001).

Within education, the bulk of the detailed measurement work has focused on the development of standardized tests for student outcomes (Pelligrino, Chudowski, & Glaser, 2001) with less emphasis on capturing delivered classroom instruction, particularly through observation. Yet the importance of understanding the delivered instruction in order to draw conclusions about its impact on student outcomes is clear, which is why most studies of instruction include some observation regardless of the overall evaluation design. Thus, the investment in standardized measures could enable streamlining the instrument development process, resulting in significant savings for individual evaluation efforts while, at the same time, increasing comparability across studies (e.g., cluster evaluations) that are using a rigorously developed and tested instrument.

There currently are several classroom observation measures including (1) the CETP Core Evaluation Classroom Observation (Lawrenz, Huffman, & Appeldorn, 2002); (2) the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000); (3) the NSF-CETP Student Teacher Videotaped Lessons Scoring Protocol (Online Evaluation Resource Library, 2004); (4) the Science Teacher Inquiry Rubric (STIR) (Beerer & Bodzin, 2004); and (5) the 2003-04 Local Systemic Change Classroom Observation Protocol (Horizon Research, Inc., 2003). Following are brief descriptions of these instruments and how the Inquiry Science Instruction Observation Protocol (ISIOP) differs from them. The CETP Core Evaluation Classroom Observation focuses on type of instruction, student engagement, and cognitive activity of students using a time-sampled observational method. It also includes ratings of "key indicators" that represent a range of outcomes and expectations for students. The items were designed to be global and capture all the possible aspects of teaching rather than focusing on a refined documentation of elements of scientific inquiry instruction. The Reformed Teaching Observation Protocol (RTOP) was designed to assess both mathematics and science instruction in grades K-20 and is heavily grounded in the national mathematics and science standards. This instrument uses an event sampling method and has a number of items that relate to some aspects of our conceptual framework of inquiry instruction. However, as with the CETP, the items were written to capture reform practices, not the grade and discipline-specific manifestations of scientific inquiry instructional practices. The Science Teacher Inquiry Rubric (STIR) was developed to assist elementary teachers in their own self-assessment of the essential features of inquiry. This protocol uses a continuum of learner-centeredness to teacher-centeredness at a very general level of descriptive precision. The 2003-04 Local Systemic Change Classroom Observation Protocol was designed to record and rate mathematics and science lessons from classrooms in Local Systemic Change districts. This comprehensive protocol is designed as an evaluation instrument to capture all of the aspects of classroom instruction. While it does reflect some aspects of scientific inquiry instruction, it does so in the larger classroom context. Although some detailed information about the development and psychometric properties of the instruments above accompanies the instruments, for most, the development process and evidence of psychometric properties are not readily available to aid evaluators in determining the utility of these measures for their specific uses and, thus, the validity of the interpretations made from these instruments.

Research must be made accessible and useful for practitioners and decision makers, rather than targeting only academic audiences.

In addition to the existing instruments described above, more are being developed. One example is the *Inquiry Science Instruction Observational Protocol (ISIOP)*. By actively collaborating with a number of the instruments' developers, the ISIOP (D. Minner, personal communication, July 31, 2008) has built on the strengths of these existing instruments, and has incorporated the numerous suggestions from these advisors into the protocol. The ISIOP is designed to assist evaluators and researchers in determining the nature of and extent of scientific inquiry instruction and best practices that are present in middle grades science classroom teaching.

Another example, described in more detail in the article by Jeanne Rose Century, included in this journal, is the Fidelity of Implementation, FOI. FOI **is** a suite of instruments for measuring the use of several reform based K-8 science programs. A User's Guide that accompanies the instruments will describe their established reliability and validity and explain how to adapt the instruments for use with other programs or for classroom instruction where no particular program is used. The suite will also include observation and interview protocols, questionnaires, and a log.

In addition to measuring science instruction, the issue of measurement continues to be relevant for student and teacher outcomes. For example, we are interested not only in students' understanding of science concepts, but also in their understanding of the scientific process, and in their ability to think and reason scientifically. There is a dearth of rigorous instruments that are designed to capture change in these skills, particularly at the elementary level. Likewise, teachers' sense of efficacy with regard to science, their pedagogical knowledge regarding the science content they are teaching, or their comfort with and ability to use curriculum materials and equipment all require instruments that, as yet, do not exist or, if they do, are not based on commonly accepted frameworks that enable comparison across studies.

Complexity and variation of contextual factors

As the discussion of the context and its components demonstrated, the environments within which these models must be studied are fluid and multifaceted. They can change quickly, and one change, such as a loss of funding or a change in leadership, often causes ripple effects in a variety of other areas. For example, conference attendees noted that specialist models often had to change their design with the arrival of a new principal or district leader, a change in available resources, or a shift in district priorities.

Understanding the relationship between contextual factors and specialist models is critical to understanding the nature and the extent to which a particular model has had an impact. Likewise, looking across models and the contexts within which they operate will shed light on how each influences the other. Conference attendees raised the concern, however, that although it is critically important to understand these relationships, the fact that they are so unique to each place and time makes it particularly challenging to study in one location, to identify patterns across studies, and to generalize findings. We do not highlight these constraints and challenges to suggest that examinations of context are too difficult to do well but, rather, to suggest to researchers, funders, and practitioners that they should be taken into account when planning, supporting, or utilizing research. These challenges suggest, as Raudenbush (2005) explained, that the value of multi-site and longitudinal studies and the use of in-depth interviews all require considerable time and resources.

Challenges associated with working in schools and districts

For all the reasons stated above, working in schools and districts is a difficult proposition. They are busy places in which the players face many pressures and constraints, and so the importance of being present without being an imposition cannot be overstated. At the same time that we have highlighted the value of conducting long-term studies that include, for example, in-depth interviews, we also recognize the difficulties of conducting such studies because access to the important players can be extremely limited. Similarly, as we seek to understand how the outcomes of different models vary across population groups, the issue of whether or not schools and districts have the necessary data, in a format research can use, and whether it will be made available becomes critically important. If studies are to be useful, they must have access to the data they need, whether it comes from district records or individuals.

Reaching the right audiences

Research must be made accessible and useful for practitioners and decision makers, rather than targeting only academic audiences. This work has meaning for the research field, of course, but it is critical for the field and should be made available to them. The window of opportunity to influence policy makers is often much shorter than the time it takes for research to work its way through the peer review process and be published in academic journals. That's a systemic problem of the academic world that affects the value and utility of research to the field.

Summary

The January/February 2008 issue of *Educational Researcher* focused on evidenced-based research, and the series of articles examined the challenges and concerns we have raised above in great detail. In his article in that series, Finbarr Sloane recalls Benjamin Bloom's plea for rigorous education research, which continues to be relevant today as it explains our reason for holding the conference on elementary science specialists and on creating this research agenda as a result of it. Bloom (1972) wrote:

> In education, we continue to be seduced by the equivalent of snake-oil remedies, fake cancer cures, perpetual-motion contraptions, and old wives' tales. Myth and reality are not clearly differentiated, and we frequently prefer the former to the latter … . We have been innocents in education because we have not put our own house in order. We need to be much clearer about what we do and do not know so that we don't continually confuse the two. If I could have one wish for education, it would be the systematic ordering of our basic knowledge in such a way that what is known and true can be acted on, while what is superstition, fad, and myth can be recognized as such and used when there is nothing else to support us in our frustration and despair (p. 332).

Elementary school principals and district leaders are facing the problem of providing science instruction to children when they are uncertain about how best to do so within the limitations they face. On one hand, this is a happy dilemma for those of us who have long felt the absence of science from elementary classrooms. Nevertheless, making important decisions in the absence of useful information is undesirable at best, most likely wasteful, and harmful at worst. Regardless of their uncertainties, decision makers must deploy the resources at hand and make an effort to meet the demands before them.

This research agenda attempts to create and organize knowledge about the relative impact of one approach to meeting the demand for elementary science instruction. It lays out the questions that should be raised, and provides a framework for asking those questions and interpreting the cumulative findings. It will not be cheap; however, good research has never been so. In the past, education research has been woefully underfunded, which explains, in part, why it has been considered under par. Our purpose is to begin the process of investigating these questions by organizing the work and laying out the challenges that should be considered in the process of taking it on. Our hope is that our research and practitioner colleagues can begin this work together so that the science instruction our children receive will excite, stimulate, and inform their thinking as young people and as they mature into productive citizens.

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Elementary Science Specialists: A Pilot Study of Current Models And a Call for Participation in The Research

The authors report an empirical pilot study of current models of elementary science instruction that utilize science specialists, and make a call for the participation of schools and districts that use a specialist model to assist in collecting the descriptive data needed to create the foundation for future research on the use and impact of elementary science specialists.

What learning experiences do elementary students need to achieve scientific literacy? How are these experiences best provided? These questions have long been the focus of research and reform (AAAS, 1993; Appleton, 2007; NRC, 1996). Paramount among the recommendations is that children should be active learners, constructing science understanding through hands-on/minds-on inquiry experiences. Young learners should engage in science investigations wherein they ask questions, collect and make sense of data, and come to conclusions that are supported by evidence (NRC, 2000; 2007). Students should investigate "authentic questions generated from student experiences" (NRC, 2000, p. 31). Students should experience science inquiry such that they develop positive attitudes, skills, and knowledge about science and the relationship between science and society. These experiences should involve collaboration and communication among students as they build expertise and confidence.

This inquiry instructional approach places demands on the elementary teacher beyond science content knowledge and traditional pedagogical knowledge. Gess-Newsome (1999) describes four attributes required of teachers to provide effective science instruction:

> (1) *Content knowledge and attitudes*: "… understanding of the four elements of scientific literacy: conceptual knowledge, nature of science, integration, and relevance. Attitudes that support science teaching include an enthusiasm and a willingness to create time for science instruction and recognize that all students have the right to be engaged in meaningful science instruction. Teachers with positive attitudes toward science will encourage similar attitudes in their students by modeling curiosity, using problem solving approaches when answering questions, relying on data, being skeptical of explanations while being open to new ideas, and respecting reason and honesty." (p. 2)
>
> (2) *Pedagogical knowledge and skill*: Teachers need to plan, implement, and assess student active involvement in science instruction. "Activities should be inquiry-oriented, support the social construction of accurate science knowledge, and develop classroom community" (p. 2).
>
> (3) *Knowledge of students:* This category includes knowledge of student development; student misconceptions; and students in one's class such that the teacher recognizes opportunities to garner interest and make relevant connections (p. 2).
>
> (4) *Knowledge of curriculum:* "… allows a teacher to select, adapt, or create instructional materials to meet

> student needs and recognize how these materials combine to create a coordinated program of science both across grade levels … and across the curriculum …" (p. 2)

Teachers are not only expected to have expertise in all these areas regarding science, elementary teachers are also expected to have expertise in all these areas regarding the other subjects they teach. Few would doubt the importance of science education for today's society. However, in the age of No Child Left Behind, elementary science instruction has been given lower priority than reading and mathematics, resulting in even less time devoted to science (Griffith & Scharmann, 2008; Sandler, 2003). The importance of early quality science learning experiences and demands from high-stakes testing has created a dilemma in elementary settings. What type of elementary science instructional model will help meet the needs of today's learner?

Most elementary classroom teachers have limited experience with science in general, let alone scientific investigations (Smith & Anderson, 1999). Lack of content knowledge and investigation experience has been linked to teachers' lack of self-confidence in teaching science and, in turn, lack of science emphasis in their elementary classroom (Appleton, 2007; Ramsey-Gassert et al., 1996; Schwartz, Abd-El-Khalick, & Lederman, & 2000; Tilgner, 1990). The 2000 National Survey of Science and Mathematics Education (Weiss, Banilower, McMahon, & Smith, 2001) revealed that 40% of K-5 teachers have had four or fewer semesters of college level science. The survey also showed that K-5 teachers' perceptions of their own preparedness reflected their minimal science background, with more than two-thirds of their sample reporting they did not feel well prepared to teach science; whereas 77% reported feeling well prepared to teach language arts and reading. Other constraints of poor facilities, overcrowded curriculum, limited time and resources, and limited administrative support contribute to the de-emphasis of science at the elementary levels (Appleton, 2007; Ramsey-Gassert et al., 1996; Rhoton, Field, & Prather, 1992; Tilgner, 1990). The persistence of these constraints, and the added constraints due to No Child Left Behind (Griffith & Scharmann, 2008), cannot be overlooked in the planning and implementation of quality elementary science instruction.

The importance of early quality science learning experiences and demands from high-stakes testing has created a dilemma in elementary settings.

Elementary Science Specialists

In response, many schools and school districts across the United States have sought the expertise of *elementary science specialists*. In 2000, as many as 15% of elementary students in the United States received some science instruction from science specialists in addition to their regular classroom teacher, and 12% received instruction solely from a science specialist (Weiss et al., 2001). Specialists have many roles and faces, but typically they have greater science content background, perhaps even holding a degree in a science area and specialize in science teaching (Abell, 1990). A specialist's main emphasis in a school or district is science instruction. They could develop curriculum, provide resources, offer professional development, deliver science instruction alone or in a co-teaching model, and serve as coach or mentor to classroom generalists to enhance science instruction. Advocates for elementary science specialists argue that the more substantial science content and pedagogical knowledge and high priority and support for science teaching will result in higher quality science learning experiences for elementary children (Abell, 1990; Gess-Newsome, 1999; Hounshell & Swartz, 1987; Jones & Edmunds, 2006; Nelson & Landel, 2007; Neuman, 1981; Schwartz et al., 2000; Williams, 1990).

Even though specialist-led models have been in place for decades, there have been few published descriptions of models (e.g. Abell, 1990; Gess-Newsome, 1999; Hounshell & Swartz, 1987; Jones & Edmunds, 2006; Nelson & Landel, 2007; Neuman, 1981; Schwartz et al., 2000; Williams, 1990), and even fewer empirical studies of existing models and their effectiveness on student achievement (Jones & Edmunds, 2006; Schwartz et al., 2000). Schwartz et al. (2000) provides one empirical study that compared instructional planning between science specialists and generalists; and student achievement between a specialist-led district and a non-specialist district. This study demonstrated the science instructional planning of the science specialists better aligned with reform-based practices in comparison with the regular classroom teachers in the same district. Further, students taught by the elementary science specialists were engaged in inquiry-oriented activities and demonstrated critical thinking abilities. In comparison to students in the non-specialist district, students taught by the science specialists were *not* significantly different in achievement on state science tests. The study lends support to the effectiveness of the district's science specialist model in enhancing learners' inquiry and critical thinking skills, while maintaining content achievement as measured on state tests. The study also demonstrated the exclusive use of science specialists for all science instruction, the model implemented in the targeted district, may have diminished science teaching abilities of the regular classroom teachers in that district. In their study of three schools employing science specialists, Jones and Edmunds (2006) found similar results regarding instructional approach employed by science specialists. These results were consistent whether the specialist was the sole deliverer of science instruction or if the specialist was a curriculum leader who worked with the classroom generalists on science instruction.

Developing a Research Agenda

Policy, curricular, and instructional decisions regarding elementary science must be informed by research. The studies described above suggest that science specialists can enhance elementary science learning experiences. To date, however, sufficient research on current practices and effectiveness of elementary science specialists is sorely lacking. In response to the interest and need for understanding and research, the Center for Science Education at the Education Development Center, Inc. (EDC) organized an invitational conference "*Exploring the impact of elementary science specialists,*" funded by the National Science Foundation. The conference was held in Boston, MA, in the fall of 2007. The purpose of the conference was to discuss the current state of affairs regarding how elementary science specialists are utilized and to set a research agenda to study the effectiveness of these programs. In this issue of the *Science Educator*, (EDC, 2008) presents the findings from the conference and has organized the more than 50 research questions generated at the conference in a proposed research agenda. At the close of the conference, we proposed to conduct an initial descriptive study of science specialist programs represented at the conference. The findings of this study are reported here, along with a call for participation in a larger comprehensive study. Before we can begin addressing the practical issues of impact on student achievement, we must have an understanding of how elementary science specialists are currently being utilized in various districts and schools. We must develop common language as well as common understanding of the phenomena related to elementary science specialists (see also the article by Century in this issue of the *Science Educator*). The discussion during the conference made it abundantly clear that there are multiple models, multiple roles, and multiple descriptions of elementary science specialists. The purpose of this paper is to begin clarifying some of these features by examining current practices.

Lack of content knowledge and investigation experience has been linked to teachers' lack of self-confidence in teaching science and, in turn, lack of science emphasis in their elementary classroom.

Problem

As described in the EDC article (this issue) articulating the research agenda, descriptive studies about the use of elementary science specialists are needed in order to develop a common vocabulary and to act as a foundation for an empirical literature base. This descriptive study is an initial attempt to provide some of the needed information. The purpose of this study was to test the validity of the elementary science specialist model descriptors as developed from the literature, educational practice, and discussion at the EDC conference. As a result of this investigation, we anticipate three outcomes: 1) the pilot testing of a set of questions that can be used in surveys and interviews to capture information about the use of elementary science specialists, 2) the identification of a set of potential school or district sites for further and more in-depth investigation, and 3) an initial trial of data analysis strategies for use with an expanded data base. The ultimate purpose of this article is to invite the participation of elementary schools and districts that use a science specialist model to assist us in collecting the descriptive data that we need to create the foundation for future research on the use and impact of elementary science specialists.

Method

This study was conducted in three phases. First, the elementary science specialist models discussed in the literature were synthesized, vetted at the EDC science specialists conference (EDC, this issue), and then organized as an initial framework for capturing the use of specialists in schools. This synthesis was built upon a model initially proposed by Gess-Newsome (1999), with the added reference to Nelson and Landel (2007) who used the term "collaborative specialist" as a model consistent with the departmentalized model. Based on the discussion at the EDC conference, the specialist-led models were categorized as Student Instructional Models or Teacher Mentoring Models, depending upon the focus of the program. For instance, the Student Instructional Models all relate to variations in the use of specialists in the direct teaching of students, where the Teacher Mentoring Models use specialists to assist classroom teachers in science instruction as opposed to direct instruction. Programs utilizing classroom generalists only, without hiring of a specialist, are classified under "Generalist Models." The conceptual organization for this study can be found in Table 1.

In order to test the conceptual organization, in the second phase, 34 school-based participants who attended the EDC conference were e-mailed a survey listing the model types and asking them to indicate the models that most closely-match their school or district. They were also asked to provide information about model variation within their district and the number of hours dedicated to elementary science instruction. Answers were received from 12 respondents, representing six large urban districts.

In the third phase of the study, an initial descriptive analysis of the data was conducted, resulting in Table 1 and the qualitative results that are presented in this paper. Based on this analysis, a second e-mail survey was sent to the 12 respondents (see note 1 for web access to the survey). The second survey sought to clarify the initial responses with questions focused on the variation in model use within a district, the variation in time spent in science instruction, and the perceived challenges to implementation (organized around the themes of financial support, school-level support, district-level administrative support, the impact of state testing, and issues related to implementation such as scheduling and curriculum materials). Six of the respondents, representing three of the districts, responded to this e-mail. This data was qualitatively analyzed using open coding (Krathwohl, 1998), looking for themes across the respondents that might illuminate further refinement of survey questions or prompt additional forms of data collection and analysis.

Results and Discussion

Elementary Science Specialist Models

Answers to the initial survey were received from 12 respondents representing six large urban districts in six different states (California, Illinois, Massachusetts, Nevada, New York, and Washington). The individuals who responded fulfilled the following roles: six were school-based science specialists, four were district-level science specialists, and two were elementary school principals. All indicated a willingness to be interviewed or to provide additional information.

In 2000, as many as 15% of elementary students in the United States received some science instruction from science specialists in addition to their regular classroom teacher, and 12% received instruction solely from a science specialist

All six of our predetermined instructional models were represented in the sample (Table 1), lending support for the conceptual organization. We were initially surprised to find districts indicating that they used several of the models described and were concerned that the multiple indications were a result of a poor conceptual organization or insufficient model descriptors. The second survey helped clarify this issue: districts often used different models in different schools. For instance, within a single district, some schools followed a generalist model while others used one of the specialist models. District 1 described a slight variation of the science specialist pull-out model whereby the classroom teachers signed up for a 4-6 week block of time to take their students to the science laboratory where the science specialist engaged the students in an extended unit. Other times during the year the classroom teacher was responsible for science instruction, with support from the specialist (support team model). This finding suggests that it will be important to determine, beyond the science specialist model in use, the level of responsibility for science instruction retained by the classroom teacher in addition to instruction provided by the specialist. Such information will help determine if the prevalence of the classroom generalist model is isolated from or in addition to a science specialist. In looking at the Teacher Mentoring Models, the level of organizational support (school or district) varied with our sample, indicating a need to specifically ask about the level at which the specialist is employed. Based on this initial analysis, the conceptual organization of elementary specialist models was supported by this pilot sample and, with minor modifications and clarification, will be used for further data collection efforts.

In this initial survey, we also sought to gain insight on the amount of time spent in science instruction. With variation by school in the use of a model, it was quickly apparent that more categories were needed to accurately capture this information. In Table 1, we modified our original question to assess the amount of time spent in science on average across the district, and asked for a comparison of time spent on science when a specialist model was in use. Based on the information provided by our informants, we also included a grade level breakdown, with time spent on science varying between grades K-2, and grades 3-5. In reflection, a more accurate set of questions may be to ask about the time spent on science in schools with and without specialists (as opposed to an average) and to break these estimates down by grade level bands. As can be seen from this pilot data, the instructional time devoted to science varied widely within and across districts, with the suggestion that schools with science specialists *may* devote more time to science instruction.

The follow up survey (see note 1 for web access to the survey) attempted to clarify the reasons for variation in the use of specialists within districts, as well as identify obstacles and facilitating factors associated with specialist-led models, and elicit perceived impacts of the models on teachers and students. Six of the initial 12 volunteers responded to our follow up request, representing three of the districts (Districts 1, 2, & 6). The results presented below are based on both sets of surveys.

Source of Variation: Site-based Decision-making

Within district variance in the use of specialist models was attributed to administrative decisions and funding issues at the school level. In general, schools were empowered to make site-based decisions in terms of the use of specialists. Funding constraints, however, seem to be the controlling factor in the hiring of specialists and the breadth of their service responsibility (a single school versus multiple schools in a district), as can be seen in the following quotes:

> Within our district, decisions are made on a site-by-site basis. This largely depends on the funding they have or the beliefs of the administrator. I happen to be at a Title [I] school where the administrator believes that science is important and allocates Title money towards my position. For the entire district there is one coordinator and project facilitator to service over 200 elementary schools. This is most likely due to a lack of funding support. (science specialist)

> It is up to the individual site administrator to decide whether or not to use school funds (Title I funds, grant money, other staff allotment funds) for a specialist. Reading and math specialist positions are funded by the district. Each school gets at least two reading positions and one math position. (science specialist)

> Funding, I think, is the major cause [of variation across the district]. While I am officially the science specialist at our school, our administrator can not afford to use any more discretionary funds for a math specialist, so I now fill both roles as best I can. Some schools can not afford either of these positions so in lieu, develop a lead teacher, lab teacher, or other such support role that would see more students and have less "free" time to work with individual teachers on their own implementation of science. (science specialist)

Within our pilot sample, only two districts employed district-level science resource specialists; all other science specialists were hired and funded on the school level. As a larger data set is collected across more schools, it will be interesting to see how funding issues and administrative commitments to science come into play in the selection of a specialist model.

Obstacles and Facilitators

Respondents were asked about specific obstacles and facilitators associated with their elementary science specialist models. We sought to identify factors leading to implementation and sustainability of the existing programs. As was true for the selection of a specialist

Table 1. Models of science instruction represented in the sample.

		District					
	Model (Gess-Newsome, 1999) -	**1**	**2**	**3**	**4**	**5**	**6**
Generalist Models	**Classroom generalist model (Traditional model)**: The classroom teacher has a self-contained class and is responsible for all the science instruction.	√	√	√	√	√	√
	Classroom science specialist model: One of the classroom teachers in the school takes the lead with science curriculum selection, obtaining supplies, and planning science instruction. All classroom teachers are responsible for delivery of science instruction within their self-contained classrooms.	√					
Specialist: Student Instructional Models	**Departmentalized model, or Collaborative specialist** (Nelson & Landel, 2007) (within grade levels): Science instruction is delivered by one of the classroom teachers who has specific interest and expertise in science. The teachers (or students) rotate for certain classes, such as science, mathematics, or social studies. The "science teacher" is also responsible for the other academic subjects within the otherwise self-contained classroom.	√	√	√	√		
	Science specialist (pull-out model): The science specialist is responsible for planning and delivery of all science instruction, which typically takes place in a science laboratory or dedicated classroom.	√	√	√			
Specialist: Teacher Mentoring Models	**Resource/Coaching model**: The science specialist provides leadership and resources for science instruction, but is not responsible for delivery. The specialist aids in curriculum development, professional development, and leadership for the science program. Instruction takes place in the regular classroom by the classroom teacher.					√	√
	Science support team model: The science specialist works with the classroom teacher to assist with planning and delivering science instruction within the regular classroom. Instruction is the shared responsibility of the specialist and classroom teachers.	√	√ (d)		√	√ (d)	
	Other -	√					
	Science Instructional Time in Minutes						
	District Average	0-250	150	60-		0-250	60
	Specialist schools: Average of All Grade Levels	250	80-300				
	Specialist Schools: Grades K-2				135		60-120
	Specialist Schools: Grades 3-5				180		450

(d) indicates district-level personnel fulfill this role of specialist. All others are school-based personnel.

model, the most common themes were *administrative support* and *financial support*. Interestingly, these features were considered to be obstacles as well as facilitators.

School-level Administration. When decision-making about personnel and curriculum emphasis occurred at the school level, the school administration played a critical role in setting the expectations and providing opportunities for a science emphasis. Those who understood the value of science instruction and had the leadership skills to extend those values to their teachers promoted an atmosphere conducive to science learning.

> [School administrators] are essential in most cases and most often follow district and region leadership/focus. We found that teachers' level of implementation closely followed the principals' level of interest, knowledge, and excitement for science. (science specialist)

> [School administration] has a huge impact. In some buildings, administrators tell teachers not to worry about science. (science specialist)

Policy, curricular, and instructional decisions regarding elementary science must be informed by research.

When considering the role of a science specialist, the administration often determined the purpose of the position and the model employed. If the role of the specialist was to provide support and leadership to enhance science instruction, and if the administrator provided the necessary leadership and support, the employed model was likely to be described as successful. In some cases, however, the use of science specialists was compromised by other influences. For instance, one informant described an administrative contractual obligation to provide a preparation time for each classroom teacher. This prep time was accomplished through the use of a pull out model for science instruction. Unfortunately, without an accompanying philosophical commitment to, support of, or expectations for science instruction, the pullout model failed to promote a science focus across the school and resulted in disconnected and limited exposure to science. As described by one specialist:

> The support of site administrators in securing the necessary funding is critical to the success of a specialist model. Without the money and space needed to implement and maintain any model, the program dies. Furthermore, the site administrator's vision of the role of science in the elementary curriculum can promote or discourage science instruction at the school. … If the specialist is providing prep time for teachers at a particular school, then they are helping teachers get the time they need to plan, grade papers, contact parents, etc. However, programs built around this organization present science instruction in such a way that it very often becomes a series of shallow, discrete "activities" designed to address specific district grade-level objectives. Because every student … in the school gets a 40-50 minute shot of science once a week outside of the regular classroom context, there is almost no room for meaningful experiences that develop over time or that develop as an integral part of the curriculum. This organization serves to reinforce the notion of science as an unconnected, unimportant part of the elementary curriculum … Having science "covered" in this way may give classroom teachers at the school an excuse for not taking time to do science as part of their regular program, a practice that further impedes their development as teachers of elementary science. Site administrators may point to this kind of science specialist program as proof that they support science instruction at their site, when the reality of the situation is much different. (science specialist)

In contrast, a school principal who values science instruction for all students can build on the positive momentum provided by specialists:

> In [our district], each elementary school had a trained science specialist and most schools use this specialist to train other elementary teachers within that school. This was done so that all students would receive improved science instruction. However, at [our school] we felt like that model was not getting quality science to students quickly enough. Therefore, in addition to having our science specialist work with teachers in first and second grade, we changed our structure so that all students in grades 3-5 would receive daily instruction from the science

> specialist … .I provide resources to support a science professional learning community. (elementary school principal)

Clearly, the school principal has a tremendous influence on the level of science instruction at the school level (Appleton, 2007). With the opportunity for site-based decision making, principals can dedicate funds for specialists, determine the model that best meets their needs, and create an academic atmosphere that promotes science teaching and learning by all.

District-level Administration. The apparent role and impact of district-level administration varied across districts in our sample. Some report that district level administrators provide nominal support through affirming that science should be taught, but fail to take action or provide supportive measures. In these cases, unless school-level personnel take initiative, science instruction remains unchanged. Others state that without district support, science specialists would not exist. Regardless, the decision-maker, be it at the district level or building level, must be supportive of science and establish support structures for the effective utilization of a science specialist. As one science coordinator elaborated:

> In the late 1980s, one of the five regional superintendents started a focus on science … . He hired an excellent university science education professor who was an early advocate for a “doing science approach.” She worked with six teachers … . They became region teacher leaders who worked with teachers during the school day … . This region started slowly and with the superintendent’s leadership, science became a respected subject over time. Other regions started a science focus, following his lead … . Science was on the map and some principals became advocates for science. Principals picked teachers who taught science to become the science specialists … . (retired district science coordinator)

> Some principals are better than others at using their budget. … They attract/hire staff that can handle new structures, [including] teachers better prepared to teach science. More important is the principal that values science and makes it a school priority. Region superintendents also have an impact when they value science. It also helps when these leaders know and understand what it takes to improve science teaching and learning. (science specialist)

This respondent reported that when teachers and administrators left schools where science was a focus, the science priority diminished. This finding highlights the fragile position held by science in many elementary schools, and the centralization of science enthusiasm in a small number of individuals rather than across dispersed leadership capacity. A similar situation was reported by a district science coordinator, who was also an elementary school principal. In her case, she had been responsible for setting schedules, refurbishing and distributing science instructional kits, and working with school administrators and resource teachers on building science instruction. When budget cuts resulted in loss of financial support for resource teachers and supplies, science instruction diminished. However, she saw possibilities for change with a change in personnel:

> We now have a new superintendent and he would like to see the science come back to more like it used to be. I am working with him and community partners to see what will be possible in the next few years. So the bottom line is that without the supervision of classroom instruction or science support people to help the classroom teacher, very little science is being taught. (elementary principal & district science coordinator)

Funding constraints, however, seem to be the controlling factor in the hiring of specialists and the breadth of their service responsibility.

Financial Support. Financial support is necessary for all curricular programs. Employing a science specialist may require additional funding or a reallocation of existing monies. Two of the six districts in our sample reported that federal grant funds were used to initiate their specialist model by providing support for new hires and professional development. The momentum built through participation in the science grants, however, only lasted as long as the administration’s advocacy for science instruction.

> When we had the [grants], schools involved became committed to the project goal of improving/enhancing teacher knowledge of science, how children learn, instructional strategies, and leadership potential. Multiple changes

> during and after the grant ended contributed to mixed messages and areas of focus: new superintendents, reconfiguration of district management, NCLB. The new superintendent commented that there was no time for science. (retired science coordinator)

> The district has cut the budget for many resource teachers, materials people, or kit builders, and doesn't have a way to really monitor science instruction. This means most of the schools have a classroom teacher, and if it gets taught, great. Some schools have teacher teams … . (elementary principal & district science coordinator)

One school (from District 1) reported that their science specialists were supported through Title I funds:

> We are able to use some of our textbook money to participate in our district's kit replenishment program, so that helps tremendously, as we get fully stocked kits and all teachers at a grade level have the same kit at the same time (within the school). In terms of funding for a science specialist, [funding] is huge. The only reason I have my job [as science mentor] is because we are a Title school. (science specialist)

Of the 13 elementary schools in District 6, two used a collaborative specialist model where a team of three teachers each teach in their area of expertise (science, mathematics, or literacy). This model was adopted following professional development of the teachers in their respective areas. The professional development was provided through an NSF-funded grant program run by a local university. The benefit of this model was that it did not require additional funding by the school or district to initiate or sustain. The administration, however, supported the model through the allocation of existing funds and sought additional funds for resources and additional professional development for the teachers involved. A principal at one of these schools commented on his need to be flexible and supportive of the program. Key school-based changes championed by the principal included establishing a science professional learning community that met twice a month, moving to block scheduling to enable extended time for specialist classes, and garnering the support of parents and the community for science instruction.

Mandated science testing drives much of what is taught, and how science is taught.

Professional Development Opportunities. A majority of the respondents felt there were insufficient professional development opportunities for science specialists as well as generalists. For example, while the school in District 6 that followed the collaborative specialist model had established a science professional learning community for its teachers, they reported that professional development for the generalists in the schools not following a specialist model was sorely lacking. Those teachers received one half-day kit training each time a new kit was adopted by the district. They and others attributed the situation to insufficient district and state funds, lack of science priority, and lack of leadership to initiate and pursue opportunities. With just a few exceptions, most reported that the science specialists have district-sponsored meetings for dispensing information about kits or curricular materials. A couple of districts offered workshops for pay or university credit, but space and time were limited such that relatively few teachers were able to take advantage of the opportunities.

> There is little to no funding allocated for after school professional development for our teachers. If I want to provide something after school, I must go to outside sources to look for forms of compensation. If we need extra materials, I must find resources for those as well. (science specialist)

> Space in the workshops is limited, and we are a rather large district, so there are many individuals who are going without professional development in the area of science. The fact that the district actually offers very little professional development opportunities for teachers is also troublesome. (science specialist)

District 2 is divided into regions that provide science professional development. These opportunities occur once a month for some areas, fewer for others. Curriculum workshops are also provided throughout the year. As with other districts in our sample, it is reported that the science specialists tend to take advantage of the professional development opportunities more often than the classroom generalists. District-level support in District 2 is demonstrated through the provision of specified district-level personnel and professional development. Each

While the impacts of the various specialist models are anecdotal, they provide a glimpse into the perceptions of those most closely involved.

region has its own Math/Science Coach that coaches the specialists within each school.

> Our area meets once a month and looks at the math and science curriculum. We meet in different schools each time to see what/how others are implementing the program. We also discuss focus points to address with teachers within our individual schools. Citywide there used to be more specialist meetings than there are now. (science specialist)

For our pilot sample, district level support most often evinced itself as professional development opportunities for specialists as well as generalists and, in some cases, district level personnel to facilitate such opportunities. Overall, support for specialists appears to be concentrated at the school level.

State Testing. We cannot ignore the realities that pressure and prioritize K-12 education. Mandated science testing drives much of what is taught, and how science is taught. For schools that have science specialists, there is some indication that the methods of instruction are more likely to engage students in meaningful learning, though such tendencies are not guaranteed. It will be important to monitor the ongoing impacts of mandated testing on the use of specialists, as is noted below:

> Mandated testing in science is viewed by the fifth grade teachers as just punishment for teaching at the intermediate level. They use [standards] … lists of things that are going to appear on the test … as the basis of their science instruction. They see the use of science texts and worksheets as the most efficient tools for teaching to these tests and are using them as the core of their science program … . Because the science test is really a reading test (no teacher help with directions or translations allowed with test items), these [instructional] practices often lead to passing test scores … . [The fear is that] test scores will be used to illustrate that science specialists, professional development in science, and reform-based instructional practices, are not necessary to the success of elementary students in learning science. (science specialist)

Impact of Science Specialist Models

While the impacts of the various specialist models are anecdotal, they provide a glimpse into the perceptions of those most closely involved. The most common impacts relate to teacher attitudes toward science, instructional style, instructional time, and state test achievement. These impacts are most closely associated with the benefits of the resource/coaching, support team, and collaborative specialist models. For instance:

> I believe the teachers at my school feel fortunate to have a specialist within their building and teach more science as a result. This [attitude] ultimately impacts the students because they are actually getting science [instruction]. Our students love science and talk with me about science each day in the lunch room. We also have a high daily rate of attendance (around 96%) that we attribute at least in part to the excitement of science. Students have said they don't want to miss because they will miss out and not know what happens next. (science specialist)

For a school-based resource/coach within District 2, the impact of the specialists across the district was seen in science pedagogy.

> Those schools with specialists seem to have a more consistent use of the science curriculum and a better understanding of what inquiry-based science looks like. Students are therefore exposed to a greater amount of hands-on science content. Schools in [our district] who have been implementing the program have seen gains in their science scores to a greater degree than those schools who have not used the program. (science specialist)

This statement is supported by our data on instructional time (Table 1) where science classroom instruction ranges from none to 7.5 hours per week. The participants in this study attributed the variation to science specialists who are thought to spend more time supporting quality science instruction in their schools. The explanation for this increase is attributed to teachers' amplified comfort with science content and pedagogy as a result of the collaboration with the science mentor. In schools using the resource/coach model, teachers reported spending more time in science instruction since the employment of the science specialist. For example, District 1 mandates 110 minutes per week of science instruction for grades 1-5, but the classroom teachers reportedly spend 250 minutes per week. Specialists at this school also reported improved science pedagogy. As one science specialist explained:

> Science specialists who function as responder mentors or coaches may serve as a valuable resource for the school's overall science program … . Because science instruction takes place in the regular classroom with the classroom teacher, this model can help to contribute to the overall development of teacher expertise in science teaching at the site. Limitations of this organization structure may stem from the ability of the specialist to work with individual teachers in an ongoing, systematic manner that supports their development. These specialists are often pulled to perform other duties at the site that impinge on the time they need to effectively mentor young or inexperienced teachers in science. This model serves the students to the extent that the specialist's expertise of science content and pedagogy informs the practice of the classroom teacher. (science specialist)

Despite this potential, we must remember that pull-out models have the potential to reduce the need for the regular classroom teacher to attend to science instruction, thus ultimately reducing a students' exposure to "meaningful experiences that develop over time or that develop as an integral part of the curriculum." Future research must explore the relative impacts of different models, as well as contexts, on science achievement, science attitudes, and science identities.

Next Steps – A Call for Participation

Based on the pilot data collected in this study, we believe that we have strong initial support for the organizational framework that we have developed to collect further descriptive data about elementary science specialists. In addition, follow-up surveys have greatly assisted us in understanding the nuances of selecting and implementing a specialist model, including administrative support, financial support, the impact of state testing mandates, and the potential benefits realized through the use of specialist models. All these areas warrant in-depth exploration.

Future research must explore the relative impacts of different models, as well as contexts, on science achievement, science attitudes, and science identities.

So where do we go from here? This pilot study provides an initial guide for a larger, more comprehensive descriptive study of elementary science specialist models. This is where we need your help and support. We have created an electronic survey based on these initial findings to collect data from a larger set of schools that employ science specialists. The survey can be found at the website listed in Note 1. We are requesting that all schools or districts that use a specialist model consider submitting information about their programs for analysis. We would like to have this data submitted to us by December 1, 2008. Widespread response to this call will do a number of things. First, it will provide additional information related to the validity of our conceptual organization of the use of elementary science specialists. If validated, both the fields of research and practice can move forward with a clarified understanding of the models that exist and a uniform vocabulary to describe specialists. Second, survey information will provide a critical conduit to sites of future research. While survey data provides an informative window into institutional practices, these reports need to be augmented by site visits, observations, and in depth interviews. Finally, the survey data generated will act to inform hypothesis generation for future research. For instance, even in the small data set examined in this study, there appears to be a relationship between the use of a specialist model and the time dedicated to science classroom instruction. Additional data will help us examine that assumption and design research to more fully investigate it. As described in the EDC article outlining the research agenda in this area (this issue), other fruitful questions across the spectrum from descriptive, causal, and process/mechanistic will be informed by this work, allowing us to better support schools and districts in their selection of models to support science instruction, to better prepare classroom generalists and specialists to teach science, and ultimately to advance a broad range of science learning outcomes in all our students. This is a call for your participation in the research agenda exploring the effectiveness of elementary science specialists. Can we count on your participation in this important work?

Note

1. To access the surveys discussed in this article, please visit <http://homepages.wmich.edu/%7Erschwart/research.htm>.

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Jeanne Century, Mollie Rudnick, Cassie Freeman

Accumulating Knowledge on Elementary Science Specialists: A Strategy for Building Conceptual Clarity and Sharing Findings

This article offers a framework for supporting identifying and organizing the elements that comprise elementary science specialist models. With these first building blocks, it is the hope of the author to create a foundation for shared language, conceptual understanding and accumulating knowledge about how to bring high quality science education to elementary schools.

Scientists and educators have argued for inclusion of science in the school curriculum from the earliest years of our public education system. In the mid-1800s, Edward Livingston Youmans suggested that science was the best means of contributing to both “useful knowledge” and “improved mental power” (Deboer, p. 6). Later in the century, Thomas Huxley made the case that science study should be part of schooling as early as possible and that it should focus on direct observation and study of natural phenomena (Deboer, p. 10). The calls that they and other scientists made for inclusion of science in the curriculum focused on student-oriented experiences that engage students in authentic practices of science; a very different type of science education from what we typically find in today’s schools.

Distinguished educators have agreed. Nearly 100 years ago in *Democracy and Education*, John Dewey wrote “… by following, in connection with methods selected from the material of ordinary acquaintance, the methods by which scientific men have reached their perfected knowledge [the student] gains independent power to deal with material within his range, and avoids the mental confusion and intellectual distaste attendant upon studying matter whose meaning is only symbolic” (Dewey, 1916, p. 221). And Charles Eliot, the head of the Committee of Ten suggested that science was an effective way to develop mental abilities and should be taught with “objects and instruments in hand” (Eliot in DeBoer, p. 30). Continuing into the 20th Century, Joseph J. Schwab a scientist-educator from the University of Chicago, suggested that science would be a means for teaching students to actively engage in a process of analysis, look for evidence, and validate their own findings (Schwab, 1962).

Elementary science education has enjoyed increased popularity in some settings during isolated pockets of time, but it has not yet made the shift from passing trend to accepted regular practice.

Unfortunately, there is yet to be a time when these distinguished individuals and others who advocated for the merits of science education would see their positions widely realized in our schools. Elementary science education has enjoyed increased popularity in some settings during isolated pockets of time, but it has not yet made the shift from passing trend to accepted regular practice throughout our country. The closest our nation has come accompanied the watershed event of Sputnik. This 1957 moment of perceived defeat sparked an unprecedented commit-

Once again, we feel the pressure of competition, but this time it is not a race to space; it is an exercise of intellectual muscle.

ment to science education in the United States. In the years immediately following, the federal government invested in curriculum programs that engaged children in "doing science" and at their peak, nearly half of school districts surveyed used one of them at the elementary level. Eventually however, their popularity, once driven by a focus on scientific disciplines and the United States' desire to develop more scientists, waned in the face of newly emerging priorities for science education such as scientific literacy, environmental education, and the role of science in society (DeBoer, 1991).

Debates about the purposes of science education have endured as long as science has been present in the school curriculum. Some arguments focus on its competitive utility and contributions to economic development. Others focus on the social elements of science learning such as environmental awareness and health. And still others point to science applications in technology and engineering. Simultaneously, there are differences in views about who should learn science—the gifted elite or the common citizenry, propagating a long-standing tension in public education rooted in the earliest years of our public education system.

Now, with over fifty years passed since Sputnik and nearly ten years since the turn of the millennium, the need for science education in our country is greater than ever. Once again, we feel the pressure of competition, but this time it is not a race to space; it is an exercise of intellectual muscle. We find ourselves in a race with every country in the world to be leaders in the growing global, knowledge economy of the future. The priority of the past—creating more scientists—is even more timely today. Simultaneously, there is an undeniable urgency to have science fluent citizens. Science is no longer something distant. Students leaving our schools need to make decisions about advocacy for scientific research, the environment, and their own health. There is no longer any room for argument. Individually and as a nation, we need science to thrive, and survive.

Science Education Must Begin In the Earliest Years

A natural starting point for those eager to see the numbers of scientists grow is the high school. With the competitive drive to create more scientists, this is an obvious place to begin in order to see immediate progress. However, if we shift to a longer-term perspective, and recognize the two-pronged science education goal of developing science fluent citizens as well as scientists, we can see that devoting efforts primarily to high school is short sighted. If we are to meet all of our goals, high school is too late.

As notable leaders in education have said from early on, children need to learn science from their youngest years. Elementary (and preschool) science education provides the foundation of science experiences, processes, facts and concepts that are the essential building blocks for the knowledge necessary to live, engage and innovate in the 21st century. When all students have that foundation, those who would go on to be scientists will be even more prepared to pursue their goals of natural discovery. And those who do not will be well prepared to understand and support increasingly visible and readily relevant scientific work.

Unfortunately, even in light of the increasingly clear need for elementary science instruction, research tells us that the current emphasis on mathematics and reading in our nation's education accountability system is having negative consequences for science. A study by the Center on Education Policy (CEP) finds that, while 62% of US school districts increased the amount of time on Reading and Mathematics under NCLB, 44% of US school districts cut time on other subjects (Center on Education Policy, 2008). A report by Martin West of Brown University provides similar evidence using longitudinal data. He finds that from 1999-2004, time on Reading increased by about 40 minutes a week on average, but time spent on Science and Social Studies decreased 17 and 23 minutes per week, respectively (West, n.d.)

With the arrival of state testing systems for science, one could argue that science will now be a higher priority. However, the consequences for high quality science instruction are unclear. Given the variability of the tests themselves with regard to the nature of content and process knowledge they measure and the undefined consequences of poor performance, it is possible that what should be a positive support for high quality science education could become a detriment. While accounting for these circumstances, there is no question that we must develop elementary science education into the culture of American schooling. And, we necessarily need to identify the most effective strategies for doing so. While past efforts espousing the merits of elementary science education haven't been heard, now, as the global economy grows and science-related issues increase in the public eye, the time has come to embrace elementary science.

The Science Specialist Conceptual Framework: A Strategy for Developing Shared Language and Accumulating Knowledge

In light of the history of elementary science education, it is not surprising that there is a dearth of research on the best strategies for improving it (Gess-Newsome, 1999). There is, however, a wealth of documentation about the barriers that stand in its way. Teachers cite time, poor equipment, insufficient space, lack of content knowledge and interest, poor confidence, and lack of preparation as some of the reasons they are reluctant to teach science (Gess-Newsome, 1999; Raizen & Michelsohn, 1994; Tilger, 1990; Weiss, 1994). Taking these barriers into consideration, some have focused on an approach that could address these challenges and provide support to widespread improvement of elementary science instruction: the science specialist (Abell, 1990; Hounshell & Swartz, 1987).

In order to realize the potential of a science specialist intervention, however, we need to identify and understand the most appropriate and effective roles that a science specialist should play. Should a specialist teach in collaboration with elementary classroom teachers? Should a specialist teach in a room that is separate from the regular classroom? How should a specialist integrate science instruction into the rest of the school day? Should the primary audience of the specialist be teachers or students? There are many unanswered questions. Before we can answer them, however, we need to recognize that currently, the "science specialist" approach is ill-defined and as such, is a poor subject of study. Before we can engage in rigorous, systematic research to understand the elements of this approach that are most effective, we must find a way to clearly and specifically describe it, in all of its variations. Only with common language, can we develop as a learning community of advocates for elementary science education.

In 2002, the publication *Scientific Research in Education* stated, "… research in education has not produced the kind of cumulative knowledge garnered from other scientific endeavors." (Shavelson, R.J. & Towne, L., p. 28) This article proposes an approach for beginning the conversation of how we get there; at least with regard to the science specialist. It offers a framework for supporting shared language and conceptual understanding, along with a process for identifying and organizing the elements that comprise science specialist models. With these first building blocks, it is our hope to create a foundation for accumulating knowledge about how to bring high quality science education to elementary schools.

The strategy described here builds on current work from the Center for Elementary Mathematics and Science Education (CEMSE) at the University of Chicago. CEMSE received funding from the National Science Foundation (NSF) to work with the Chicago Public Schools over three years to develop a suite of instruments for measuring the use of standards-based science and mathematics instructional materials at the K-8 level. When complete in 2009, this project will have produced a suite of instruments for measuring use of five science curricula – *FOSS, STC, Science Companion, SEPUP,* and *IES* – (as well as *Everyday Mathematics*) and a *User's Guide* that describes procedures for adapting the instruments for use with other instructional materials and instruction not associated with a particular program. For more information on these instruments, go to <http://cemse.uchicago.edu/foi>.

Individually and as a nation, we need science to thrive, and survive.

At the outset of this work, we recognized that in order to develop data collection tools for use across a "family" of interventions (e.g. a group of interventions with many shared characteristics but still quite varied - in this case, reform-based science instructional materials programs) we needed a conceptual framework that would encompass the range of elements common to the interventions but still allow us to identify and clearly and specifically describe their differences. We accomplished this by developing a conceptual framework (described further below) that became the basis of our instrument development. Along the way, we came to realize that we could apply the framework, and the process we engaged in to develop it, to other interventions. This article reflects our effort to apply that work to the intervention of interest here—

the science specialist—in order to initiate a dialogue that will lead to a rigorous, collaborative community of researchers studying the potential of this model in all of its variations.

The process we followed was emergent and iterative, but in retrospect, for these purposes, we can retrospectively identify the following steps: 1) describe the intervention and its "critical components"; 2) organize the components into categories within the framework; 3) develop clear and specific definitions for the critical components; 4) identify models or "types" of science specialists; 5) identify and/or develop tools to measure the critical components based on the clear and specific definitions.

Only with common language, can we develop as a learning community of advocates for elementary science education.

So, although we may be impatient to learn more about the potential of the science specialist intervention, we need to ensure that as we move forward, we have the tools we need. In the pages that follow, we make a first attempt by applying these steps that have worked for instructional materials interventions to the science specialist intervention model. In doing so, we begin to "map" the components that comprise the science specialist models into a framework that can be a tool for supporting the shared vocabulary, common measures, and organizational structure that will help us more accurately interpret our findings and together accumulate a sound growing body of knowledge.

1) Describe the Intervention and Its Critical Components: The first step for developing a tool for accumulating knowledge on an intervention is a clear description of all of the essential elements that comprise that intervention strategy. Indeed, the "science specialist" intervention strategy suffers from a problem pervasive in education: the absence of a clear and specific definition. "Science specialist" has been a catch-all label in science educators' conversations (used synonymously with phrases like "science resource teacher," "science coach," and "science lead teacher") nearly assuring that we are not communicating the messages we think we are to one another.

Rather than focus on the labels and debating the meaning of each, we can instead direct our attention to identifying and defining the range of elements any model could have. This focus on what we in CEMSE have come to refer to as the "critical components" of the intervention builds on earlier studies that highlight their use as key to measuring implementation. Hall & Hord (1987) for example, note that in order to analyze different instantiations of a program, "the components or building blocks of the innovation must be identified" (p.117). They later refer to these as "innovation components" and "critical components" (1987). Wang refers to the essential elements of instructional materials as "critical program dimensions" (1984) while others stress the importance of identifying and operationally defining "model dimensions" (Bond et al., 2000).

In other words, "critical components" are the elements of an intervention that are essential to its implementation. They are the variables one must measure in order to determine the extent to which the intended intervention is in place, and in turn, the impact of that intervention. Likewise, they are the variables one must identify and measure in order to engage in studies that clearly and specifically compare interventions and their relative effectiveness. Clearly articulating critical components of the science specialist intervention is key if we are to make progress in understanding the impact of science specialists as an improvement strategy.

Leithwood and Montgomery (1980) suggest that information about the critical components of programs should be taken from the program developers, written materials produced by the developers, or those involved in the implementation of the program. While not exactly a "program" we can apply this approach to the science specialist intervention. A meeting convened by Education Development Center in September 2007 generated a strong starting point. The meeting brought together district and school leaders engaged in using science specialists, individuals serving in the science specialist roles, and researchers and evaluators who had written about science specialist models. (The outgrowth of this meeting is chronicled in the first article of this issue of the *Science Educator*.) These three audiences have the knowledge and experience to articulate the elements of the science specialist intervention model. It is worth nothing that it is often the case that "models" of interventions are not necessarily explicit at the outset. But descriptions of science specialist interventions, their comprising elements, and the theories of action regarding their impact—even when implicit—are models, nonetheless.

When asked to identify the elements of their "science specialist" intervention, the meeting participants generated lists of roles and responsibilities that comprised the operational definitions of their science specialist models. The list read like a proverbial collection of "apples and oranges" ranging from "materials set up, refurbishment and management" to "take responsibility to continue to learn." A selection of the complete list, as generated by participants, is in table 1.

These roles reflect the wide ranging ways science specialists can contribute to improving science education. There are many more, including providing assistance to teachers while they teach, providing materials to teachers, coaching teachers, facilitating data based decision making, science curriculum assessment and revision, conducting system-wide science festivals, designing laboratories and co-teaching; and the list can go on. (Rhoton, Field, and Prather, 1992; Gess-Newsome, 1999). Given the variation, it appears that there are countless models comprising different combinations of roles.

Table 1. Science Specialist Roles Identified by EDC Meeting Participants

Role		Role	
1	Teach students science in science room	7	Conduct Professional Development – lesson study
2	Teach students science in another room	8	PD – demonstration lessons
3	Set up, refurbish and manage materials	9	PD – kit trainings
4	Take responsibility to continue to learn	10	PD – principal trainings
5	Plan with classroom teacher	11	PD – special education trainings
6	Collaborate with other specialists	12	Assist with test preparation

The first step for developing a tool for accumulating knowledge on an intervention is a clear description of all of the essential elements that comprise that intervention strategy.

Thus, although these roles were described within the contexts of models currently in place, the names of the models are not important. As we learned in our work measuring instructional materials, when we start using names for interventions that aren't clearly and specifically defined, we cannot be certain that others understand our assertions and findings. Thus, the key is to throw away our labels and instead describe our models using the combinations of "critical components" that comprise them. With these descriptions, we have a tool for knowing where models are similar and different and a basis for research that can explore the elements of those models (alone or together) that seem to contribute most to our desired outcomes.

The process of identifying critical components calls for more than articulating a list of intended roles like those above. These are often the most explicit elements, but there are also other inferred critical components that are either so obvious, or are so subtle, that sometimes even program leaders haven't clearly identified them. For example, there are expectations not only for what science specialists need to do, but also for what they must know in order to fulfill the expectations of the science specialist position. There are also expectations for the nature of specialists' interactions with their "recipients" (whether it be teachers or students); and, for the recipients' interactions with the specialist. As the list of components grows, one can see the value of organizing them into different categories.

2) Organize the Elements into Categories within the Framework: As we proceed with organizing the critical components of science specialist interventions, we will turn to the conceptual framework CEMSE developed for guidance. Notwithstanding the differences in instructional materials and science specialist interventions, the basic framework structure still applies. Using it as a starting point, we will develop a science specialist conceptual framework that will support the clear description of science specialist models, and facilitate the accumulation of data and knowledge on the different critical components.

Following, is a brief description of the existing instructional materials implementation conceptual framework. As we developed this framework, we carefully considered others' approaches to measuring implementation and in the end chose an approach aligned with Mowbray, et al. (2003) who focused, as already mentioned, on the "critical components" of the programs.

In order to analyze different instantiations of a program, "the components or building blocks of the innovation must be identified."

Mowbray, et al., (2003) organizes what they call "fidelity criteria" (our critical components) into two groups - those that focus on structure ("framework for service delivery") and others that focus on process ("the ways in which services are delivered"). Mowbray, et al. weren't the first to organize program elements this way. In 1984, Wang, et al. studied the Adaptive Learning Environments Model that identified two types of "critical program dimensions." In their work, the structural program elements were described as "those that relate to the provision of adaptive instruction" and the process elements included those that relate to "supporting effective implementation of adaptive instruction. The CEMSE conceptual framework builds on these and others (Dane & Schneider, 1998; Dusenbury, Brannigan, Falco, & Lake, 2004; Lynch & O'Donnell, 2005; Lynch S., 2007; Mowbray, et al., 2003) who measure implementation of interventions in two general categories that we came to informally refer to as "structure" (our structural critical components) and "process" (aligned with our instructional critical components).

The framework (Figure 1) has two broad categories of critical components of instructional materials interventions: 1) Structural Critical Components and 2) Instructional Critical Components. Structural critical components reflect the design and organization of the physical materials. Instructional critical components, on the other hand, reflect the intended behaviors during classroom interaction. Then, each main category has sub-categories that further classify the critical components.

In the "Structural" category, procedural critical components are the organizing structural elements of the program (e.g. order of activities within the lesson, time spent on instruction, lesson overview). In other words, they focus on expectations for what the teacher needs to do. The educative critical components, on the other hand, are structural representations of the developers' expectations about what the teacher needs to know in order to teach the program (e.g. unit level information on content, background information on pedagogy). These components represent a recognition that teachers need a certain minimum level of content and pedagogical knowledge to teach reform-based programs and that while some teachers come to the classroom with this knowledge, others do not. Given the fact that developers cannot rely on all teachers receiving the same amount of professional development, educative program components are analogous to "built-in" professional development.

In the "Instructional" category, pedagogical critical components reflect the developers' expectations about the teacher's behaviors during instruction (e.g. teacher facilitation of group work, teacher facilitation of reasoning). In other words, they represent the instructional strategies the teacher needs to employ and interactions the teacher needs to have with students in order to use the program as intended. Similarly, there are student engagement critical components (e.g. students engage in discussion, students communicate) that reflect the developers' expectations for what the students need to do in order for the program to be enacted as intended. Together, the instructional critical components represent the developers' beliefs about the nature of the instruction that will lead to desired student outcomes.

Given that this framework built from others' work across multiple fields studying different types of interventions, its applicability to a range of programs in education is not surprising. To operationalize this idea for the science specialist then, we begin with the intervention critical components identified in the last step. Figure 2 demonstrates one way to organize the science specialist critical

Figure 1. Instructional Materials Intervention Conceptual Framework

Implementation of Instructional Materials Interventions			
Categories of Critical Components			
Structural Critical Components		Instructional Critical Components	
Procedural	Educative	Pedagogical	Student Engagement

components into categories within the framework for easier communication and analysis.

Figure 2. Science Specialist Intervention Conceptual Framework

Implementation of Science Specialist Interventions			
Categories of Critical Components			
Structural Critical Components		Instructional Critical Components	
Procedural	Educative	Student Educator	Student Engagement
		Adult Educator	Adult Engagement

Structural Critical Components

Like the framework for instructional materials, the science specialist framework includes structural procedural critical components. These critical components are the organizing elements of the program and communicate intentions about what the science specialist should do. For example, critical components in this category could address structures such as "the specialist's "home base" (classroom, school laboratory, district office) and the amount of time that is committed to his role as a specialist (e.g. full-time classroom teacher; half-time; full-time released). They also can communicate the roles the science specialist is intended to play (e.g. organize and distribute materials; plan with teachers, communicate with parents).

The educative critical components of instructional materials programs focus on the content, pedagogy and assessment background the teacher needs in order to teach the program. In the case of the science specialist intervention, the educative critical components reflect what the specialist needs to know in order to enact the specialist model as intended. In addition to science content, pedagogical strategies, strategies to support adult learners, and knowledge of the curriculum, Gess-Newsome (1999) suggests that they need knowledge of students and how to plan for and assess student engagement.

In instructional materials interventions educative critical components are evidenced in the programs' written materials (e.g. sections on science content background information and background information on supporting small groups). In the science specialist model, educative critical components may evident in written materials provided for the specialist, but they are more likely to be evident in professional development experiences provided for the specialists. These may range from individual topic-based workshops to on-going, in-depth study groups.

Clearly articulating critical components of the science specialist intervention is key if we are to make progress in understanding the impact of science specialists as an improvement strategy.

Instructional Critical Components

On the right side of the framework, rather than two sections beneath the heading, there are four - two for each of the main audiences specialists may serve—students and adults. Like the instructional critical components in the materials interventions, these critical components can occur at any time in the specialist-recipient interaction and as such are not bound to particular roles identified on the structural side. When the science specialist is acting as a student educator, the instructional critical components are quite close to, if not the same as instructional strategies/pedagogies a teacher would use and thus, map quite closely to those already identified as part of the instructional materials conceptual framework. This is the case for student engagement as well. For more on the instruments already developed for measuring these critical components, see the section on measurement below.

For the models that entail the specialist acting as a teacher to adults, other critical components would apply. For example, "specialist supports the development of teacher confidence" may be an instructional critical component. Within the constraints of any particular science specialist model, behaviors indicating the presence of instructional critical components can occur at any time and so are measured independent of the structurally identified roles.

The student engagement critical components reflect expectations about the students' participation in the instructional process including their interactions with the content as well as with the teacher and one another. Like the pedagogical critical components, these critical components (with a few exceptions) are not tied to specific section(s) of the lesson or teacher's guide. In the case of the adult learners, the critical components reflect the expectations for the adults' behavior during the specialist-adult interaction. For example, "teacher seeks advice of specialist" is an example of an adult engagement critical components.

As we revisit the roles identified at the EDC meeting in light of the framework categories, we can see that nearly all of them are structural-procedural critical components. This is not unexpected since in this particular context the meeting participants were asked to identify some of the structural roles specialists play. However, if one is to measure the implementation of the science specialist intervention, it is essential to measure the other elements of the intervention as well.

Of course, any intervention to improve instruction is necessarily complex; critical components most certainly cross boundaries. While the organizational structure described here could change with a continued dialogue in the field, it is a first attempt to demonstrate how we can build from work already in place to benefit new questions about improving education. It paints a picture of a place where we have clarity of our terms and can have a common framework to guide the sharing of data and findings with reasonable compatibility.

3) Develop clear and specific definitions of the critical components: Once we have identified the critical components, we need to define them, clearly and specifically. To simply say "co-plan with teachers," for example, leaves many unanswered questions such as: what is the nature of the planning, the length of the planning, and the focus of the planning? Likewise, "manage and organize materials" while somewhat more focused, needs a clearly articulated description. Without it, one would have no way of knowing whether the specialist is responsible for organizing an old materials closet, or for providing each classroom teacher with neatly packaged materials for each lesson. Developing definitions for the critical components that reside in the framework is beyond the scope of this paper; and ideally, this is a process that is not done in isolation. Definitions, with concrete observable, measurable behaviors must emerge from the field, and then adjust over time with more refined, agreed upon meanings.

4) Identify models or "types" of science specialist models: In a report by Jones and Edmunds (2006) they identify three models for science instruction – "traditional" (the classroom teacher teaches science), "specialist" (the teacher serves the whole school from a lab); and "science resource teacher" (supplements classroom teaching with whole class instruction and workings with teachers). They refer to these models as "archetypal variation" and indeed, they, and others like them are embedded in the dialogue about science specialists that take place across the field.

While the organizational structure described here could change with a continuing dialogue in the field, it is a first attempt to demonstrate how we can build from work already in place to benefit new questions about improving education.

But rather than introduce confusion into systematic efforts to learn about the models by using poorly defined names, we can use the framework and its comprising critical components to specifically describe the models of interest. It is better to bypass the vague model names and focus instead on the specifics that comprise the models.

Table 2 shows a hypothetical list of critical components and model titles. The first row identifies some of the ways we currently refer to different science specialists. The phrase "resource teacher" or "science specialist" are no more informative than "regular classroom teacher" and as such do not help us further knowledge in the field. The next row indicates how one can use names as "generic" titles and then define the generic model name by indicating the critical components present in the model.

For example, rather than conduct research on an intervention known as the "in-school specialist" model and accepting its vague—or even absent—description, we can instead suggest that science specialist model "A" comprises critical components "1," "3," "4," "7," and "9." Using this approach, another researcher or community using an in-school science specialist model, will do the same for their model "B" and together, we will be able to discern the extent to which the models are in fact the same. This strategy is similar to Hall and George's (2000) work using what they referred to as "innovation configurations" to assess program implementation. They refer to their innovation configuration map as a "roadmap" documenting the presence of program components in implementation (Hall and George, 2000).

As mentioned at the beginning of this article, these steps are, in fact, not discrete steps at all. For example, identification of the critical components comprising a model can take place at the beginning of the process when determining what the intended science specialist model is; and, it can take place during or after implementation, when one seeks to determine what the enacted science specialist model is, or was. This flexibility represents the fact that when models are implemented in increasing numbers of settings, variation is inevitable. And not only is it inevitable, one could argue that it is desirable; we expect that specialists will vary what they do based on the contexts and conditions surrounding their circumstances. Thus, the framework serves as a tool for describing the variations that the specialists make to their intervention model and in turn, interpreting the extent to which the contexts and conditions surrounding the implementation of the model affect it and its relationship to desired outcomes.

In other words, we do not need to agree on what to call the models. Rather, we need to agree on describing the models using critical components and their accompanying definitions that reside in a shared conceptual framework. By documenting the components of the intervention at this level of specificity, we can begin to accumulate data and knowledge not only on the larger models, but on the individual components that comprise them. In the end, we can move closer to our goal, which is not to determine which "model" is best; but rather it is to determine the combinations of components that work under particular circumstances to achieve our particular desired outcomes.

Definitions, with concrete observable, measurable behaviors must emerge from the field, and then adjust over time with more refined, agreed upon meanings.

5) Identify and/or Develop Measures of the Critical Components Based on the Clear and Specific Definitions. The science specialist intervention framework is a helpful tool for talking with one another. And, it can be used as a landscape on which we can place rich and specific descriptions of our interventions and where they do and don't overlap with other models or with "business as usual" approaches to science instruction. While supporting the field's discussion of science specialist models through the use of common language and clarification of components of each model, further utility of the model comes with its support of accumulation of data and findings on the different components of science specialist models and their relationships with desired outcomes.

Clear and specific measures of classroom practice are critical tools for understanding which interventions, and practices associated with those interventions yield desired student outcomes. In this case, there are some existing instruments that one can use to measure the presence of a portion of the identified critical components. On the instructional side of the framework, when the specialist is in the "student educator" portion of the framework, he is in fact acting as a teacher and existing measures of teacher and student interactions during instruction apply.

A sound starting point are the instruments developed through CEMSE's currently funded NSF project mentioned earlier. In 2009, CEMSE will release a suite of instruments for measuring implementation of five science instructional materials programs for grades K-8 and *a User's Guide* that describes procedures for adapting the instruments customized for these particular programs for use with other instructional materials and "business as usual" classrooms. Among the seven instruments in the suite are classroom and school observation protocols, teacher and school leader questionnaires, teacher and school leader interview protocols, and a teacher instructional log. These instruments focus on measuring the use of reform-based instructional materials, but can be applied to measures of teacher and student interactions and behaviors during instruction and thus, can support data collection on science specialists who interact directly with students.

It is important to acknowledge that there are at least two well-known existing observation protocols for collecting data on science instruction. They are *Inside the Classroom Observation and Analytic Protocol* (ITC COP) (Horizon Research, Inc., 2003) and the Reform Teaching Observation Protocol (RTOP) (Sawada, et al., 2000). One of the key distinctions between the CEMSE instruments and these is that the Horizon and RTOP instruments target data collection on reform-based science instruction broadly defined while CEMSE's constructs address instruction, but do so within a broader conceptual framework that supports detailed analyses of relationships

Table 2. Hypothetical list of Critical Components and Distribution Across Models

Too general to Accumulate Knowledge	Traditional or regular classroom teacher		Science Specialist Alone			Specialist-Teacher Combo with Classroom			Resource Teacher Combo with Classroom	
Generic Model names	Traditional Model A	Traditional Model B	Specialist A	Specialist B	Specialist C	Specialist Teacher A	Specialist Teacher B	Specialist Teacher C	Resource Teacher A	Resource Teacher B
Possible Critical Components from the Conceptual Framework										
1. Organize materials	•	•	•	•	•	•	•	•		•
2. Manage materials	•	•	•	•	•	•		•		•
3. Provide materials						•			•	•
4. Outreach to parents	•	•	•				•	•	•	
5. Outreach to community		•	•				•	•	•	
6. Supervise teachers								•		•
7. Collaborate: coaching and mentoring							•			•
8. Collaborate: planning							•			•
9. Collaborate: co-teaching		•					•			•
10. Model instruction in science room		•	•				•			
11. Model instruction in teacher's room						•		•		•
12. Be a leader			•			•	•			•
13. Assist during a lesson						•		•		
14. Lead professional development										•
15. Facilitate school-wide science related events			•	•			•		•	

between those constructs and materials interventions. Furthermore, the RTOP observation protocol is a stand-alone instrument while our instruments (and the Horizon instruments) are part of a larger suite of data collection tools supporting more flexibility of use and triangulation of findings. Also under development at EDC is the Inquiry Science Instruction Observational Protocol (ISIOP), which is focused on determining the nature and extent of science instruction in middle grades.

Together, these instruments may comprise a complementary collection of tools to measure the critical components that reside in the cells of the framework focusing on teacher and student behaviors and interactions during instruction.

However, the instruments that measure the other critical components on both the structural and instructional sides are lacking. Here we have yet another reason to work from a shared conceptual framework with shared language. The CEMSE instruments provide an example of what measures of structural critical components can look like, but they are only an example since the structural critical components of science specialist models are of a completely different nature. As we move forward, it is essential to ensure, as much as possible, that instruments focused on these areas are, in fact measuring components defined in similar ways and ideally, are compatible so that we can truly accumulate data and findings to develop a growing body of knowledge in our field.

Where does this Framework reside in the larger research agenda?

Now that we have developed a conceptual framework for the science specialist intervention, it is important to acknowledge that carefully and specifically describing any innovation is just one small piece of the larger research landscape. Looking at figure 3, one sees a very simple illustration of where the science specialist conceptual framework resides. In this over-simplified scenario, a science specialist intervention is implemented with the expectation that it will lead to desired student outcomes. However, interventions are rarely, if ever implemented as intended. Implementation is shaped by various contexts and conditions that reside outside of the intervention (e. g. administrator support, the presence of instructional materials, student demographics). Thus, in order to draw truly meaningful conclusions about the impact of the science specialist model, it is essential to do more than determine the nature of its implementation; we also need to account for the other variables affecting the implementation and outcomes.

The science specialist intervention framework is a helpful tool for talking with one another.

We know that there are many elements of improving science instruction that could be considered "inputs" to an enacted intervention. In the case of the science specialist, we might consider financial resources, materials, and time. Likewise, there are many contexts and conditions that affect the implementation of the intervention, sometimes at more than one point during the intervention's duration. These might include characteristics of teachers (e.g. years of experience, confidence in their instruction), student demographics, and accountability systems. And of course, researchers would want to measure outcomes – ranging from student outcomes (e.g. science content and process as well as attitude) to teacher outcomes (e.g. teacher engagement, development of teaching strategies, pedagogical content knowledge) and system outcomes (e.g. visibility of science, increased commitment of time to science, and community involvement).

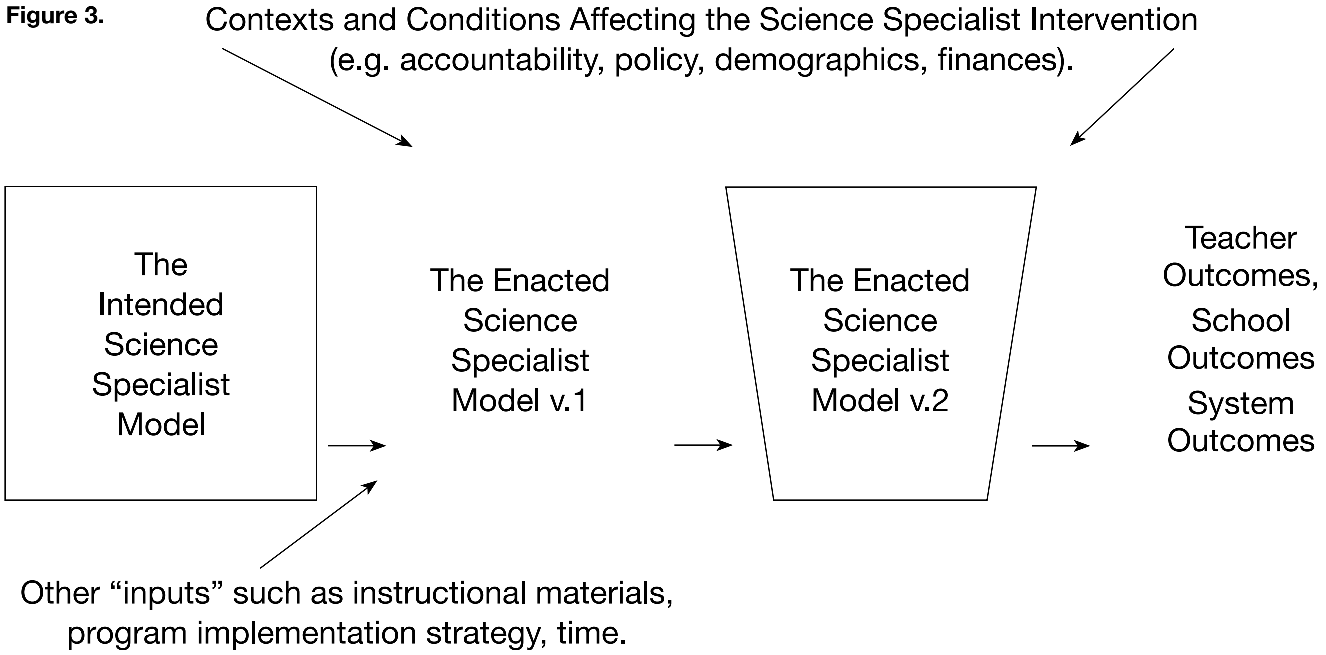
It is unlikely that any single research effort will focus on all of the reform elements illustrated in this diagram. Thus, it is essential to be able to "map" the findings of our studies on this larger landscape with language and tools that are compatible. The science specialist conceptual framework described here is only part of the picture. Researchers can use it to describe the intended science specialist model, and then to measure and describe the model as it is enacted over time, with the expected shifts from the intended model.

With the models named and specifically described, we can explore many different hypotheses about the possible impact of science specialist models and the "pros" and "cons" of each. For example, when there is no specialist, one might make the case that the teacher can fully integrate science teaching into the regular instructional day and other subjects; students can have science present as part of their regular classroom setting; and the teacher can differentiate instruction based on his knowledge of the students' strengths and weaknesses. However, the model creates a scenario in which the teacher is not likely to have a degree in a science content area, and has a greater ability to make science a lower priority in the instructional day.

In contrast, one could consider the pros and cons of a specialist model in which the children have a separate science class. Some of the benefits of the model include: regularly scheduled science instruction; a science teacher more likely to be knowledgeable and/or experienced with science teaching; and the experience of working in a science "lab." Shortcomings include: less integration of science with other classroom instruction, the apparent lack of engagement their regular classroom teacher has with science, and the implication that science is separate from other areas of study.

We could imagine both of these approaches embedded in a study in a large school district that assigned its schools to two different types

Figure 3.



of models. In one case, there are science specialists, and in the other, the teachers are responsible for the regular classroom instruction. At the end of the school year, researchers might find that students in the science specialist schools perform better. Or, they may find the opposite. Or, they may find no difference at all.

In order to draw meaningful conclusions from this study, we must ask ourselves – what happened in the science specialist schools? What roles did the science specialists play? Were some enactments of the science specialist role different from others? Were there people in the comparison schools who were enacting some of the same roles, even though they weren't "official" science specialists? Data collected with tools grounded in the framework will not only help answer these questions and increase the rigor and clarity of the study, they also have the potential to contribute to broader understandings about these models in the field.

Next Steps

This framework is a first attempt to organize the wide range of strategies underlying the science specialist models into a meaningful structure that will help us build a knowledge base about these models in our field. We would expect others would refine, revise, or perhaps completely re-invent the framework; it is the nature of systematic research. It must build on work that came before and contribute to work that is yet to come.

This framework is a first attempt to organize the wide range of strategies underlying the science specialist models into a meaningful structure that will help us build a knowledge base about these models in our field.

In *Issues in Education Research: Problems and Possibilities*, Cohen and Barns (1999) state, "The lack of systematic intervention that is linked to careful research also has contributed to the scattered and frequently inconclusive character of research and the inability to decide what had been solidly learned from a very important tradition of deliberate inquiry"(p.38). Thus, the main purpose of this framework is to support a continued conversation among educators, policy makers and researchers that benefits from shared, clear language and will move us toward a less "scattered" body of knowledge. We will not be able to navigate the landscape of research questions regarding science specialists and accumulate knowledge we can share if we aren't using the same map. This is not a simple task. It is not easy to arrive at the level of clarity and specificity we need - particularly if we need to come to agreement with others. The time has come for us to embrace the complexity of solving educational problems through research by collaborating as a community and making the essential, albeit sometimes difficult, commitment to speaking the same language and sharing tools. We need all of the benefits of our collective knowledge; the challenges of improving elementary science education are far too difficult to take them on alone.

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Developing Teacher Leaders in Science: Catalysts for Improved Science Teaching and Student Learning

The Reaching for Excellence in Middle and High School Science Teaching and Learning Partnership Project at East Tennessee State University has a long history in the development of teacher leaders. This article describes the professional development model, the challenges addressed, and the impact on both teacher and student learning.

The science education reforms in our recent educational history brought to center stage the important role of professional development. Recognizing that science teachers represent the major link between the curriculum and student learning, expert practitioners, researchers, and policy makers emphasize professional development as an essential mechanism for deepening teachers' content knowledge and developing their teaching practices. Professional development has traditionally focused on the need to enhance and enrich teachers' content knowledge. Subsequent to the release of the National Science Education Standards (National Research Council, 1996), an increased emphasis on pedagogical knowledge has found a prominence in the role of professional development. Building on teachers' renewed grasp of content knowledge and inquiry-based pedagogy, an expanding view of professional development has incorporated a leadership component in which educators are recognizing the need for science teachers to become leaders within their own school and school district to advance reform efforts and impact student learning (Guskey, 2003; National Staff Development Council, 2001; Sparks, 2004). This role of professional development promotes job-embedded, sustained opportunities for professional growth and systemic change (Loucks-Horsley, Love, Stiles, Mundry, & Henson, 2003).

"The litmus test of all leadership is whether it mobilizes people's commitment and energy into actions designed to improve things."

Working with thousands of teachers over a decade, Katzenmeyer & Moller (1996) elaborated on the important role of teacher leaders and the important role teachers must exert if meaningful change is to be made and sustained in the school. They define teacher leaders as those "who lead within and beyond the classroom, influence others toward improved educational practice, and identify with and contribute to a community of teacher leaders" (p.6). Teacher leaders build the school's capacity to improve. According to Fullan (2007), "the litmus test of all leadership is whether it mobilizes people's commitment and energy into actions designed to improve things" (p.1). The essential role of leadership, therefore, is the ability to work and collaborate with others. For example, teacher leaders are able to cultivate and encourage colleagues to support new ideas, support the growth of others, and build consensus among diverse groups.

The challenge for teachers and principles is to promote and design professional development programs that encourage and promote effective teaching practices and increased student learning. In recent years, a body of research has emerged on characteristics of effective professional development, teacher learning, and teacher change. The research summarized by Hargreaves and Fullan, (1992); Hawley and Valli, (1999); Leiberman,(1996); U.S. Department of Education, (1999); Loucks-Horsley, Hewson, Love, and Stiles, (1998); Sparks and Loucks-Horsley, (1990); Stiles, Loucks-Horsley, and Hewson, (1996); Rhoton and Bowers, (2001); Rhoton, (2001); Rhoton and Wojnowski, (2006) identifies such approaches.

- Professional development addresses issues of concern recognized by teachers themselves. One-size-fits-all professional development does not, in fact, meet the needs of all teachers. Teachers at different stages in their teaching career will require professional development to meet their specific needs.
- Professional development is connected to classroom practices. It should address issues and immediate concerns relevant to the classroom, such as teaching practices and working with different ability and motivation groups.
- Professional development includes sustained support and takes place over an extended period of time. Lasting change usually occurs only when teachers are given the sufficient time, resources, and training to carry out the innovation.
- Professional development helps teachers learn science content in new ways. These experiences allow teachers to genuinely address change and renewal and reach beyond the "make and take" workshop and the "idea swap" session to more global, theoretical conversations that focus on teachers' understanding of the processes of science teaching and learning and of the students they teach.
- Professional development challenges pedagogical beliefs and practices. Teacher perceptions about student learning, confidence in subject matter understanding, and pedagogical beliefs will affect student learning.
- Professional development promotes incremental change. Although large-scale change may be needed, incremental change allows teachers to retain existing effective practices.
- Professional development encourages collaboration. Teachers consistently rank professional development activities that take place close to the working environment as the most important. Change usually occurs in small pockets within the school.

When school leaders implement the preceding approaches to build the professional development infrastructure, the school's culture and climate will be more conducive to practices that allow teachers to gain enhanced science content knowledge and pedagogical skills, interact with their professional peers, enhance student learning, and meet school-wide goals. However, school administrators must commit to creating a professional development climate that nurtures lively learning environments for communities of teachers.

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Even though these prominent characteristics and particular approaches of effective professional development, as well as others, are quite visible in the literature, very few systematic research studies have been conducted on the extent to which these approaches contribute to better teaching and improved student learning (see, in particular, Guskey, 2003). Some recent studies are beginning to show, however, along with the experiences and wisdom of expert practitioners, that professional development that incorporates all or most of these approaches can have substantial, positive influence on teachers' practices and student achievement (Hildreth & Rutherford, 2004; Rhoton & Bowers 2001a, 2001b; Loucks-Horsley, et al., 1998; U.S. Department of Education, 1999).

Professional development reform initiatives have directed the largest resource investment to teachers' professional development; however, researchers and expert professional developers have seen much of this investment as supporting ineffective practices. Although educators may recognize the importance of new training models for improving science teaching practices, professional development strategies remain largely unchanged, detached from the realities of the classroom, and ineffective for promoting long-term change (Elmore et al., 1996; Stiles et al., 1996). Even as we go deeper into the 21st century, too much of what is promoted as professional development is dominated by stand-alone workshops and short after-school meetings. Moreover, teachers have typically perceived their professional development programs as ineffective, poorly planned, and lacking in relevance to their instructional practices (Sparks & Loucks-Horsley, 1990).

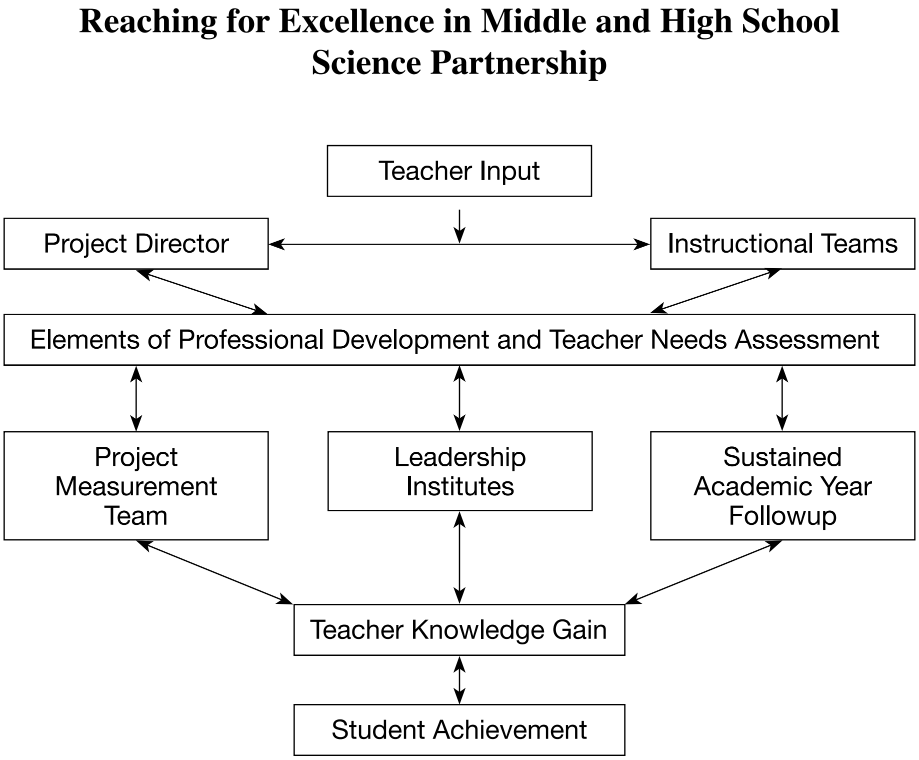
The Model Implemented

What does an effective professional development program look like when it captures the elements of effective professional development and supports an ongoing, sustained approach for science teaching and learning? One thing we have learned is that short-term, one-shot workshops do not greatly enhance teachers' learning or the transfer of that learning into the teachers' classrooms. The East Tennessee State University Science Partnership (ETSUSP) provides an example of one way in which an ongoing, sustained professional development support system can assist elementary and high school science teachers in improving their knowledge of science content and pedagogy and engage students in meaningful science learning experiences.

The ETSUSP has established a collaborative relationship, extending nearly two decades, with various funding agencies and local school districts in the Upper East Tennessee Educational Cooperative (UETEC) to develop and implement a model of professional development for science teachers.

The model (Figure 1) emerging from this 15-year partnership differs from traditional professional development paradigms. First, it offers sustained professional development support and teacher training throughout the academic year. Second, it requires the simultaneous development of instructional skills, administrative insights, and content expertise. Third, it is a grass roots effort involving teachers who implement and maintain the change.

Figure 1: ETSUSP professional development model



The model accommodates teams, composed of middle and high school science teachers, in the ETSU service area. Since the inception of the program, 750 teachers have been trained and more than 50 principals have been directly involved in the activities of the model. The ETSU model captures many of the principles of effective professional development as described in the professional development literature (see Table 1 for a comparison).

The model allows teachers to have control over their own needs. The following sections describe each component of the model and provide insights into ways in which the program is addressing professional development issues.

Content and Pedagogical Knowledge

Effective science teachers need a deep understanding of science content and pedagogy (Rhoton & Bowers, 2001a). Researchers and expert practitioners agree that content knowledge can have a positive influence on student achievement, especially in secondary science (Blair 2000; Whitehurst, 2002).

To build opportunities for participants to gain enhanced content and pedagogical knowledge, the ETSU model makes available summer science leadership institutes (Summer Institutes) for elementary and high school science teacher participants. The institutes run for 12 days each

Table 1: Principles of effective professional development for science teachers

Cited by various sources	ETSU Framework and Model
Focus on content knowledge, pedagogy, and leadership	Science institutes for content, pedagogy and leadership
Focus on student learning	Analysis of teaching and learning
Collective participation	Teacher teams
Links to high standards	State and national standards
Opportunities for teachers to be engaged in leadership roles	Teachers as mentors
Bringing together various stakeholders	Project management team
School-based and job embedded	School-site professional development
Use of date to inform professional development decisions	Analysis of student classroom data
Monitoring and assessing	Assessment each year

summer and are taught by ETSU science faculty and science educators. Institutes focus on both science content (inquiry in science) and inquiry in teaching and learning. Participants engage in a variety of science investigations in the areas of biology, chemistry, and physics, with topics for investigations driven by the participants, student data, and local and state science standards. Investigations and institute activities are presented in the context of how the teacher participants can implement them effectively in their own classrooms.

In addition to learning science content, participants explore questions and ideas about their students' learning, their teaching, and their curricular approaches. These conversations prepare the participants for examining meaningful ways to connect their students' understanding with accepted practices of teaching and learning, thereby providing for a seamless integration of content and scientific ideas with knowledge of student learning and pedagogical practices.

Each participant in the project receives the science supplies and equipment necessary for his or her science curriculum, graduate credit, and a stipend for participating in the project.

After participants return to their schools to implement the science program, university science faculty provide ongoing support for them by visiting them in their schools during the academic year. During these visits university faculty can gather information from teachers and principals as they implement the professional development model as well as support teachers in their classroom environment. Program participants work with their peers by leading monthly science in-service training sessions, observing peer teachers, teaching model science lessons, and assisting their peers in analyzing and selecting instructional materials for their classrooms.

These conversations prepare the participants for examining meaningful ways to connect their students' understanding with accepted practices of teaching and learning, thereby providing for a seamless integration of content and scientific ideas with knowledge of student learning and pedagogical practices.

Administrators' Roles in Science Education

In our lengthy professional development work, we have learned that the school administrator plays an important role in maintaining an effective school science program. The instructional management role of the principal is complex, shaped and constrained by many issues. Current reform initiatives in science education, moreover, compel the school administrator to think of new ways to accomplish standards-based reform in his or her school. For example, there are matters of teacher time, structural arrangements, cultural norms, and teacher learning, all of which affect student learning, either directly or indirectly.

The detached manner in which professional development for science teachers is typically handled compounds the problem. Programs may be coordinated from the district office and conducted during after-school hours or during summer months, perhaps on a local college campus or other off-school location. In many cases, principals may not even be aware of the type of in-service training their teachers have received. Similarly, teachers are seldom aware of their principals' academic backgrounds or preparation in specific subject areas. Consequently, teachers and principals alike may despair of improving science instruction and never realize their mutual interest or the others' resourcefulness in developing constructive programs. Clearly, they need effective channels of communication to ensure the combination of administrative and instructional insights and cooperation needed for reform of science teaching.

The teaching and learning of science are generally perceived to take place in the context of an individual teacher working with a group of students in an individual classroom, but teaching is not a solitary activity. Many dynamics affect the teaching and learning of science in a school or even in a single classroom. Having a clear set of standards for classroom practice is an important part of the equation, but real, long-lasting change calls for the principal playing an active role. The principal who recognizes the crucial importance of school-and district-based initiatives can use his or her influence, power, and authority to help shape critical approaches to science education reform efforts (see Figure 2). Changes in educational practices rarely happen quickly, and pervasive and permanent changes rarely come from without. Successful programs involve many participants—including teachers, science coordinators, and administrators—playing different roles (NRC, 1996).

The principal who recognizes the crucial importance of school-and district-based initiatives can use his or her influence, power, and authority to help shape critical approaches to science education reform efforts.

Project Management Team

The project director of the ETSU summer institutes works closely with each layer of the project and serves as a vital link among the ETSU science faculty, local education agencies (LEAs), and the Project Management Team (PMT). In addition to the project director, the PMT consists of central office curriculum directors with decision-making authority, school principals, university science professors, and middle and high school science teachers, all of whom represent participating school districts. For nine months before each of the summer leadership institutes, members of the PMT meet quarterly to establish an agenda based on the needs assessment described below. The PMT designs the summer institutes and follow-up academic year professional development activities for the subsequent year. The PMT meets throughout the academic year to realize the project goals and build leadership capacity.

To examine student learning more closely and to collect evidence to inform the professional development process, institute participants, working in conjunction with the PMT, evaluate science lessons from their classrooms, explored questions and concerns about their students' learning and analyzed data from classroom assessment and end-of-course exams. This data analysis assisted the PMT and the teacher participants in identifying, prioritizing, planning, organizing, and making resource allocations for the professional development activities during the summer leadership institutes and the professional development activities during the academic year. As the ETSU professional model has matured, this data analysis has become increasingly important in informing both the professional development process and the teaching process.

Science Standards

According to the National Science Education Standards, "Learning science is something that students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others" (NRC 1996, p. 20). This approach is consistent with the East Tennessee State University Science Partnership Model, which considers students as active constructors, rather than passive receivers, of knowledge. Accordingly, students who bring their own view of the world into the classroom are encouraged to be engaged in the learning process. An important role of the teacher in this process is to create learning environments that allow students to

Figure 2: Approaches principals can take to support science education reform

Creating an instructional organization and climate that are conducive to school-based initiatives and innovations

Creating a clear vision of effective science teaching and learning, as well as goals that reflect content knowledge

Providing high-quality instructional materials that support a coherent presentation of important science concepts

Providing the necessary resources to make materials available to all students

Supporting alternative assessment methods that more accurately measure students' deep understanding, not just short-term recall, of science ideas

Supporting ongoing and long-term professional development of science teachers

Maintaining class size appropriate for the science discipline

Hiring new science teachers who are well grounded in science content, the processes of science, and learning theory

Supporting environments in which all students can learn science in some meaningful way

Communicating to teachers about research and innovative practices outside the school district

Allowing teachers to visit innovative science programs both within and outside the school district

Encouraging grant proposal writing to supplement school resources

Pairing induction teachers (new science teachers) with compatible mentor teachers in an effort to provide neophytes with role models at the beginning of their teaching careers

engage in problem solving and higher-order thinking so they can integrate information and build on their own understanding of a particular topic or idea (Anderson, 1998).

School-Based and Job-Embedded

When university faculty make their monthly school site visits during the academic year, they can accomplish two other objectives. They can gather information from teachers and principals and provide support to participants as they implement the professional development model. During the visits, model lessons are presented. Visits, however, do not provide the continuous networking inherent in the professional development model. The project model gives participants an opportunity to develop a networking force for improving middle and high school science teaching and learning in the participants' schools.

The model allows for several kinds of communication and networking between and among teacher participants, both within the classroom and across the science program. Teacher participants play the role of sensitive facilitators to establish a climate in which team members build mutual trust and share what they have done in their classrooms. The professional development model allows for the teachers to network in the following ways:

- Members of the science department meet throughout the academic year to discuss and share information and classroom feedback. During this time science teachers may elect to discuss content and methodologies or reflect on classroom events of that week. These meetings are also used by participants to share information from the summer institute with their colleagues.
- Science teachers in targeted districts observe their colleagues teaching a science lesson using the methodologies and content gained during the summer institute. Teachers share feedback from the lessons and reflect on the appraisal of the lessons taught. These sessions provide insight, solutions to problems, and support and encouragement to one another. Teacher participants receive a great deal of input from one another and benefit form sharing of ideas from their own classroom experiences.
- Teacher participants lead professional development sessions for their colleagues during the school year.

- Principals in participating schools meet with science faculty in their schools to provide information and resources concerning science teaching and learning and to reduce barriers that impede effective science teaching.

Major rewards of the program have been the personal renewal of middle and high school science teachers' expertise in science content and pedagogical skills, increased focus on active student participation and student learning, frequent teacher-teacher and teacher-student interaction, and implementation of lessons that provide an accurate portrayal of disciplinary knowledge, nature, and structure.

An important outcome of this model has been continuous and ongoing professional development opportunities for participating school districts to track and document change systematically. These data revealed the following outcomes for participating schools:

- Planned and systematic scheduling of professional development in each participating school.
- Professional development that accommodates participants' needs and is embedded in practice.
- Networking of stakeholders (teachers, curriculum supervisors, principals, and university staff) who are responsible for student achievement in the training process.
- Sharing of support materials and resources in support of the science program.
- Using student data to inform professional development decisions.

Teacher Participant Evaluation Results

Teachers who were selected for the program and attended the twelve-day Summer Institutes in the summers of both 2006 and 2007 participated in a variety of assessments. The two cohorts of teachers participated in the Summer Institutes preceding implementing their newly learned skills in their classrooms during the 2006-07 and 2007-08 school years. Data from the 2007-08 cohort is reported first as the design included both ETSUSP and comparison groups. Teachers participating in the comparison group were selected who taught at the same schools as the ETSUSP treatment teachers, but did not participate in the project. The same number of non-participating teachers (total of 23) was selected from each school as the number participating. The comparison teachers were also volunteers as were the ETSUSP treatment teachers. Both ETSUSP and comparison teachers were given a 45-item multiple choice test based on the workshop content that was developed by the ETSUSP faculty who taught at the workshop. Previous analyses indicated the test was reliable and content valid. ETSUSP teachers were given the test on the first and last days of the summer workshop. The comparison teachers were given the pretest and twelve days later completed the posttest so the time interval was the same for both groups of teachers.

Three separate analyses were run. First, a number of descriptive statistics were computed. Second, an independent groups t-test was run on the pretest results between the ETSUSP (treatment) and comparison (non-ETSUSP) groups to determine if there were any knowledge differences between the two groups at the outset. Finally, a repeated measures ANOVA was run to determine if the treatment group demonstrated learning from the summer workshop at a rate different from the comparison group.

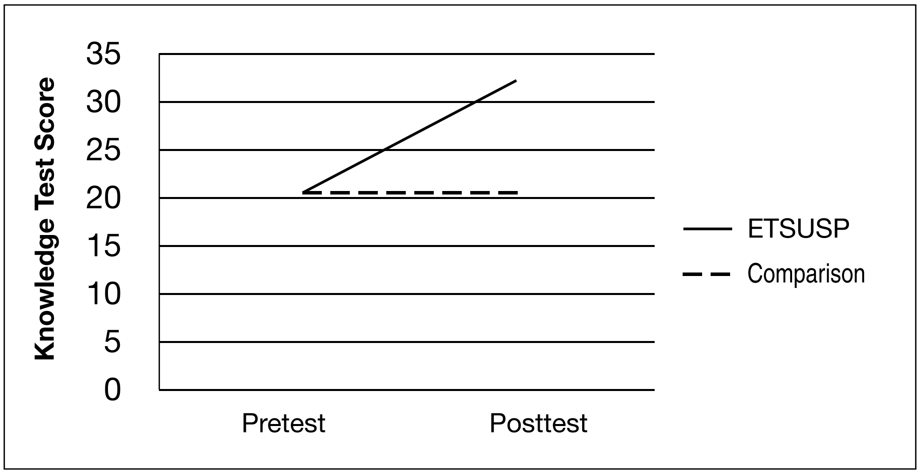
The pretest mean of the ETSUSP group was 20.04 (*SD* = 7.16) and the pretest mean of the comparison group was 20.35 (*SD* = 7.88). That difference was non-significant (t (44) = -.14, p = .892). The posttest mean of the ETSUSP group was 32.09 (*SD* = 5.48) and the posttest mean of the comparison group was 20.13 (*SD* = 8.07). However, the ETSUSP group's gain was significantly larger than that of the comparison group (*F* (1, 44) = 87.8, p < .001; partial eta square = .59) with an effect size gain in the ETSUSP group of 1.68. This is illustrated in Figure 3.

Since NCE scores are interval in nature, a repeated measures analysis of variance was used to analyze the results.

Thus, we can attribute the knowledge gain of the ETSUSP teachers to the workshop as those teachers demonstrated a major gain in knowledge while the comparison teachers did not show any gain at all.

The 25 teachers who participated in the 2006 ETSUSP Summer Institute also demonstrated statistically and practically significant knowledge gains, but there was not a comparison group. However, the 2006-07 cohort did participate in a number of follow-up activities during the fall of 2006. The pretest score mean for the 21 teachers who participated in the summer institute and had both pretest and posttests scores was 51.7 and the

Figure 3. Comparison of Pre and Post Teacher Knowledge of 2007-08 Cohort



posttest mean was 73.7. This gain was statistically significant (t (20) = 15.64, p < .001) with an effect size of 2.29. This means that the gains were statistically significant (less than one chance in 10,000 that this level of gain occurred by chance) and practically or meaningfully significant with the average gain being more than two standard deviations. Using any effect size rule of thumb, this increase is, from a practical standpoint, very meaningful. In addition, all 21 teachers showed impressive pre- to post-test gains. They ranged from 9.2 percentage points to 34.8 percentage points with an average of 20.0 percentage points.

As part of this follow-up, the teachers responded to a seven-item Likert-type Rating Scale Form (patterned after the summer Formative Rating Scale Form). It was administered to all 25 participating teachers during fall 2006 to determine their satisfaction with the follow-up and follow-along involvement of science faculty, the graduate assistant, and the project director. The participants were asked to respond to each of the items as they perceived the quality of assistance received by university personnel. The instrument was administered to the participants during the months of October, November, and December, 2006. The results of this survey are presented for each of the seven areas addressed by the questions.

- Ninety-two percent of the teachers indicated that the instructional materials used by the university personnel when visiting the classroom were effective. The other 8% indicated they were "somewhat effective."
- One hundred percent of the teachers agreed that the lesson plans taught by the university personnel were well-organized and geared to the level of their students.
- Ninety-six percent indicated that the university personnel shared appropriate science content background information and teaching strategies that were age appropriate for their students and the other 4% indicated they were "uncertain."
- Eighty-eight percent of the teachers agreed that the university personnel placed an emphasis on problem-solving and higher-order thinking skills rather than on exclusively factual information. The other 12% were uncertain.
- Eighty-four percent of the teachers agreed that the university personnel demonstrated how project materials and project resources could be presented or shared with peers. The other 16% were uncertain.
- One hundred percent of the teachers agreed that the instructional methods and procedures demonstrated by university personnel helped them in learning more effective methods of delivering their science curricula.
- One hundred percent of the teachers rated the overall effectiveness of university personnel visits to their classrooms as more effective than the in-service provided by their school systems.

Teachers from the 2006-07 cohort not only completed the pre and post knowledge tests and responded to the Rating Scale, but each of the 25 teachers' classrooms were observed and rated by the observer. Each classroom was rated on basic science, the level of learning, definitive curriculum, and effective instruction as "on target," "near target," or "not on target." Based on the observed results, the following summaries are provided:

- Eighty-eight percent of the classrooms were rated as "on target" and 12% were rated as "near target" in terms of the basic science content of the lesson.
- Sixty-eight percent of the classrooms were rated as "on

target" and 32% were rated as "near target" in terms of the level of learning that was taking place.

- Eighty-eight percent of the classrooms were rated as "on target" and 12% were rated as "near target" in terms of the how definitive the curriculum in the classroom was.
- Seventy-two percent of the classrooms were rated as "on target" and 28% were rated as "near target" in terms of the effectiveness of the instruction.

ETSUSP teachers have reported meeting with peer teachers 60 times, with a total contact time of 32 hours. Participating teachers reported they have observed their peer teachers a total of 15 hours. Project materials shared with peer teachers ranged from microscopes to sensor probes. The most common items shared with peers represented kits, probes, hard copies of activities/lessons, periodic tables, etc. Participating teachers reported peer teachers observing their classes a total of six times. In all cases, the teachers rated the lessons as excellent. Each of the project teachers reported teaching an average of 13 lessons each month using materials or ideas gained from the summer workshop. When asked to describe the methods/strategies used to teach these lessons, they listed the following: hands-on, minds-on activities, inquiry investigations, lecture and discussion, library work, writing lab reports, and scaffolding activities techniques with students having problems learning science concepts. Nine of the project teachers reported meeting in after school science in-service sessions with their peers.

Although teachers are integral to the science education reform process, they should not be placed in a position of carrying the entire load of science education reform.

It is clear that participating teachers gained significant knowledge, applied this knowledge in their classrooms, and the lessons were perceived as effective by the teachers. Based on the classroom observations, it is also clear that the material taught in the summer workshop and provided through the follow-up visits were being implemented in the classrooms.

Student Evaluation Results

Ultimately, the success of any educational program is determined by student performance. The results presented in this article are for students whose teachers completed the Summer Institute in 2006. Student performance data were collected for the students in each of the cohorts and the results have been consistent, but results from only one year are presented here. Students in Grades 5-8 whose teachers participated in the ETSUSP Program were given the Tennessee Comprehensive Assessment Program (TCAP) Achievement Test each spring. Thus, by using the spring to spring scores for each student, we can examine performance using a pretest to posttest design. Students in Grades 9-12 must complete the Tennessee end-of-course tests (called Gateway tests) at the completion of biology regardless of what year they complete the course. However, their Science Subtest score from the TCAP in Grade 8 was available so this was used as the pretest score. Thus, a pretest/posttest design was used for students in Grades 9-12 who took biology.

Again, for students in Grades 5-8, scores on the Science portion of this test from the prior spring were used as the pretest and scores from the spring test given at the end of the experimental year were used as the posttest in establishing the pretest/posttest design. Two types of outcome scores from these tests were used to evaluate student performance—Normal Curve Equivalent (NCE) scores and their Proficiency rating (Proficient or Not Proficient). Since NCE scores are interval in nature, a repeated measures analysis of variance was used to analyze the results. The pre and post scores were the repeated measures and "Grade" was the other variable. This allowed the evaluation of significant growth at each level. Effect sizes are also reported at each grade level. It should be noted that NCE scores are derived from percentile ranks and a student who maintains his or her place in a norming distribution will stay at the *same* NCE score from pre to post. Therefore, any increase in a student's NCE score indicates an improvement of their position within his or her norming group. Thus, a significant increase of the group in terms of NCE scores would represent a positive movement from status quo. In addition, the percentage of students who move from the "Not Proficient" category to the "Proficient" category were compared using a chi square statistic. Descriptive results were provided by grade and gender. It should be noted that these data came from Tennessee's assessment program which has been recognized as a model for the country.

The scores of students in Grades 9-12 who took the Tennessee end-of-course tests (called Gateway tests) at the completion of Biology regardless of what year they completed the course were compared to their Science Subtest scores from the TCAP in Grade 8. Thus, a pretest/posttest design was also used for ETSUSP students in Grades 9-12. Again, both NCE results and the level of proficiency were collected for each student. A confidence interval was computed for the NCE results and the proportion of students in each proficiency category (Not Proficient, Proficient; Note, Advanced scores were collapsed into Proficient) was computed.

The results for Grade 5 are shown in Table 2.

The percentage of students who were proficient decreased slightly from 87.3% to 84.5%. This represents five students who moved from the "Proficient" to the "Not Proficient" categories. However, the average gain of 4.4 NCE points was statistically significant (t (180) = 4.24, p < .001) and had an effect size of .29. Since NCE scores would not be expected to change if a student just maintained his or her place in the norming group, these results demonstrate that students in the program treatment, as a group, improved their positioning among students in the overall norming group.

The results for Grades 6-8 are shown in Table 3.

The percentage of students who were proficient did not change. However, the average gain of 1.3 NCE points was statistically significant (t (1206) = 3.22, p < .001) and had an effect size of .07. Since NCE scores would not be expected to change if a student merely maintained his or her position in the norming group, these results demonstrate that students in the program treatment improved their positions on the average as compared with students in the norming group.

The Results for Grades 9-12 are shown in Table 4.

Ninety-nine and two-tenths percent of the 252 students were proficient on the posttest. This is nearing the 100% goal of No Child Left Behind. If the posttest NCE score were compared with the norming group average of 50, the posttest average is significantly above the norming group (t (176) = 4.7, p < .001). While this performance cannot be attributed only to the ETSUSP intervention, it is unlikely that this level of performance would have been observed without the ETSUSP intervention.

Summary

Although teachers are integral to the science education reform process, they should not be placed in a position of carrying the entire load of science education reform. Science teachers will need to work within the context of policies that are "supportive of good science teaching" (NRC 1996, p. 27). The principal plays a role in the process of developing and sustaining healthy science education programs and practices by supporting professional development. In this way, the principal can create opportunities for teachers to become actively engaged in curriculum development and assessment as well as in setting standards and evaluating practices—processes that allow teachers to take more control of teaching practices. To a large extent, the desired changes in science education have not been fully realized because they have not been totally effective in influencing the classroom. Moreover, change that is

Table 2. Student Performance in Grade 5 Science, N = 181

	Pretest	Posttest	Change
Percent Proficient	87.3%	84.5%	-2.8%
Mean NCE Score	54.0	58.4	4.4

Table 3. Student Performance in Grade 6-7 Science, N = 1215

	Pretest	Posttest	Change
Percent Proficient	80.6%	80.6%	0.0%
Mean NCE Score	53.8	55.1	1.3

Table 4. Student Performance in Grade 9-12 Biology, N = 252

	Pretest	Posttest	Change
Percent Proficient	96.8%*	99.2%	2.4%
Mean NCE Score	NA	54.8	4.8**

*The percentage of proficient students on the Grade 8 TCAP was used as the pre measure.

**The change that is shown is the achieved NCE Score minus an NCE Score of 50, the norming group average.

championed by individual teachers and implemented in individual classrooms has a greater chance for success (Springhill, Reiman, & Thies-Springhill, 1996). Policies calling for change in practice have not always aligned with teachers' needs. Teachers have also lacked the resources to deliver an effective science education program. However, resources and funding are not enough; both teachers and administrators must play leadership roles in the creation and maintenance of an effective standards-based science education program.

While this program was for a selected group of teachers in a rural setting in Northeast Tennessee, these results demonstrate that an effective teacher professional development program with in-class follow ups with the participants can have an impact on both teacher performance and student learning. More study would need to be completed before it could be known whether this particular program could be implemented in other settings; the results suggest that the process is very promising.

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Michael Klentschy

Developing Teacher Leaders in Science: Attaining and Sustaining Science Reform

An argument is made that teacher leadership at both the system and school level is an important part of the science systemic process intended in science education reform. This article describes the design of such a professional development program, the challenges addressed, and the impact on teacher leaders.

Introduction

The wave of reform that has swept across the United States over the last two decades has created a climate of change that requires school districts, schools, administrators, and classroom teachers to reexamine their core beliefs regarding teaching and learning. These reform efforts in one way or another all require systemic change. Bybee (1996) describes that as schools and districts plan for systemic change, they must consider changes in purpose, policies, programs and practices. Purposes relate to the general agreement on the need for science literacy for all; state and national science content standards are the policies that guide education toward those purposes. However, in order to move to students, programs need to influence practice. This is the only way that students will have improved opportunities to learn. The development of teacher leaders may be one of the critical links in this chain, one that can take purposes and policies and influence student learning through its impact on teaching.

The development of teacher leaders requires a different method of addressing the challenge of systemic reform.

The development of teacher leaders requires a different method of addressing the challenge of systemic reform. This method requires school districts to utilize an "inside-out" type of systemic reform. This type of systemic reform results in changes in the system because people are changing and are influencing the structures, procedures and the policies that guide teaching and learning. Fullan (1993) emphasizes the importance of all educators being change agents; that it takes all stakeholders to make change in order for systemic reform to happen. Nesbit, DiBiase, Miller, and Wallace (2001) suggest that in order for systemic reform to take place at the school level, teachers and principals must take on new roles. Therefore, it is critical to develop a mechanism to create a cadre of teacher leaders who will play an important role in this change process.

The *National Science Education Standards* (National Research Council, 1996) also recognize the importance of teacher leadership in several standards. While classroom teachers have defined roles and responsibilities, clearly defined leadership roles are required for systemic reform to take place. Program Standard-A indicates that responsibility needs to be clearly defined for determining, supporting, maintaining, and upgrading all elements of the science program. This means that the district or system must recognize the importance of leadership and create mechanisms for the development of teacher leadership. Teaching Standard–F establishes an expectation that teachers assume a leadership role in improving science programs. This will require districts and systems to develop mechanisms that will enable teachers to increase their ability to work with others to improve science teaching and student learning.

What Does Research Tell Us About Teacher Leadership

Instead of the traditional role of being receivers of change, teacher leaders will become key decision makers, and in the "inside out" view of systemic reform, become the owners of change and work with their colleagues to share that ownership.

In order to design a professional development program that prepares teacher leaders to assume leadership roles, those characteristics of leadership must be identified that are necessary for teachers to become the change agents for the systemic reform process and provide opportunities for teachers to lead at the school level. In order to attain school wide results Darling-Hammond and McLaughlin (1995) recommend that such professional development programs must consider a variety of elements that include the traditional elements of the deepening of content and pedagogy, but go beyond these traditional approaches to include adult development, problem solving, and collaboration. Other characteristics of teacher leadership development that should be considered are decision making, building vision, how to conduct and organize professional development, skills for team building, resolving conflicts, and problem solving (Loucks-Horsely, Hewson, Love and Stiles, 1998). Pellicer and Anderson (2001) report that teacher leaders also need opportunities to practice leadership. Klentschy and Molina-De La Torre (2003) suggest that in order for systemic change to take place, teachers need time for collaboration within and between schools in a system. Teacher leaders are the catalyst for this type of collaboration and need both the knowledge and practice base to facilitate this type of collaboration. Zinn (1997) reports that there are four key factors that must exist within the system to support the development of teacher leadership:

- a climate that is supportive of teachers as key decision makers
- principals or other administrators who are supportive
- teachers supporting each other
- a supportive relationship between colleagues.

It is critical to develop a mechanism to create a cadre of teacher leaders who will play an important role in this change process.

Informed by teacher leader research, a consortium of school districts in Imperial County, California recognized the importance of the development of teacher leadership as a key element in their science system reform efforts through a National Science Foundation Local System Initiative called the Valle' Imperial Project in Science (VIPS) more than a decade ago 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 Thompson, 2008).

Imperial County, California is a geographically isolated agricultural region of southeastern California bordered by Mexico on the south and Arizona on the east. It is one of California's largest counties in terms of area, but it is sparsely populated, and its residents are among the poorest in the state in terms of real income.

The students in Imperial County are predominately Hispanic English Learners, and most of them are eligible for the federal free and reduced price lunch program. There are fourteen districts participating in VIPS. Six rural single school districts; six districts have between three and six schools each; and two larger districts, one with ten schools, and the other with eleven. El Centro is the economic and administrative hub of the county, and the El Centro Elementary School District is the largest district serving K-8 students. El Centro is also the lead VIPS district. This countywide collaborative partnership also included San Diego State University, Imperial Valley Campus and the California Institute of Technology. This countywide collaborative partnership has remained in tact since 1996 and is currently a member of the California Mathematics-Science Partnership network.

The Valle' Imperial Project in Science recognized that the development of teacher leadership was needed at two different levels: 1) teachers on special assignment (TOSA) were needed to provide leadership at the system or consortia level; and 2) teacher leaders were needed at the school level to become liaisons between the consortia level and the school level and to help lead the reform efforts in their individual schools. The VIPS leadership was challenged with the question of what should a professional development program look like to create a dual level of teacher leaders possessing the knowledge and skills to bring about and sustain the changes needed to attain the initiative's goals.

The Teacher Leadership Professional Development Model

The development of teacher leaders at both of the school and system levels required the VIPS leadership to carefully craft a professional development design that addressed the differences in roles and responsibilities that would be required at each of these two levels. When the science reform initiative began there were no existing teacher leadership development programs in the region for science or any other curricular area to draw upon for teacher leadership professional development program design. Therefore, a new model was needed. After carefully examining the scale up design of the science reform initiative, the VIPS leadership started with the program design to develop teacher leadership at the system level. The scale up design of the science reform initiative started with the establishment of three pilot schools. These pilot schools would become the starting point for the implementation of the science reform initiative. Thus, teacher leadership at the system level would be needed to support the teachers at these three pilot schools in the early phase of the scale up. Teacher leadership at the pilot school level would also be developed during this early phase of scale up. The design was aligned to scale and would expand as the scale of the science initiative expanded over time.

A TOSA was hired by the initiative six months prior to the scale up at the three pilot schools. The TOSA had a background in science education, was enthusiastic, but had little experience in leading professional development or in mentoring and providing collaborative support to other teachers. The TOSA became an active member of the local VIPS leadership group including the university partners at San Diego State University, Imperial Valley Campus, and at the California Institute of Technology. The TOSA also became a collaborator in the development of teacher leadership at the school level. In order to prepare the TOSA to take on this role and the associated responsibilities, they were released for a month and actually job shadowed a TOSA in another reform initiative, Project SEED in Pasadena, CA. This job shadowing provided the TOSA an opportunity to learn on the job what a TOSA does and how they support teachers. In addition, the TOSA participated in several workshops at the Exploratorium in San Francisco, California. These workshops were designed to prepare teacher teachers to lead systemic change, experience immersion in inquiry, and plan effective professional development. The value added dimension of these two experiences also afforded the new TOSA to immediately become part of a larger professional network of educators all working in science reform from across the United States.

In the early phase of scale up, the development of teacher leadership at the three pilot schools was also important. Teacher volunteers at these pilot schools became the first cadre of school level Lead Teachers. The professional development was designed to meet the growing needs of teachers to move along three distinct professional growth continua described by Berlinger (1994); content knowledge, pedagogical knowledge, and student learning knowledge. In fact, in a standards based environment, there was a fourth continuum or pathway that was also considered, pedagogical content knowledge (Marks, 1990). There was a belief by the VIPS leadership that professional development could be optimized when it was long-term, school-based, collaborative, focused on student learning, and linked to curricula (Darling-Hammond and Sykes, 1999. 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 was favorably received by teacher leaders. The VIPS leadership including the new TOSA worked with the Lead Teachers at the pilot schools in a collaborative model. Lead Teachers and TOSA's from Project SEED also mentored new Lead Teachers.

When the science reform initiative began there were no existing teacher leadership development programs in the region for science or any other curricular area to draw upon for teacher leadership professional development program design.

Lead Teachers became the liaisons and direct link between the science reform initiative and the classroom teachers. Individual school level and system wide professional development was implemented for all teachers at the three pilot schools with Lead Teachers participating in leadership roles, assisting and shadowing the TOSA and the Lead Teachers from Project SEED. This process lasted for a period of three years.

During this period of time, VIPS leadership recognized that the next level of scale up would encompass forty-two schools, not just three. Additional TOSA's would be needed to provide training and collaborative support to thirty-nine new schools entering the science reform initiative. A new cadre of Lead Teachers would need to be selected to become the liaisons between the initiative and their schools. Recognizing this need, one of the partner universities, San Diego State University, Imperial Valley Campus (SDSU-IVC) launched a new Master's Degree program in Curriculum and Instruction with a Specialization in Science Education. The program focused on the development of the same four pathways of teacher development as the professional development design of the teacher leadership development program of VIPS. Twenty-five teachers began the program and twenty-two completed it. This group of teachers along with the Lead Teachers from the three pilot schools provided VIPS with the pool of teacher leaders needed for the scale up to forty-two schools.

With scale up to forty-two schools, there was also a scale up in the number of TOSAs from one to three. The first TOSA became the Project Director and three new TOSA's were selected. Two of the TOSAs came from the pilot schools and one from the Master's Program at SDSU-IVC. This provided an excellent career pathway for teacher leadership. The initial training of these new TOSAs was similar to the training received by the first. Job shadowing of existing TOSAs in Project SEED and professional training at the Exploratorium were again utilized. In addition, these new TOSAs became involved in science education professional networks through state and national professional organizations. Each of these TOSAs and the Project Director were assigned to a group of schools to provide collaborative support to Lead Teachers and classroom teachers through regular campus visits. In addition to these responsibilities, the TOSAs and Project Director were involved with planning and leading professional development for more than 1200 classroom teachers now participating in the science reform project.

A unique element of lesson study is that discussions are data based, and connected to actual lessons.

A seventy hour professional development program was designed for new Lead Teachers. The VIPS leadership recognized that professional development should be integrated into the regular practices of teachers.

Since the 2000-2001 school year several iterations of the initial professional development design for Lead Teachers have evolved. A critical component of this evolution was the creation of a plan of action to transform practitioner knowledge into a professional knowledge base for both TOSAs and Lead Teachers and then have both groups work at the school level to do the same with classroom teachers. The core of the professional development design to attain this goal has always included five dimensions: 1) a focus on working with adults and polishing professional development presentation skills as outlined by Garmston and Wellman (1999); 2) deepening teacher pedagogical content knowledge related to the science content students need to know (Vanosdall, Klentschy, Hedges and Weisbaum, 2007; Klentschy and Thompson, 2008); 3) creating reflective practice through collaboration, lesson study, and the examination of student work (Stigler and Heibert, 1999; Heibert, Galimore and Stigler 2002; Amaral and Garrison, 2004); 4) literacy connections designed to assist students in making evidence-based explanations of their science experiences through science notebooks, talk, and embedding English Language Development strategies into the context of science content instruction (Amaral, Garrison, and Duron-Flores, 2006; Duron-Flores and Macias, 2006; Klentschy and Molina-De La Torre, 2004; and Klentschy, 2008); and 5) scaffolding inquiry (Klentschy and Thompson, 2008). These sessions were designed to provide a variety of pathways for teacher expertise development and yet at the same time focused on three outcomes:

1. 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
2. To be exposed to alternatives
3. To develop situational judgment to know when to employ which method

These three outcomes were based upon a belief that 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 or practitioner knowledge 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. The explicit representation of the knowledge to be learned through the standards movement serves as an organizational framework for all elements of instruction, including the determination of learning sequences, the selection of teaching methods, the specific activities required of learners, and the evaluative assessment of student learning success.

Practitioner knowledge is useful 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
- Recording what is learned in a way that is shareable with other teachers

This form of knowledge is linked to practice because it is created from the problems of practice and connected to the process of teaching and learning occurring in classrooms.

Lesson study and other such efforts to promote professional learning communities at the school level have proven most effective to develop practitioner knowledge by including the sharing and dissemination of results among participants working in collaborative groups led by Lead Teachers and TOSAs. A 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 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 practitioner knowledge in that the group members work on a problem that is directly linked to their practice.

Over the last several years**,** almost 100 classroom teachers and 6 TOSAs have participated in the Lead Teacher professional development program.

Challenges and Outcomes

With any science reform initiative there are unexpected challenges as change takes place in real time. VIPS leadership anticipated four challenges in the development of Lead Teachers: 1) teacher mobility; 2) competing priorities; 3) a national focus on reading and mathematics; and 4) time. All four of these challenges surfaced over the last decade and a plan of action was in place to address each.

Teacher mobility is a fact of life in public education. Teachers change grade levels and schools, and some leave the profession for a variety of reasons. To address this challenge, VIPS leaders recognized that a pipeline of Lead Teachers and possibly TOSAs**,** needed to be developed over time. A new cadre of Lead Teachers was recruited by TOSAs each year to fill this pipeline. The VIPS leadership established a goal of having at least two Lead Teachers at each school in order to address the challenge of teacher mobility. While this goal has not been met at every participating school, a significant number of schools have at least two teachers who have participated in the Lead Teacher professional development program.

The national focus on reading and mathematics instruction and student proficiency levels required by states and the federal government have reduced the emphasis placed on science instruction and science professional development in many parts of the United States.

In an era of standards, assessment and accountability, several new initiatives have been created at the state and federal level. In many cases, these initiatives have a leadership development strand or requirement. Thus, the recruitment of potential new Lead Teachers for science may be competing for the same teachers with other initiatives. To address this challenge, VIPS leadership conducted several awareness sessions for district administrators and school principals. These awareness sessions centered on the notion that science was the perfect content area to address the needs of students and teachers based upon the principles of how students learn most effectively - activating prior knowledge, teaching to the big ideas, and utilizing metacognitive approaches to teaching and learning (National Research Council, 2005). The principles of student learning were deeply embedded into the five dimensions of the Lead Teacher professional development. The awareness sessions for administrators demonstrated the transfer of these principles to other reform initiatives, thus increasing the support by administrators for the science initiative.

The focal point for the creation of teacher leaders in science requires districts and systems to develop mechanisms that will enable teachers to increase their ability to work with others to improve science teaching and student learning to accomplish the goal of scientific literacy for all students.

The national focus on reading and mathematics instruction and student proficiency levels required by states and the federal government have reduced the emphasis placed on science instruction and science professional development in many parts of the United States. To address this challenge, VIPS leadership recruited several reading coaches as science Lead Teachers and also conducted several awareness sessions for school reading coaches and mathematics specialists. Again, the three principles of student learning identified by the National Research Council (2005) were used as the focus of these sessions. Reading coaches soon recognized that science was a perfect content area to apply the communication skills of reading, writing, listening, and speaking. The mathematics coaches also recognized the importance of application of mathematics skills and the thinking strategies embedded into the science instruction. As a result of these efforts, there is greater collaboration at schools with TOSAs, Lead Teachers, reading coaches, and mathematics coaches, all working together to address the need to create a change in culture and teaching practice.

Time still remains a challenge. Many teachers feel pressed to cover required content. The awareness sessions for administrators and the inclusion of reading coaches and mathematics coaches have helped somewhat to address this challenge, but the challenge of time still remains an issue.

There have been positive outcomes for the TOSA and Lead Teacher professional development program. This leadership development program has become an important career pathway for the former participants. One of the TOSAs is now the Project Director for the science program. Another TOSA is now a principal. A third is now an assistant principal. Several of the Lead Teachers have become reading coaches at the school level. Two have become principals. Five are working in curriculum leadership positions at the district and county level. Three have become new TOSAs for the science program. The leadership training for each of these teachers has provided them with the ability to succeed in these new positions.

The other significant outcome for the leadership development program has been the creation of a strong cadre of site based leaders in science. This cadre has been instrumental in influencing teaching practice in their schools. One of the major goals of the science reform initiative was to create such a base.

Connections to Student Learning

While it is difficult to draw specific causal relationships between the development of teacher leadership and increased student achievement, Lead Teachers have been instrumental in assisting VIPS leadership staff in redesigning curriculum and practice designed to do so. VIPS leadership have been working on redesigning and realigning science curriculum to better match state science content standards and to utilize best practices for student learning. Lead Teachers were involved in focus groups to provide feedback to the VIPS leadership as scaffolded guided inquiry (SGI) curriculum replacement units were developed and field tested. The impact of the SGI replacement units on student achievement were the focal point of a three year longitudinal research study conducted in Imperial County and in Wake County, North Carolina. The data from these studies indicated that these SGI replacement units and teacher practice contributed to significant increases in student achievement (Vanosdall, Klentschy, Hedges and Weisbaum, 2007; Klentschy and Thompson, 2008).

Implications for Reform

The focal point for the creation of teacher leaders in science requires districts and systems to develop mechanisms that will enable teachers to increase their ability to work with others to improve science teaching and student learning to accomplish the goal of scientific literacy for all students. School districts and systems must also recognize that for change to occur at the system or district level, it must occur at the school level. Therefore, a well designed program of teacher leadership development must be provided for classroom teachers to develop the leadership necessary to accomplish this task.

For students to reach the goals to which the standards require and that school districts wish to attain, teacher learning and change are essential.

Sustainability has been a challenge for many initiatives. Quite possibly the key to sustainability for any initiative is the degree that teacher leadership carries and sustains the initiative after the initial funding is gone. One effective way to measure the true impact of a science teacher leadership development program is to measure its impact on the participants.

One Lead Teacher leadership development participant shares:

> *"For the past three years, I have been actively involved with VIPS as a Lead Teacher and trainer. I wholeheartedly value the experience of working with the TOSAs and other Lead Teachers. I have grown confident in my public speaking, in my leadership skills, both inside and outside the classroom, and in assisting my fellow teachers better address the needs of our students."*

Another Lead Teacher concludes:

> *"VIPS has helped me develop a deeper understanding on the productive way to teach science to my students while awakening student interest through inquiry. I have acquired ELD strategies to use with my students and these strategies also apply to other subject areas, not just science. My training has allowed me to develop a stronger professional relationship with other teachers at my school. We have become a very dynamic group and all of us have a common focus. This training has also improved my presentation skills and has helped me evolve and relax while presenting, training or when working with my peers. Overall, this training has enabled me to grow in all aspects of my career and I have met great people along the way. I feel part of a larger network"*

Finally, a first year Lead Teacher states:

> *"As I reflect on my experience as a first year Lead Teacher I am amazed at the growth that I feel at a personal level as well as at a professional level. Being involved as a VIPS Lead Teacher opened my eyes as to the importance of the lesson study process. This process has enabled me to work closely with the other teachers at my grade level to become more collaborative and reflective in our teaching. I feel much more confident in all of my teaching as a result of this experience."*

For students to reach the goals to which the standards require and that school districts wish to attain, teacher learning and change are essential. This requires a different method of addressing the challenge of systemic reform. This type of systemic reform required must address changes in people within the system because people influence the structures, procedures, and the policies that guide teaching and learning. The development of a strong cadre of teacher leaders at the both the system and school level are an essential element in this process of change. The importance of teacher leadership to the change process should not be overlooked as school districts plan and implement science reform initiatives.

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Anthony W. Lorsbach

A School District's Adoption of an Elementary Science Curriculum

The author describes how case study methods were used to understand the intricacies of curriculum adoption in one school district and the context in which an adoption decision was made. As data collection and interpretation commenced, understanding of the perceptions of the district stakeholders of their process of curriculum adoption became an emerging concern.

What is the process a school district uses to choose an elementary science curriculum? The process as stated on paper seems straightforward and objective. For example, agreed-upon criteria are used to evaluate textbook series. Many resources are available to assist in such a process: The National Academy of Sciences and National Science Foundation both offer resources to aid in the selection of curriculum materials, not to mention the National Science Education Standards and Project 2061 Benchmarks. However, many schools continue to choose curriculum materials that are considered dubious?

"At the local level, textbook adoptions are the primary routine in most districts for updating curriculum."

Tyson and Woodword (1989) report that "textbooks structure 75- 90 percent of classroom instruction," (p.14) yet few studies describe elementary science adoption processes by schools. Kelly and Staver (2005) assert that "there exists a dearth of curriculum adoption and implementation studies in the literature; consequently, far too little is known about what happens as science programs are implemented in schools" (p.27). Ball & Cohen (1996) described curriculum materials as "the stuff of lessons and units, of what teachers and students do" and describe curriculum materials as "part of the routine of schools" and "at the local level, textbook adoptions are the primary routine in most districts for updating curriculum," yet "the relationship between textbooks and teachers has rarely been taken up with much care or imagination" (p.6). Stein, Stuen, Carnine & Long (2001) examined statewide adoption practices and found that most research about the adoption process was published in the 1980s. Studies do exist which examine the quality of textbooks (e.g., Kesidou & Roseman, 2002), but recent research in elementary science adoption processes is limited, focusing instead on the implementation of new curricula (Cannon & Crowther, 1997; Kelly & Staver, 2005). This case study set out to examine one school district's elementary science curriculum adoption process and the context in which an adoption decision was made.

Methods

Case study methods were used to understand the intricacies of curriculum adoption in one school district. This study developed from an initial inquiry that sought reasons for River Valley's rejection of National Science Foundation-sponsored curricula in favor of a more traditional text-based curriculum. However, as data collection and interpretation commenced, understanding of the perceptions of the district stakeholders of their process of curriculum adoption became an emerging concern. The district curriculum adoption process became the "bounded system" (Stake, 1997) of this case study. As such the focus of this study is the adoption of an elementary science curriculum. It is not a "search for what is common, pervasive and lawful" but for "understanding of the particular case, in its idiosyncrasy, in its complexity (Stake, 1997, p.405).

The committee developed curriculum maps for each grade level.

Data Sources

Interviews.

Interviews were conducted with members of the Elementary Science Committee, including the two co-chairs of the committee. The Director of Elementary Education, the administrator in charge of the curriculum adoption, was also interviewed. Finally classroom teachers were interviewed to understand their perceptions of the adoption process. These interviews were transcribed for analysis.

Observations.

Observations of a textbook publisher's presentation was recorded in the form of field notes to gain an understanding of the decision-making process.

Documents

All documents pertaining to the adoption process were made available and became part of the data set. Documents included results from the Science Committee's own evaluation forms and feedback from teachers on the final two proposed curricula. Teachers' feedback was in the form of tabular results from a survey and open-ended questions. District grade-level curriculum maps developed by the Science Committee were also examined, as were publicly available documents relating to district demographics.

Data Analysis

A grounded theory approach as described by Strauss and Corbin (1998) was used for data analysis. Data were analyzed by a series of coding. Initial coding was used to develop common elements across the data. Subsequent coding led to provisional themes which guided further data collection. Themes reported here were central to many of the categories developed through coding and may have implications for a more general theory of curriculum adoption processes. The data are reported here in the form of a case study with a discussion of the emergent themes at the end of the chronological narrative. To the degree possible, participant quotes are used to tell the story; however, the story told here is my own, based upon my own interpretations of the data.

Setting

River Valley School District (pseudonym) is a K-12 school district with approximately 12,000 students employing over 1600 teachers and support staff with an approximate yearly budget of $90 million. The district has a student body which is approximately 75% White, 12% Black, 5% Asian/Pacific Islander and 5% Native American. The low-income rate of approximately 24% is based upon students from families who receive public aid, live in institutions for neglected or delinquent children, are supported in foster homes with public funds, or are eligible to receive free or reduced lunches (State of Illinois definition). The district has been growing for several years. Between 2006 and 2010 enrollment is projected to continue to increase at a rate of nearly 3% per year. Three new elementary schools and one new middle school are currently in the planning stages. Most district challenges relate to the growth of the district in recent years.

Terminology

The interchangeable use of the terms curriculum adoption and textbook adoption is deliberate and is consistent with the use of the terms by the participants. It can be argued that a formal curriculum can differ substantially from an implemented curriculum or the instructional procedures of classroom teachers; moreover, participants made no such distinctions. Similarly, River Valley came to see curriculum planning as akin to the textbook adoption process.

The Process

River Valley School District is located in Illinois, a state where curriculum adoption is entirely a local decision. The State of Illinois only regulates prices to be paid by districts by demanding curriculum developers file a sworn statement with the state indicating they are bonded and will not charge Illinois school districts more than other districts nationwide (Illinois School Code 105 ILCS 5/28-1) – requirements easily met by scores and scores of companies selling instructional materials.

Curriculum adoption, at the elementary level, was overseen by River Valley's Director of Elementary Education – an administrator from the central office who reports to the Assistant Superintendent for Curriculum and Instruction. The typical curriculum cycle in River Valley is 10 years. The process of adopting a new curriculum takes two years. Barbara, the Director of Elementary Education during the science curriculum adoption process, described the typical adoption of a curriculum as one year to discuss best practices, articulation and curriculum mapping and one year to choose the curriculum. Jean, a veteran third-grade teacher and one of the elementary science committee co-chairs, described the process for choosing the science curriculum:

> *This is usually a 10 year process where you have a textbook, like our last science books we had for 10 years. Two years before, in the eighth year of the series … you get a task force together and they try to have each grade level K-5 represented. They [central administration] try to have equal representation. They try to get the schools represented; they try to get the grades represented.*
>
> *I think we met 4 times the first year where you are getting some ideas for series and then you start to look at some of those series, you get a few samples sent in and then you narrow it down to maybe 2 or 3 and then those companies come, they have presenters come show you all the different stuff like they are selling their product.*

Abby, a veteran kindergarten teacher and the other elementary science committee co-chair recalled spending time during the first year of the adoption process examining the standards to be better prepared to select a curriculum.

Choosing the Committee

Barbara had primary responsibility for forming the elementary science committee and was pleased that Abby and Jean would co-chair the committee.

> *We are fortunate in this district we do have curriculum chairs at the elementary level. Two curriculum chairs for the whole district. It is a paid position but it is a miniscule amount of money and they don't get release time so they are still full-time classroom teachers and they just have more work to do and a small amount of money for doing it. But they are also extremely knowledgeable in the area of science because I will be the first to admit that science is not my area and the committee did look to those ladies for guidance in terms of: is this good material, is this grade appropriate, and they did a wonderful job of leading and guiding our committee.*

Filling out the rest of the committee was also charged to Barbara:

> *We sent out a call for volunteers and in some buildings we had more volunteers than we could use and in other buildings we had to shake the bushes a little bit and so I was allowed, with the permission of the Assistant Superintendent of Curriculum and Instruction, to cull the list in those buildings where we had more than we needed and I was allowed to shake the bushes I wanted to shake in those building where we needed more people, and I did so.*

Criteria for Choosing the Curriculum – Narrowing the Choices

More Depth – Less Breadth

The first year, the committee developed curriculum maps and planned the adoption process; it was the job of the committee to narrow the possible choices of curricula to two or three before seeking input from all teachers. Barbara and the Science Committee used the following criteria to select a manageable number of curricula to be presented to teachers.

The basic commitment of the committee, from the beginning of the program, was the idea of "more depth, less breadth." As Barbara described it:

> *One of the things that really came out [of school-level science meetings] was we were skimming lots and lots of topics and not giving depth and that was the other thing the elementary science curriculum can include more depth rather than breadth. That was a key issue.*

And Abby, a science committee co-chair:

> *We had originally thought that we wanted something that really went deep into one subject area at a time and we would really focus on that.*

Barbara did not want teachers to see components of the curriculum they were not going to receive.

Standards and Testing

While 'less breadth, more depth' was a consideration, participants' discussion of the criteria for choosing the curriculum was dominated by how well the new curriculum addressed, and used the language of the Illinois Learning Standards. Abby described her perceptions of the influence of state standards and tests:

> *They* [teachers] *wanted to hit some of those topics they know are on the ISATs* [Illinois Standards Achievement Test] *and these tests, that was a big*

concern and that was one of the things that as a task force that we looked through to see. So we would look at the series to make sure that those things were covered for the student, to make sure they had been exposed to those things before they took the test. So that was a big, big concern.

We first tried to talk about the standards and what we would look for in a new series. We really just wanted to make sure we hit all the standards and this one had textbooks directly written for Illinois state standards, which was really a big plus for that and I think that was why it was chosen.

But we wanted to make sure … and we were … you know originally we were saying we have to make sure we cover the standards so let's write this [curriculum maps to outline the standards]. But then when we found that they had the standards already in it we didn't need to do it that way. It was a lot easier to do. Nobody wanted it to be a unit that just followed a book, you know, we want to create our own curriculum and then find something to support it but we felt that this series really did incorporate all the different things we were looking for.

(Tony: Your text series was chosen over the others because of this standards issue?) *It really seemed that most of the teachers felt that that was the easiest way. You know there were a lot of appealing features to it but the standards were really a main focus for this. We really wanted to make sure the standards were right there for the teachers because that's been such an issue - our teachers teaching to the standards. We really wanted to get away from those lessons that teachers just were doing because they like to do them, which is still a problem, you know, it really isn't in their curriculum at all anymore, and so, that is really not following the standards at all, so we wanted something that really you could not not teach to the standards.*

At the beginning of the school year all teachers were required to attend training sessions.

Barbara, Jean and Sharon (a Science Committee member) confirmed in their interviews the primacy of the state standards and tests for the selection of the science curriculum. Barbara, a longtime administrator was surprised at how standards- and test-savvy her teachers had become:

And the teachers were more aware than I realized of even the kinds of questions on the Stanford Achievement … not the kinds of questions but the topics that were addressed on the Stanford Achievement Test and, again, I have been out of the classroom long enough that I couldn't tell you that in second grade they were asking these kinds of questions. In sixth grade these kinds of questions and in our series now we don't even get to this topic until this grade. We at least need a series that addresses it at the right time. And that was interesting to me that they knew that. It goes to show how test aware our teachers have become. Not just of ISAT but of Stanford Achievement Test as well. It's gotten out of control.

Copyright Date

The data revealed other criteria that were important to the committee at this juncture of the process. The adopted curriculum would have a ten-year lifespan. Given that lifespan, Barbara would only consider curricula with a copyright date of no more than two years from the time of adoption.

We eliminated things that had a copyright date that were two years out. Again, knowing that we had ten years that we were going to keep this, then we were down to five. That made it relatively easy.

Professional Development

Since many teachers in the district were not "content comfortable" in science the committee felt that ongoing professional development for the life of the text series in the district (10 years) was important and something that Barbara wanted in writing from the publishers.

… there also had to be a component of ongoing professional development. That was promised to our teachers. Not just for the first year, but for the life of the series because the other thing the teachers told our committee was we always get professional development the year that a series is adopted but as new folks come on they never get that and it is "figure it out on your own" and traditionally we have a series for 10 years. And when we are hiring 100 new

> *teachers a year, you have a lot of people who don't know how to use the materials.*

A teacher hired seven or eight years from the adoption year was entitled to free professional development from the publisher. The professional development is best described as an introduction to the curriculum materials. Only publishers willing to guarantee such professional development would be considered finalists for curriculum adoption.

Influence of Social Studies Curriculum Adoption

Finally, only textbook series were considered for adoption. Kit curricula such as Full Option Science System (FOSS), Insights, and Science and Technology for Children (STC) were *eliminated early on* (Barbara). The last curriculum adopted in social studies was a kit curricula and implementation of those materials did not go well. As Barbara put it:

> *We went the non-text route with social studies and it turned into a veritable nightmare and our curriculum committee said we are not going down that street. We are not going to be held responsible for a non-text curriculum. We are not going to get beat up the way those poor social studies people did.*
>
> *As we narrowed things down and knowing what their* [the Science Committee] *colleagues would and wouldn't use, they eliminated some things right off the bat and FOSS was one.*

Jean concurred:

> *I am a firm believer anymore in textbooks after seeing what happened with the social studies.*

Absence of Research and Outside Influences

None of the participants mentioned any reliance on research or resources related to science curriculum adoption or best practices. The participants said that Barbara had given them a notebook with articles to be read; however, when I asked Abby if she had any professional development related to curriculum adoption she said

> *There wasn't any formal training, [Barbara] just would say, okay, this is our goal, this is what we need to do, this is where we are headed, you know today we are going to do this. She really step-by-step led us through that process. She didn't lead us through the answers but what do we want to look for.*

Taking into consideration these main ideas—"more depth/less breadth," alignment of curricula to the Illinois Learning Standards, a copyright of no more than two years old, on-going professional development for new teachers, and no kit-based curricula—the committee narrowed the choice to two textbook series to present to all teachers for their input.

Making a Decision

Who's in Charge?

Barbara, as Director of Elementary Education at River Valley, was the administrator charged with curriculum adoption in all content areas at the elementary level. As such, the adoption of a science curriculum was her responsibility. She was hesitant to take too much credit for the process and decision:

> *They* [the science curriculum co-chairs] *did a wonderful job of leading and guiding our committee in that area—though again, we had passionate science people on the committee so they know what they were talking about and in that area I looked to them for direction. My role was really keeping the group moving forward and then doing the negotiation to make sure the teachers got what they needed.*

However other task force members characterize Barbara as very much in control of the process:

> *Barbara met with us, when we first started, she told us what we needed to look for. We had the Illinois Standards, we had the criteria that we had come up with that we thought would be a valid checklist, so as far as that training goes, yes. Outside people coming in and training us? No, but Barbara did.* (Jean)
>
> *I was on the task force and the chair but she really did all that behind the scenes and talking to the different companies and kind of leading us in the right direction.* (Abby)
>
> *I didn't really head the task force, she* [Barbara] *did that.* (Abby)
>
> *Barbara had it narrowed down to four or five before she brought it to the task force … We didn't go out there and search as a task force. Barbara brought just, I think there were five, in the beginning and the task force limited it to three and let the teachers choose among the three but it ended up being that no one wanted the third, which I don't even remember what it was anymore, she just, we just presented two to the teachers.* (Abby)

> *Barbara narrowed down the curriculum choices and I don't know what criteria she used. I imagine she would be helpful for you to talk to.* (Sharon)

No one seemed willing to take responsibility for the curriculum adopted. Barbara described herself as a facilitator, while committee members described her as making most decisions. All participants do agree that Barbara narrowed the curricular choices for the committee to examine by excluding for consideration any curriculum that had a copyright two years or older, lacked professional development or was kit-based. This effectively narrowed the choices to five similar textbook-based curricula. Barbara also provided the training the committee members received.

Preparations for Making the Decision

There was little professional development provided to the committee about science curriculum adoption. When asked about resources used and training provided Barbara replied,

> *We also really looked at the resources we had in place and talked about what's good about what we have, what's bad about what we have, what are the practices currently in place and what are we missing. The committee talked about what they were doing and then they went back and held meetings with their staff to provide input. We garnered some really good information from the staff in terms of what is good about science in River Valley and what is bad about science in River Valley. And that also helped in terms of giving us a little bit of direction of what we needed.*

The committee did not use resources from professional organizations or the research literature to become better informed about making curricular decisions. For example, Project 2061 has a curriculum evaluation tool (Roseman, Kesidou, S. and Stern, 1997) for choosing curricula that is aligned to AAAS Benchmarks (American Association for the Advancement of Science, 1993) and National Science Education Standards (National Research Council, 1996). It appeared that River Valley felt it had enough information about elementary science curricula to proceed.

There was preparation for evaluating the curricula. The committee developed curriculum maps for each grade level. These maps outlined what concepts would be taught at each grade level and what learning standards were addressed. The maps were to be used to assist in the curriculum decision making by finding which curricula most closely matched the curriculum maps. However, when the committee compared the initial drafts of their maps to the final two curriculum choices, neither curriculum matched up very well to the curriculum maps. So, the committee changed the curriculum maps. As Abby related,

> *Nothing matches something that you just create so we ended up doing it the other way around and it was a lot easier. But we wanted to make sure … and we were originally saying we have to make sure we cover the standards so let's write this now. But then when we found that they had the standards already in it we didn't need to do it that way. It was a lot easier to do. Nobody wanted it to be a unit that just followed a book, you know, we want to create our own curriculum and then find something to support it but we felt that this series really did incorporate all the different things we were looking for.*

And Jean:

> *We didn't really go and fill that in until we figured out which series because we wanted it to obviously match the series. It* [the curriculum maps] *really states what you're going to teach and what resources you have, so the curriculum really was written after the fact of the adoption. Originally we thought it would be the other way around—we would write the curriculum and then find a series that matched it.*

The Publishers

Five publishers met with Barbara and the Science Committee initially to present their textbook series (by this time a kit-based curriculum was out of the question). The publisher's presentation I attended, which participants concurred was very similar to the presentations of all the publishers, took place in a classroom that had been prepared by the sales staff. Rich-red tablecloths covered the classroom tables. Three tables on the periphery of the classroom held displays of the text and teacher resource materials, science equipment, and consumables that could be purchased and a display of the technology resources available. On a middle table was the fully-catered meal the publisher was providing the science committee: salads, sandwiches, bagels, muffins, cookies and drinks. While the teachers entered the three sales staff engaged in small talk, primarily about the food. After the teachers filled their plates the projector was turned on and the sales presentation commenced.

Without any significant professional development or curriculum guidance from the district for a number of years, a laissez-faire system evolved for elementary science: Teachers did as they pleased.

The sales staff began by telling the committee how the text series was based upon the professional literature, national standards and the research conducted in the development of the curriculum. The committee was then shown how the Illinois Learning Standards were integrated into the curriculum, which included the text, teacher resources, and online materials. How the publishers dealt with the reading abilities of students was discussed; not only the text series but the leveled readers that supplemented the text. In this case, small paperback books summarizing material in the text were available for students reading above, at and below grade level. Supplemental materials and technology resources were then presented. The committee was shown equipment tubs with place mats that had lined drawings of the equipment to be laid on them for an activity; audio readings of the text; parent resources; and technology resources such as an online text, test bank (including questions formatted to the style of the Illinois Standards Achievement Test), and movie clips. Finally, the teachers left with a tote bag full of gifts and preview materials from the sales staff.

A Problem

After presentations from the publishers the committee narrowed the selection to two text series that would be presented to all elementary teachers in the district. However, there was a problem: none of the curricula met the goal set by the committee that the new curriculum should represent more conceptual depth and less breadth. The eventual chosen publisher provided an answer. They told the committee that their curriculum was a spiraling curriculum—every topic was covered at every grade level and as students spiraled up the curriculum their understanding would increase.

> Tony: Did the publisher say, basically, here's this spiraling idea?
>
> Barbara: *Yes. Yes.*
>
> Tony: Is there a research base that the publisher used …
>
> *Barbara: Oh my gosh. They provided that information for us and again our teachers on the committee did their own research and brought it in …*

And Jean:

> *Tony: You know that's interesting because that really is not the way the National Science Standards talk about things. They're still saying it's a problem when it's an inch deep and a mile wide. We want fewer subjects taught in more depth and you have this curriculum not necessarily doing that?*
>
> *Jean: The National Standards want depth taught but no, this is not … it's following standards but it's not in depth from everything that I'm seeing. It's not in depth. I may go in depth on one subject that has been touched upon in K, 1, 2. Fourth grade will go in depth on a different subject that has been touched on 2, 3 you know? Fifth grade may go really in depth on something that they had in 2nd, 3rd, and 4th. So in that respect, yes, everything that we are teaching is not in depth but it is almost like a whet your appetite, so by the time, like, by the time kindergartners get up here, by the time they are doing the butterflies, they are like 'we saw that one' … well now we are learning that you need a male and a female butterfly and there's no way without a male and a female that the eggs can be fertile. They are not learning that in kindergarten, you get more added to it each year.*

And Abby:

> *The curriculum that we adopted really does not do that. It is the same topics year after year after year and don't go as deep. You go … you know it's a spiral, so we just keep going around. So really, if we did it again, I don't think we should spend a whole lot of time talking about … we spent almost a year talking about what we were looking for and then when we saw the different series, none of these were exactly what we had talked about so we kind of had to readjust what we were thinking.*

The committee did have to explain to teachers why the two text series chosen did not match the district goals of more depth:

> *In the beginning there was some discussion of a few teachers, especially in the second grade,*

> *that didn't like that there was so much to cover and they thought we agreed that we were going to go deeper and do fewer topics. I told them the knowledge would get in depth but that you needed the knowledge here to get to there. I think it is more developmentally appropriate as far as the depth goes.* (Sharon)

A Problem Solved

The publishers did ease the minds of the committee members by relating the spiraling curriculum to the state testing.

> *This is the first time ever that 3rd grade has ever had simple machines. Now, simple machines were always massively in-depth done in 5th grade. Okay, ISAT had simple machines on it and 4th grade takes it* [the ISAT science test]. *Now simple machines are in 3rd grade, it's in 4th grade, it's in 5th grade. But it is enough in 4th grade … we just touch upon it a little bit, they go into it deeper in 4th grade but they go into it deeper in 5th but they've got enough to … you know, answer the* [ISAT] *questions. It's exposed them enough so that they can figure out the answers on the ISAT. So, is the curriculum developed around the ISAT?* (Barbara)

Sharon concurred:

> *That was something Jean mentioned, that we were taking a chance before when the kids were taking their test in fourth grade they may not have had something, but this curriculum where you hit everything a little bit at least you are assured that everything is getting hit.*

Committee members' anxiety was further eased by how informed the sales staff were.

> *Tony: So the idea going in was that the curriculum would be in depth, more a mile deep and inch across than the other way around?*
>
> *Abby: Right and then as we got more into it the different series were really not doing that as much and we put our trust that they [the publishers] knew what long-term was more effective with the kids. We figured they had studied it.*

District-Wide Teacher Input

Having narrowed the curriculum choices to two text series the committee was ready to gather input from teachers. Barbara asked the publishers to make presentations to all elementary teachers, being adamant that the publishers only include in their presentation that which the district agreed to purchase. Barbara did not want teachers to see components of the curriculum they were not going to receive.

The committee developed an instrument for teachers to use in evaluating the final curriculum choices. Teachers would attend sessions and fill out the survey; the committee would tally responses of the surveys and use this data in their deliberations to choose a curriculum. No operational definitions were given for terms listed on the form. For example, "appropriate resources," "hands-on involvement" or "rubrics that are easily accessible" were not explained. There also was a proviso to teacher participation:

> *The teachers had to attend both* [presentations] *in order to give a vote. And, again, that was because of past practice where they didn't have to attend both they would attend only one and vote for the one, which seemed ludicrous to me. Though I have to tell you that created a furor within the district because it's the first time anyone said "you're not voting unless you're there for both. This was an after school activity so they were giving up their own time to attend and they weren't paid to attend and we're a pretty union strong district but we held fast on that issue and attendance was taken and your evaluation had to have your name on it and, um, we were very secure in the fact that only people who attended both of the showcases were allowed to provide input into which was actually the best series for our district.* (Barbara)

Teachers were upset that their opinions did not count unless they attended both presentations. It also meant that the committee had much less teacher participation.

> *The problem was when we put the survey out, it went after school and not very many people went. So there wasn't as big of a turn out for that and then later people were upset that they didn't get to vote.* (Abby)

Less than 30 teachers of a population of more than 260 elementary classroom teachers attended both presentations and whose evaluation data was tallied. There were 19 open-ended comments from the teachers. Most positive comments focused on two main topics: reading level, particularly the leveled readers and vocabulary (15 responses), and the equipment tubs for the activities (5 responses). Only one of the comments mentioned standards alignment but negative comments about both curricula included overly simplistic activities (2 responses), the number of topics to be covered (5 responses). One second grade teacher did remind the committee that the curricula presented strayed from their original intent:

> *I have concerns about both sets of science materials. First, I was under the impression that we had a goal to teach fewer science topics, but more in depth. Both of the science series we looked at include a little information about a lot of topics. I recall hearing about recent research on science education that supported the concept of fewer topics, more study in depth. Second, I know that our guiding principles for curriculum are to align our curriculum to state standards for our grade level, and to use resources that support the standards. With a science series that is so highly structured and "basalized" it will be almost impossible to avoid teaching lessons that are straight from the textbook, beginning to end. This gives me the sense of teaching the text, as opposed to teaching science and teaching children. I appreciate the work of the committee, and I appreciate the opportunity for all teachers to see the materials. I do wish there had been more opportunities for dialogue with all teachers throughout the process. Thank you.*

The new text series was chosen shortly thereafter. The series includes student textbooks; teachers' guides, including CDs with worksheets and assessments; supplementary (leveled) readers for students reading above, at and below grade level; each classroom gets a cart with tubs of materials to complete activities in the textbook; and a technology component which includes online access to the text by students and parents.

Curriculum Implementation

The committee was pleased to have a curriculum that specifically addressed the Illinois Learning Standards. After all,

> *You know you couldn't not teach to the standards. So a new teacher or something like that, rather than them looking at the standards and saying am I doing that and then looking at their lesson plans and trying to correlate, it was already done for them. If you taught the series you were teaching to the standards and you didn't really have to constantly be checking that and writing it in your plan book which ones you were covering because it was right there for you, which we felt might be more effective in making sure those standards were covered on a regular basis.*(Abby)

A New Mandate to Teach Science

> *We're telling them resistance is futile.* (Barbara)

After adopting the new text series the committee went back and completed their curriculum maps. The maps also include what topics should be completed every grading period. Jean:

> *Our science committee went through and did a curriculum guide, a curriculum map, and it says you are to cover unit A—chapters one, two, three and four in the first nine weeks. Unit B the second nine weeks and we mapped it out because if kids move they are not going to totally miss out and have an empty space because they didn't get plants and animals or something like that.*
>
> *I'm laughing to myself because this is going back to twenty years ago when a child moved from one school to another we used to have to know what page students were on in each subject, what book, you know and then we got away from it because everyone was doing their own thing and now it's sort of like going back to that.*

The idea is that with the new curriculum there are no excuses for not teaching science or for not keeping up. Barbara explains the new policy:

> *There is now a mandate in River Valley that you teach for the required number of minutes and before that was not the case. Before it was 'I teach science for 6 weeks, I teach social studies for 6 weeks'.*
>
> *We have principals who were also inserviced on the teaching of science by our committee. Here are the resources, here is the grade articulation and here are the things you should be seeing in the classroom, and here are the things you shouldn't be seeing in the classroom. And so our principals went out better armed than they had been before in terms of: these are the best practices in science and this is the inservice and these are the resources. The principals have gone back to their buildings and said, honestly folks, I expect*

> *to see this happening in my building. We spent the money so that you could do this, so that our students could experience this, I want to see it happen.*
>
> *They have the resources. They have the texts. The materials that they have are unbelievable. They have tubs for every single chapter. The tubs literally have little trays that have every single thing that a student is supposed to get. The kids from kindergarten on can go to their tub, lift out their tray, take it. It's there. No excuses for not doing the activities.*

The notion that a mandate from the district insisting science be taught regularly to the point of keeping up with a timeline for covering chapters in the district curriculum maps may have hardened teachers' resistance to the curriculum.

Professional Development

The publisher provided inservice sessions during the spring subsequent to the adoption. At these sessions teachers did receive their teachers' guides but it was months before teachers received their other materials. At the beginning of the school year all teachers were required to attend training sessions. The publisher returned with more inservice in the fall, providing sessions for each grade level. After these publisher sessions the Science Committee decided that more needed to be done.

> *What we are finding already is that our teachers respond better to professional development done by our teachers than they do by outside people. They want the outside people to come in and give them that first flush of information because they know we don't know that, but once that happens they really want it to be our people providing the professional development. They would rather us provide release time for our curriculum chairs or our technology people to really figure out the technology pieces or figure out what resources we have available in River Valley to supplement what's available through the series or the timing of the series or how best to use the series and then have them put on the professional development than have somebody come in and say this is the way you should be doing it in River Valley. Abby and Jean are looking at that piece and seeing how feasible it is. They do have two classrooms of their own and only so many days, and I know they really have people pulling at them.* (Barbara)

Eventually Abby and Jean did provide more inservice opportunities during the district institute days. These sessions were offered on a voluntary basis so many teachers did not have any professional development beyond what the publisher delivered the prior spring.

Principal Inservice

Barbara felt that in order for the implementation of the new curriculum to work, and to ensure that science was actually going to be taught that principals also needed inservice.

> *We have principals who were also inserviced on the teaching of science by our committee. Here are the resources, here is the grade articulation and here are the things you should be seeing in the classroom, and here are the things you shouldn't be seeing in the classroom. And so our principals went out better armed than they had been before in terms of: these are the best practices in science and this is the inservice and these are the resources.*

Jean described what her message to the principals was during the inservice sessions:

> *The other K-2 curriculum chair and I are showing, in the principal's forum, what they should look for when they are in a classroom observing and evaluating a teacher on science. And number one is they shouldn't have lessons going on for a month. If teachers spend more than a day or two on a topic they aren't doing it right.*

In essence River Valley believed that the new curriculum was standards-proof and an introduction to the materials was sufficient for teachers and principals to begin implementing not only the new science curriculum, but the mandate that science would be taught every day and teachers would keep up with the pacing outlined in the curriculum maps. It also was believed that these actions and policies would be sufficient to ensure not only that science was being taught but that activities in the text would be done in classrooms because the materials were readily available. Further, all these actions and policies would be policed by principals.

Implementation Problems are Encountered

The curriculum was adopted, the spring and summer workshops were completed, and teachers began using the new curriculum. Barbara and the Science Committee met with some problems with teachers' implementation of the curriculum.

"Love Lessons"

> *We have some who say "I don't care what we are supposed to be doing, I'm doing butterflies!"* (Barbara)

The first issue that Barbara and the Science Committee dealt with after teachers received the curriculum and curriculum maps was teachers' reluctance to give up their favorite lessons—what Jean referred to as their "love lessons." Without any significant professional development or curriculum guidance from the district for a number of years, a laissez-faire system evolved for elementary science: Teachers did as they pleased. Many teachers did not teach science at all, many others developed their own love lessons. While both groups were reluctant to change their practices, teachers who developed love lessons loathed giving them up and were vocal in their objections.

Jean and Abby, who were running the workshops for teachers, dealt with the issue repeatedly. Abby:

> *We really wanted to get away from those lessons that teacher just were doing because they like to do them, which is still a problem, you know, it really isn't in their curriculum at all anymore.*

Jean was known all over the district for her intensive butterfly unit (she had even created a butterfly garden at her school), spending over a month studying all aspects of butterfly biology as her third graders observed their caterpillars morph into butterflies. She knew she could lead by example:

> *But that was our big thing with science that you have to let go of those "love lessons." You know, I love butterflies but we had plants first. We did raise the butterflies but we used to spend a month doing it and nothing else. Well, this time we raised them and they were in the back of the room on the science table and the kids fed them and stuff and now, when we got to butterflies and the life cycle of animals* [a two-day lesson in the text] *last week it was like, okay, you remember this because we saw them go from the egg and you saw them go into their chrysalis and emerge like this, but I couldn't spend the time I used to. I had to be one of them I mean I'm on the task force; I'm the science curriculum chair. I had to tell the teachers: Yes, I'm doing butterflies but I'm not spending more than a couple days on it. They* [the butterflies] *are in the classroom so we can see the full, you know, three or four week process. But I am not spending much time on it.*

Barbara felt that once the mandate was given it was up to principals to make sure that teachers adhered to the curriculum maps:

> *Change is very difficult and when you have district this size. It is so easy to have a lone ranger and I know that we, in every building, and have one or two people who will say I'm just going to go in my room and do what I've always done. If you don't give principals the information that they need to help turn that around then you have one person, then two people, then three people, then four people and then this adoption can become a nightmare because you haven't provided the principals with the information that they need.*

A few months into the school year, Barbara felt as though the issue had been worked out:

> *We literally had teachers in tears. Tears. Very dramatic. We worked through it and all I can tell you is that there is more science being taught this year than there has been in the last few years.*

Reading Level of the Text

Interviews conducted in November with Jean, Abby, Sharon and several teachers implementing the curriculum revealed that many teachers were concerned about the reading level of the textbook. In fact, Jean conceded that the reading level of the text is difficult and does not expect her students to be able to read the text on their own.

> *The textbook is a little difficult reading so it's not something that I say to my third graders go read pages 7-10 and answer the questions at the end. I read it with them because some of my kids couldn't read it on their own.*

While variability in reading level among students in a classroom is common and to be expected, several teachers interviewed have abandoned the textbook as a source of text material and say they use the textbook only for graphics and activities. Sharon, a Science Committee member, is one teacher who relies almost entirely on the text series' leveled readers as a source of text. The leveled readers are small booklets supplemental to the text which are at three levels—below grade level, at grade level and above grade level. Sharon described her science lessons as breaking her students into groups to read the supplemental leveled readers and then following up the group readings with a discussion. Sharon also noted that group readings of the leveled readers were "a great way to get your 30 minutes of science in." In many classrooms it appears the science text of choice are the supplemental leveled readers.

Lack of Depth

The issue of breadth over depth in this "spiraling" curriculum did not go away with the implementation of the curriculum. There was a general sense of wonder in many teachers why the "more depth, less breadth," which was thought to be a primary consideration in the curriculum adoption process, was so obviously not a part of the adopted curriculum. Many teachers were concerned about the lack of depth not only as an issue of student understanding but as an issue of developing and satisfying student curiosity.

> *They want to stop on butterflies and do everything there is to know about butterflies but students are going to get the life cycle over and over and over and they are going to get the exact same butterflies again in second grade that they had in kindergarten, you know, and go deeper and deeper, but people just want to stop and spend time on butterflies. And the kids are interested and so, you know, you could go on and on and on because they are thrilled with it - so it is hard to keep moving through the curriculum. You have to look at those tabs - we taught some classes over the summer and tabbed the manuals to try to keep us on track, you know, you can look and make sure you are covering everything because we are a little nervous that the end of the book each year is not going to get hit. We are concerned about that. But that's not going to happen. We are going to get to the end.*

To expect that teachers will implement a new curriculum with workshop overviews from the publisher and science committee chairs, along with a mandate from the district is naïve given our current level of understanding of the change process.

The Science Committee believed that every teacher, if they spend the correct amount of time on each chapter, should get through the entire text by the end of the school year. If teachers spend too much time on a topic, they will get behind and the later chapters will not get covered. In other words, despite teachers' beliefs that some topics should be treated in more depth, such an idea is contrary to the newly adopted curriculum and district curriculum maps.

Eventually teachers' unease with the notion of a spiraling curriculum in which topics were covered quickly led to teachers' objection to a curriculum that was the opposite of "more depth, less breadth." Consequently, after the first year of implementation, the district arranged for teachers from each grade level to meet to develop units which treated one topic each quarter in more depth. These units were developed with materials outside of the newly adopted curriculum.

Discussion and Conclusions

Several themes emerged from this study have implications for the study of curriculum adoption processes at the district level.

Mandates did not work. The notion that a mandate from the district insisting science be taught regularly to the point of keeping up with a timeline for covering chapters in the district curriculum maps may have hardened teachers' resistance to the curriculum. And, when teachers found the policy was not enforced, many quickly reverted to prior practices. Other teachers, in an effort to keep up, settled for simply reading the supplemental leveled readers.

The criteria for choosing the curriculum were malleable. The National Science Education Standards (NRC, 1996) state that "curriculum frameworks should be used to guide the selection and development of units and courses of study" (p.211). This was certainly the intent of River Valley's Science Committee, until other criteria (copyright and necessity of a text-based curriculum) rendered it impossible. Instead the committee used the adopted curriculum to fill out the maps after the fact. Determining criteria for selection and using it throughout the adoption process should not be assumed. Decisions and circumstances led the committee to abandon one of it's top priorities: a curriculum with "more depth and less breadth."

Some criteria were specious. The criteria of copyright and textbook-based curriculum effectively narrowed the curricular choices to five (and then two) very similar options. These two criteria eliminated many curricula favored by the larger education community, limiting the district to traditional textbook options of very recent vintage.

Outside resources were not considered. The committee did not investigate the science education literature for guidance of the curriculum selection process; e.g., Project 2061's curriculum analysis tools (Roseman, Kesidou and Stern, 1997). Nor did the committee consider looking to science curriculum specialists outside the district. Looking outside the district, beyond meeting state standards, never occurred to Barbara or the science committee; though relying on the expertise of the sales staff was mentioned by participants.

Few individuals were involved in the selection process. Despite more than 260 elementary teachers less than 60 of these teachers were involved in any aspect of the adoption process (30 teachers were on the science committee and 29 attended both sales presentations allowing them to fill out a survey). Perhaps some teacher resistance was a result of a lack of participation in the process. If getting member buy-in is an important part of a change process then greater effort at wider participation was needed.

Curriculum-related professional development was cursory and much of it voluntary. To those familiar with contemporary models of professional development so few professional development opportunities offered by River Valley might be surprising. Since the 1970s models of professional development such as the Concerns-Based Adoption Model (Hord, Rutherford, Huling & Hall, 1987) have informed educators that "change is a process, not an event" (p.5); "change is accomplished by individuals"; "change is a highly personal experience"; (p.6) and teachers concentrate on meeting their own needs first and only after their needs are met do they look to the needs of their learners. To expect that teachers will implement a new curriculum with workshop overviews from the publisher and science committee chairs, along with a mandate from the district is naïve given our current level of understanding of the change process. None of the participants interviewed were able to articulate a model for professional development considered as part of the adoption process, including Barbara, Director of Elementary Education for River Valley. In the case of River Valley it seems that "wishing it can make it so" was the strategy for success. As Cannon and Crowther (1997) point out in a similar study, curricular implementation is doomed to failure without sufficient professional development.

What can River Valley's elementary science curriculum adoption teach us? The Science Committee worked very hard toward the goal of curriculum adoption; however, one year after the curriculum was implemented many teachers struggled to keep up with the pacing outlined by the science committee in the curriculum maps, and many have returned to their old ways—either ignoring science or simply using science time to read from the supplemental leveled readers. Few have adopted the curriculum as intended by the committee. Principals have done little to ensure the new curriculum is being used as intended by Barbara and the committee. To appease those teachers upset at the lack of depth of the curriculum, additional units were developed that treat some topics in more detail. Despite the time, money and energy devoted to the adoption task the prospect remains that very little will come of these investments in terms of valuable science instruction.

Principals have done little to ensure the new curriculum is being used as intended by Barbara and the committee.

What can be done to help districts like River Valley to heed the findings of research about curriculum decision making and professional development? The curriculum adopted may preclude River Valley from changing the state of elementary science teaching in the district. Eisner (1990/1997) believes the domination of the textbook is a stabilizing factor that reduces the likelihood of change in schools. Textbooks, he says,

> are designed to take no risks, and they strive to alienate no one. They are usually models of the dull, the routine, and the intellectually feckless. Typically, they are dense collections of facts that read much like the Los Angeles telephone book: a great many players, but not much plot (p.339).

Eisner further argues that "teachers with limited time for planning and little intellectual contact with their professional colleagues are unlikely to redefine curriculum content radically" (p. 339). Indeed, given River Valley teachers' complaints with the more radical social studies curriculum (i.e., requiring more work and preparation time than the old curriculum) the science committee decided early to restrict their choices to text-based curricula.

Apple (1990/1997), discussing the curriculum deliberation process, states that:

> the prominence of the standardized textbook was the result not only of rationalizing influences imposed from above or of the lure of a lucrative market for textbook publishers, but also of collective pressure from elementary teachers to change the awful conditions in which many of them worked. Overcrowded classrooms and the difficulties of planning for multi-age groups and for teaching a variety of subjects led teachers to argue for textbooks to help them. The result was a curriculum increasingly dominated by standardized—and finally, grade-specific—texts (p. 346).

Has the working lives of teachers changed appreciably in the last 30-40 years? The River Valley teachers associated with the science curriculum adoption did the committee work in addition to their classroom duties. The administration admits that the co-chairs were poorly compensated for the amount of work they did. Administrators might elevate the work of curriculum committees by providing better compensation. Maybe the adage "you get what you pay for" applies to the work done by teachers over and above their instructional time with students.

When the work of teachers changes, concomitant changes in curriculum and instructional practices might follow. The Organization for Economic Cooperation and Development (2006) reported the teaching time and teachers' working time for several countries. Primary teachers in the United States spend the greatest amount of time teaching even though most counties have longer school years. Primary teachers in Finland, whose scores on international tests we seek to emulate, spend considerably less time teaching and more time planning instruction. Finnish primary teachers teach an average of 680 hours per year in a 190 day school year while U.S. primary teachers teach 1080 hours per year in a 180 day school year. Little wonder U.S. teachers spend too little time researching curriculum options and desire a ready-made curriculum. [It should also be noted that the Finnish schools also do considerably less testing than their American counterparts.] Despite perennial claims by science educators that teachers need more content knowledge, more understanding of how students learn and more professional development (National Research Council, 1996), very little changes in the working life of elementary teachers. Perhaps administrators need to be at the forefront of efforts to provide elementary teachers a working environment that will allow them time in the professional day, like their international colleagues whose test scores we envy, to pursue curriculum adoptions and renewal that is valued.

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Kenneth W. Miller

Teaching Science Methods Online: Myths about Inquiry-based Online Learning

The author addresses six myths about inquiry-based online science delivery and offers some strategies to demonstrate effective online science teaching.

Introduction

With universities, teacher education institutions, and high schools gearing up heavily in online course delivery in every discipline, science educators specifically are asking themselves "How do we provide this access to our students and still maintain our pedagogical integrity in science instruction?" This question seems to be at the heart of a national discussion. The standards in science promote an inquiry-based approach at both the national and state levels, therefore, an arguable difficulty exists in adapting a reticent online inquiry approach that is more consistent with the excitement of an inquiry based face-to-face classroom approach. Today's students require coursework when they want it, where it is convenient for them, and how it fits their needs. Many students need online delivery because of distance from the university or their already demanding schedules. Delivering coursework using scientific inquiry techniques can be problematic. This paper discusses six myths about inquiry-based online science delivery. Examples of how to design and promote inquiry that is embedded in the delivery of an online course are provided.

Katherine started her degree from Montana State University-Billing by driving three times a week from her home and family over 50 miles away. The worst part was not the slippery roads during the winter or the two-hour-a-day commute. The worst was that she often ran behind schedule to pick up her two sons after school in her hometown miles away.

David lives over 90 miles away from a community college or university. He helps his wife with their tamale company business which turns out over 600 tamales a week in a hometown kitchen, and he also drives a school bus route and works with the school district's technology department. David has a two-year associate degree from a community college, and he is also a substitute teacher.

Given the plethora of online learning courses at most post secondary institutions, we as science methods instructors find ourselves discussing the issues of sound pedagogical delivery.

Programs in teacher education for learning online have given both these students options to fulfill their dreams of becoming teachers that previously were not available to them. The benefits do not stop with the individual. Rural schools in the Northwest are in dire need of elementary and secondary teachers. The state of Montana is a perfect example. Montana is the fourth largest state geographically in the United States, with many of its 900,000 people living in remote areas, hundreds of miles from the nearest four-year institution. Many of those seek to finish their degrees in elementary and secondary education and teach in the schools where they live, but it is emotionally, physically, and geographically impossible to restructure their lives and families to do so. Providing methods of teaching courses online within their regions and offering opportunities to intern in the schools where they weave theory into practice helps these students to earn their bachelors or masters degrees and become certified teachers.

Almost every community college and university within the current milieu offers online course offerings, and science teacher educators often find themselves in a quandary. Coursework and scheduling for online delivery increases, and there exists a philosophical struggle between perceived appropriate teaching strategies that promote the national and state science standards and what many believe we are capable of doing in online delivery platforms. Given the plethora of online learning courses at most post secondary institutions, we as science methods instructors find ourselves discussing the issues of sound pedagogical delivery.

Mission statements of public universities have at their heart *outreach and accessibility,* yet many state funded institutions do not provide, or cannot provide, outreach opportunities to their constituency unless those opportunities are offered online. Distance to universities, in many rural states is a barrier to possible on-campus attendance and participation; however, providing access to state institutions is the duty, and many times, the mission of those institutions. Access to institutional grounds should mean more than being physically able to set foot on the university campus quad. Using metaphoric language like "e-learning" or "open-education" advocates have hailed online learning as the harbinger of a complete transformation in teaching and learning (Cox, 2005). A synthesis of the professional development principles found in the standards, Loucks-Horsley, Stiles, and Hewson (1996) suggest that there should be an emphasis on "inquiry-based learning, problem-solving, student investigation and discovery, and application of knowledge" (p. 1). They continue by stating that approaches should be used to help students to "construct new understandings, through experiences that extend and challenge what they already know" (p. 1). Loucks-Horsley et al., thoroughly relate these practices to teacher education. They state that "engaging teachers in learning experiences that enhance their understanding" (p. 2) of science concepts and appropriate pedagogy should be a definite priority. They suggest that teachers, like students, learn best by doing science in an inquiry approach, investigating and constructing their own understandings. Loucks-Horsley suggests that professional development must include the modeling of effective learning environments.

Instruction in an online format requires that faculty re-think the tried and true methods they use to teach on campus.

These reasons make online learning attractive and challenging. Gill (2003) suggests that almost 20% of training in "world class organizations" is being delivered online with an even greater percentage foreseen for the near future. Change of any kind is difficult and hence, fraught with myths. This paper will discuss six myths of online learning in an inquiry-based science methods course and begin to construct a better understanding of the power of online science content and pedagogical learning. Some strategies will be provided to demonstrate effective online science teaching.

Myth One: *Good on campus face to face instructors make good instructors online.*

Most faculty, though quite pedagogically sound for on campus delivery, also understand that teaching online requires a different mindset and delivery style. A small on-campus survey showed that 10 faculty members were questioned prior to experiencing, developing and teaching courses online. All responded that they were quite hesitant to teach online, and most reported they did not think it was possible to teach their courses and their content totally online, void of face to face interaction. However, after planning online delivery and actually experiencing teaching online, this same faculty reported a new understanding of delivery methods and discussed how much learning took place in their online courses (Miller & Knuth, 2004). Some faculty echo, "It can't be done! To prepare science teachers appropriately, you have to be able to monitor student learning, model teaching strategies for the student, and mentor students in their teaching careers." Generally, these words originate from faculty relatively inexperienced in online delivery and/or those that lack the technological expertise to format an inquiry-based online course. Faculty with no experiences with online teaching typically made comments such as these:

- I think it will compromise quality, and that we will eventually lose our share of the market to larger universities with more attractive transcripts.
- When I first heard about online instruction, I thought, 'I don't like it and I don't think I will ever do it.'

After having taught their course online, faculty became more aware of the variety that online delivery could produce. They then made comments like these:

- After teaching an online class, I think I really like teaching online. I get to know my students individually. Each one becomes unique, and I learn about each one's strengths better than when I had them in class. I also have the opportunity to relate each unit with a field experience, which I am unable to do with face to face, since we have so many restrictions on placements in our college.
- It is great! It forces me to be more constructivist. I lay the groundwork. I set the stage. I become a facilitator. The students have to get involved and take responsibility for their own learning!

Instruction in an online format requires that faculty re-think the tried and true methods they use to teach on campus. Online delivery, sometimes call ePedagogy, does not provide instructors with instantaneous cues regarding their teaching and the students' learning. Online delivery must be well thought out in advance, as it is virtually impossible to 'shoot from the hip' and improvise online. Teaching online is different from teaching face-to- face, and instructors who teach online should receive training in online communications and course facilitation (Kleinman, 2005).

Being void of visual cues, online teaching forces instruction to be more reflective and planned. "It is true that face-to-face pedagogy can and should be used to inform online pedagogy. However, this in itself can not be the driving force to designing online courses; one must consider ePedagogy to create a successful and meaningful course" (Li & Akins, 2005). Consequently, a weak on campus teacher will quite likely make a weak online instructor. It can also be suggested that without appropriate e-pedagogical decisions, a good on-campus instructor will not necessarily make a good online instructor.

Myth Two: *Online delivery is similar to correspondence coursework and limited to content learning*

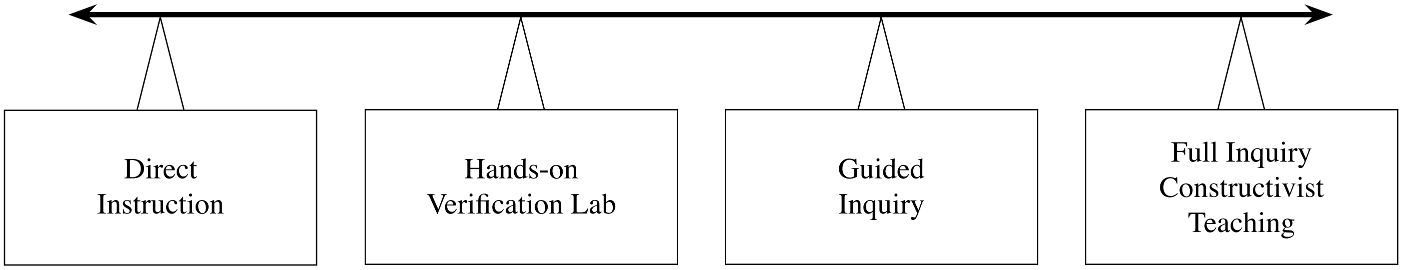
The definitions of inquiry and constructivist teaching come into play when we begin to think of training science teachers to teach. Certainly, the National Science Education Standards (NSES) call for inquiry as a way of life in the science classroom.

> The world is filled with the products of scientific inquiry, and scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology, and everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. (National Research Council, 1996, para 1)

The NSES also suggest that the science teacher must use these inquiry-based techniques to develop appropriate content development in their students. However, an inquiry-based online science course is certainly not the same as the mail delivered correspondence course of yore. In sharp contrast to some initial perceptions, online courses can be designed to simulate constructivist teaching and inquiry approaches.

Figure 1 represents the continuum from which online courses can be designed. If the nature of the coursework is to develop a content knowledge base and provide student access to information, feedback loops from peers or the instructor do not need to be as prominent an embedded feature in the course. Hence, an instructor could possibly design a content driven course using a direct instruction model with little instructor or peer

Figure 1. Continuum from which online courses can be designed.



feedback. Given such a scenario, an online student could sign into a course, determine the unit's requirements, read, do activities, research, and comply with the requirements of that unit. The student would eventually be assessed on those requirements. The unit assessment, likely true/false or multiple choice, could quite possibly be the only feedback that the students might receive. Further, in some cases, that feedback can be totally computer generated. For example, at a nearby university, a beginning personal health course is offered each semester with almost one thousand students enrolled. The students read the material and respond to the content with exams to determine content understanding. Evaluation is multiple choice and true or false. The computer scores each student and records the grade in the online gradebook. This type of course is extremely efficient and generates a large number of FTE for the university. However, it is a course that is based upon content knowledge understanding; not pedagogical, attitudinal, and following the inquiry standards-based understandings as prescribed by the NSES.

Toward the middle of the continuum, a course can be developed that would enable more in-depth instructor feedback and can also include peer-to-peer discussions and feedback. Logistically, this type of feedback limits the total number of students in a course simply because of the time required by the instructor to interact with individuals and monitor their responses. Should there be a large number of students in the course, the instructor may establish discussion groups to facilitate content understanding. This plan allows for the instructor to interact and provide feedback to groups of 5-8 as they discuss with each other pre-determined questions, rather than to specific individuals. The instructor can direct or re-direct discussions of the group, thus providing the necessary feedback loops. Assessment can be more individualized and can provide the instructor with a deeper understanding of the students, as seen in more interactive, discussion-based, on-campus classrooms.

It can also be suggested that without appropriate e-pedagogical decisions, a good on-campus instructor will not necessarily make a good online instructor.

Myth Three: *You cannot model constructivist inquiry teaching strategies online.*

Further along the continuum (see Figure 1), we can establish a guided inquiry course nearing full inquiry. How does an instructor design an online course that models appropriate standards based teaching pedagogy? Certainly, this is a daunting task. It requires that the instructor plan for inquiry-based activities that model appropriate constructivist techniques, yet with clearly defined e-pedagogical objectives. Let's see how this might be done.

Assume that you have introduced various teaching models, i.e. The Learning Cycle (Karplus, 1974; Lawson, Abrahamn, & Renner, 1989), The Conceptual Change Model (Hewson, 1992; Posner, Strike, Hewson, & Gertzog, 1982) The Instructional Theory Into Practice (ITIP) (Hunter, as described by Darling-Hammond, 1990); and the 5E teaching model (BSCS, 1989) in previous coursework. Now, you would like to have your students do an activity to experience one of these. You choose the Conceptual Change Model (CCM) because you are fairly sure from previous courses that your students need experiential opportunities with Bernoulli's Principle. You are fairly certain your students do not understand the CCM teaching model, and this becomes your primary objective for this unit. Bernoulli's principle, at a basic level, suggests that a fluid in motion has a lower pressure that surrounding fluid. Consequently, the surrounding fluid (or air) tends to move from a higher pressure to a lower pressure. You need to take into account that your students do not have access to equipment other than most household materials. Again, your major objective in this method of science teaching course is for the students is to understand the steps and stages of the CCM and how it is used in the classroom.

A series of digital video segments are constructed by the instructor to model this inquiry-based activity. These videos represent a modeling of the steps of the CCM and help to develop the activity sequentially, following the CCM format. Students are directed to watch a segment of a video and respond online in a discussion format. The following segments and directed student responses show how to model inquiry-based teaching through online delivery.

Video Segment One: Show a video where the instructor asks the students to predict what would happen, if anything, to a strip of paper when you blow across it. (the paper moves up and flutters). Have the students enter into the discussion area of the online course, where they are directed to predict what will happen to the strip of paper and why they think this will happen. Students are encouraged to discuss these concepts within their small groups and try to come up with a collaborative answer. Once they all agree on an answer, direct the students to try the activity and discuss their results.

Myth Four: *Interaction among peers is weak in online delivery formats.*

Video Segment Two: Students are directed to another video, where they are asked to view a folded piece of paper making a tent. Another video segment shows the instructor modeling the set up of the experiment. The students observe the instructor about to blow through a straw and through the paper tent. The instructor directs the students to go back into the threaded discussion area and predict what they think will happen, form a consensus with their group, and finally try the activity. An additional discussion area is set up for the students to discuss their results. They are then directed to additional video segments, using different materials that also demonstrate the same concept. Students continue to interact in similar discussions.

The instruction proceeds to the stage of the teaching model, where the concept is developed. Students are encouraged to discuss their understandings in additional discussions. From there, the instruction leads to another stage of the CCM into an extension or application of the concept. Students again are led to the discussion area where they discuss where they have seen this concept before.

Given the primary objective being an understanding of the CCM, the lesson continues with an assignment to complete and return digitally to the instructor for grading. This assignment instructs the students to replay the entire activity around the concept of Bernoulli's principle and write what was occurring in class for each step of the CCM model. This now creates student reflection necessary to provide closure, and more importantly, a deeper understanding of the CCM, which becomes an assessment tool for the instructor.

The very nature of online is that of interaction within the medium.

The interaction between and among peers and the instructor is strong. Students in an online format are not allowed to simply sit back and let others discuss and lead discussions. The very nature of online is that of interaction within the medium. To encourage this sort of collaboration, it is important to value the discussions, and that should reflect in the course grade. My experience and other research (Nicaise & Crane, 1999) show that many of our students tend to do only that which is required. Valuing the amount of collegial interaction with peers and the instructor, as a representative part of the student's grade, can certainly enhance the discussions. It is in this manner that myth number four—suggesting a weak interaction amongst peers—is debunked.

Myth Five: *Online delivery does not allow students to take theory into practice.*

The structure of many online courses might not allow students to take theory into practice. It is arguable though, that online might allow for a more significant experience for students if the requirements for the teacher education program are such that it necessitates an interaction in the schools. For example, if students are required to interact in field experience with assignments from a co-existing online course, theory into practice can easily occur, especially if the instructor allows online interaction regarding the field experiences. Miller & Knuth (2004) found that students involved in field experiences while taking an online course scored as well with no statistical differences on student teaching measures as students taking courses on campus. A comparison of an online course and a face-to-face science education course, Harlen & Altobello's (2003) results showed better learning outcomes online.

Certainly, field experiences can enhance the understandings presented in an online format, but the format can also expand the community of learners and decrease the physical isolation of online learning. Discussions can be incorporated easily that allow for peer to peer and instructor to student dialogue that truly dispel the theory into practice myth.

Myth Six: *In order to succeed as a teacher, students studying to be teachers must be able to watch the instructor model an appropriate lesson.*

Faculty discussions related to the innovation of online instruction have certainly been diverse, if not in a direct dichotomy. Faculty argue that learning apart from the intensity of the classroom cannot occur outside of their ownership, direction, and personal interaction. Many claim the need for *appropriate modeling,* and suggest that their *materials and mode of presentation will not fit an online environment.* When faculty members discuss the topic of online instruction, several suggest that their methods of teaching are not conducive to an online format. In essence, they have difficulty seeing how their materials and classroom instruction can transfer to an online environment. Some charge that learning cannot occur in absence of good instruction, with the understanding that good instruction occurs only from the pedagogical structure of face-to-face communication. These arguments are of value and need to be understood. Accommodations for these understandings are appropriate, keeping in mind that learning is experiential and most faculty have little or no online experiences of their own. Nor have they been tooled in online learning e-pedagogy. Still, theoretical constructs for learning are similar for both online and on-campus delivery. As discussed in previous myths, being "sage on the stage" is not a necessary component of constructivist "guide on the side" learning.

Conclusion

Certainly as higher education, secondary education, and other uses of internet based learning continue to grow, those asked to design courses and teach those courses will have discussions as to the appropriateness of the delivery system. But, as Li and Akins (2005) suggest, the quality of that education is dependent on the clarity of the goals and good e-pedagogy designed to meet those goals. We will need committed learners and instructors and excellent supporting structures willing to learn to implement inquiry based methods into online teaching. The potential for e-learning is great and certainly in demand. It appears that the quality of the course content and design, and the nature of the interactions with the instructor, are more important determinants of learning than whether the course is taught face-to-face, online, or some blend of both (Koory 2003). As faculty members begin the arduous journey toward making their online teaching more inquiry-based, there will be other barriers with more myths to dispel.

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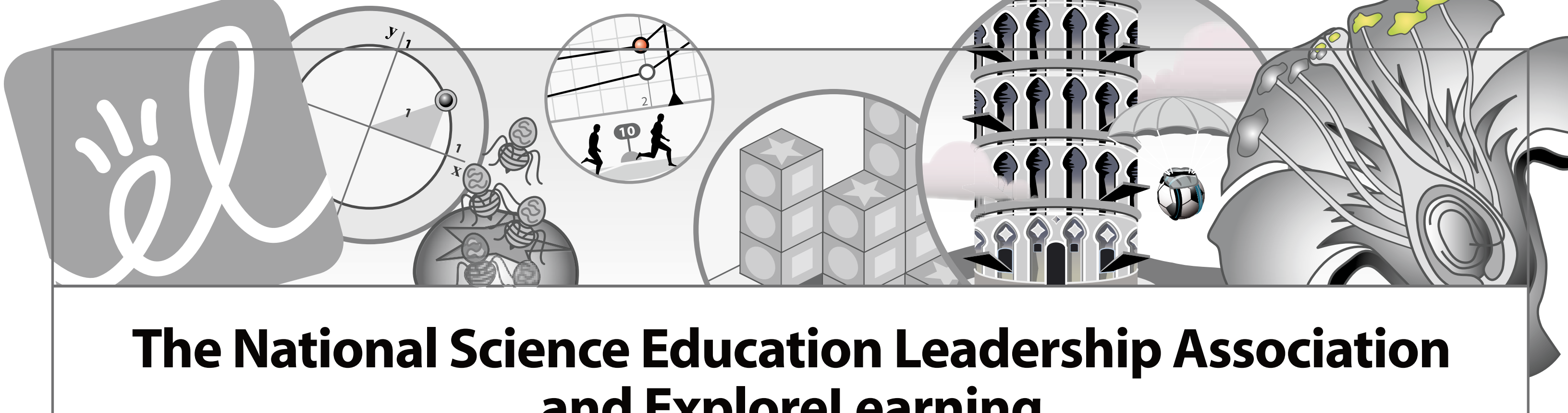

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