4-2014

Preparation for Practice: Elementary Preservice Teachers Learning and Using Scientific Classroom Discourse Community Instructional Strategies

Elizabeth Lewis
University of Nebraska-Lincoln, elewis3@unl.edu

Oxana Dema
University of Nebraska-Lincoln

Dena Harshbarger
University of Nebraska-Lincoln

Published in *School Science and Mathematics* 114:4 (April 2014), pp. 154–165; doi: 10.1111/ssm.12067

Preparation for Practice: Elementary Preservice Teachers Learning and Using Scientific Classroom Discourse Community Instructional Strategies

Elizabeth Lewis, Oxana Dema, and Dena Harshbarger

Department of Teaching, Learning, and Teacher Education, University of Nebraska-Lincoln

Abstract

Despite historical national efforts to improve elementary science education, science instruction continues to be marginalized, varying by state. This study was designed to address the ongoing challenge of educating elementary preservice teachers (PSTs) to teach science. Elementary PSTs are one of the science education community's major links to schools and science education reform. However, they often lack a strong background in science, knowledge of effective science teaching strategies, and consequently have low confidence and self-efficacy. This investigation explored the initial learning of elementary PSTs using an interdisciplinary model of a scientific classroom discourse community during a science methods course. Findings post-methods course suggested that the PSTs gained confidence in how to teach inquiry-based elementary science and recognized inquiry-based science as an effective means for engaging student learning. Additionally, PSTs embraced the interdisciplinary model as one that benefits students' learning and effectively uses limited time in a school day.

The Challenge of Preparing Elementary Teachers to Teach Science

Consider that the following statement, "At the elementary school level, instruction in science has almost ceased, being no more in most classrooms than a few minutes each week of reading from textbooks" (Greenleaf, 1982, p. 19), could be said of today's elementary classrooms but is actually a quote by James Rutherford of the American Association for the Advancement of Science (AAAS) from 30 years ago. Despite concerted, national efforts to improve elementary science education in the United States (e.g., the National Science Foundation's Science Curriculum Improvement Study in the 1960s and the National Science Education Standards [NRC, 1996] in the 1990s), elementary science instruction remains marginalized. However, with the release and implementation of the Next Generation Science Standards (NGSS) (Achieve, Inc., 2013), there will be an even stronger emphasis on building elementary science education as a vital foundation for K-12 science education and a scientifically literate citizenry, and thus a greater need for practical solutions.

Elementary science education has many challenges, centrally, the effective education of teachers to teach K-5 science standards. By inspecting this teacher preparation challenge, there are three identified aspects in the research literature that must be addressed to improve: (a) negative dispositions of elementary teachers toward teaching science (Lee & Houseal, 2003); (b) elementary teacher education programs that only require minimal or inconsistent learning objectives based on national standards (Smith & Gess-Newsome, 2004); and (c) U.S. educational policy within a culture of accountability that overemphasizes "the basics" as a result of No Child Left Behind (NCLB) (Goldston, 2005). Each of these three factors has been documented frequently in studies of elementary science education, preservice teacher (PST) education, and time spent on science instruction. With the NGSS for state-level adoption, it will be imperative that these issues be addressed with feasible solutions to improve K-5 students' opportunity to learn science.

In this article, we provide (a) an overview of recent research on the aforementioned challenges to preparing elementary PSTs to teach science, (b) a research-supported interdisciplinary model for teaching elementary PSTs how to build scientific classroom discourse communities (SCDC), and (c) the resulting learning by a group of PSTs in an elementary science methods class aligned with this particular framework of an SCDC.

Preparing Teachers to Teach Elementary Science

Appleton (2007) reviewed the research on elementary science education and identified three major issues with elementary teachers teaching science: (a) their limited science subject matter knowledge, (b) limited pedagogical science content knowledge, and consequently, (c) low confidence and self-efficacy with science content and science teaching (Cavallo, Miller, & Saunders, 2002; Cone, 2009; C. A. Lee & Houseal, 2003; Minger & Simpson, 2006; Tosun, 2000). Each of these critical issues must be addressed as we prepare elementary teachers to teach science. In this study, our focus was on building elementary PSTs' knowledge of how to teach science. We used a previously developed teacher professional development (PD) model of an SCDC (Baker et al., 2009) and adapted it to a preservice elementary science methods course. Having witnessed the success of this model with in-service teachers, the next logical step was to try it with PSTs. In framing the teacher education course as its own SCDC, the goal was for the elementary PSTs to learn how to teach inquiry-based science activities using a wide variety of oral and written discourse instructional strategies. This instructional model will be described in greater detail in the section on the context of the study.

Limited Opportunities to Learn and Practice Teaching Science

Although the National Science Educational Standards (NRC, 1996) was not a curriculum for science, it provided vision, guidelines, and goals for K-12 science education. Thus, teacher educators were tasked with educating all PSTs to be better equipped to teach science in accordance with the standards. Ironically, in an analysis of a national sample of elementary science methods course syllabi, Smith and Gess-Newsome (2004) found that there was no clear link between the course goals and the learning activities and assignments; course content was mostly selected according to instructors' personal bias, knowledge, goals, and program needs. To compound the issue, there is little empirical data about PSTs' clinical experiences teaching science (NRC, 2010). This leads to natural and problematic variability in PSTs' knowledge of, and attitudes toward, science and teaching science. In our study, the science methods course was carefully designed around critical aspects of teaching science, e.g., inquiry-based instruction, cognitive learning principles, and mirrored practices of scientists and scientific communication. The same model can be applied to other classrooms and instruction.

McMurrer (2008) reported that nationally post-NCLB science instructional time has decreased by one third from 226 to 152 minutes per week. Smith and Southerland (2007) suggested that teachers' ability or inclination to change is affected by the amount of time devoted to science instruction. With less science being taught by cooperating teachers, student teachers' opportunities to observe and practice teaching science are also reduced.

Elementary Teachers' Dispositions toward Teaching Science

Lee and Houseal (2003) found that elementary teachers' self-efficacy can be an obstacle to teaching science, especially through inquiry-based instruction. Specifically, they asserted that self-confidence is an internal constraint on teaching elementary school science and that teachers modify their practice based upon their degree of self-efficacy and content knowledge. Richardson and Liang (2008), studying an integrated math and science teaching methods course designed to produce well-prepared, self-efficacious teachers, concluded that "an inquiry-based mathematics and science preservice teacher education course can foster increased preservice teacher efficacy" (Richardson & Liang, 2008, p. 11). The elementary science methods course designed for this study also modeled inquiry-based instruction and provided PSTs the opportunity to plan and implement their own inquiry-based lessons with elementary students.

Culture of Accountability: Effects of the NCLB Act

By limiting elementary curricula to math, reading, writing, and test-prep lessons (Nichols & Berliner, 2007), schools and administrators continue to ignore longstanding science education research showing that elementary students can learn "the basics" (e.g., vocabulary enrichment, verbal fluency, and improved communication skills) through activity-centered science instruction (Mechling & Oliver, 1983). As previously mentioned, McMurrer (2008) documented that the post-NCLB national average instructional time for elementary science has decreased; students receive 33% less science instructional time than before NCLB was instituted. The sacrifice of teaching science allows more focused instruction in reading and math during the school day (McMurrer, 2008), with the implicit goal to improve students' test scores. For example, with low teacher expectations and impoverished curriculum selection because of school- and district-level tracking policies of lower-achieving students (Oakes, 1986), the more at risk a school is for not making adequate yearly progress, the more students are perceived to need remedial instruction. Consequently, at-risk students' curricula are more likely to focus on rote learning exercises. This practice reduces children's access to quality, standards-based science education and maintains inequities in our educational system. In order to address limited time for instruction throughout the school day and to improve students' reading and math skills without sacrificing science and social studies education, teachers need to know how to implement interdisciplinary curriculum with cross-cutting learning objectives. Such objectives are already a part of the NGSS (Achieve, Inc., 2013). We argue that to improve elementary students' science learning, teacher educators should teach PSTs to use an interdisciplinary approach such as an SCDC, thus optimizing time to teach subject area knowledge while leveraging natural connections between oral and written discourse, and scientific inquiry. In this way, teachers may concurrently build children's language and scientific literacies. Teacher educators can also better prepare PSTs by modeling the use of an interdisciplinary approach within methods courses. "Integrated and thematic approaches to curriculum can be powerful; however they require skill and understanding in their design and implementation" (NRC, 1996, p. 213).

Rationale for Study

This study focuses on one aspect of elementary science education, preparing PSTs to teach science. As a group, PSTs are one of science education's major connections to schools and ultimately, young students. It is during teacher education programs that we have the opportunity to engage PSTs in learning best science teaching practices. By modeling such practices, teacher educators begin to address PSTs' concerns and self-efficacy about teaching science. In addition, by integrating the so-called "basics" with science standards, elementary teachers can be relieved of the pressure to teach all curricular content separately with limited time in the school day. Other research (e.g., Schroeder, Scott, Tolson, Huang, & Lee, 2007) supports student learning the "basics" when science is taught in activity-oriented, learning cycle, inquiry-based ways that support students in making meaning of science concepts. In our study, the methods course was designed to (a) improve PSTs' dispositions toward teaching science, (b) increase PSTs' teaching self-efficacy, (c) increase PSTs' knowledge of how to teach science, and (d) aid PSTs in setting long-term PD goals for teaching science.

Research on Elementary Science Methods Courses

Other studies (e.g., Varma, Volkmann, & Hanuscin, 2009) of elementary science methods courses have shown that PSTs find inquiry-based teaching strategies in the elementary science methods courses beneficial in developing their own teaching strategies. Park Rogers (2009) proposed implications for teaching elementary science methods and the importance of iterative opportunities for PSTs to experience scientific inquiry. Britner and Finson (2005) concluded that in order to adequately prepare future elementary teachers to incorporate inquiry in their science teaching, one must engage them in inquiry in their methods classes. Accordingly, inquiry-based science lesson planning and instruction was a dominant feature in the science methods course in our study. The use of an SCDC to frame the course ensured that the oral and written discourse and academic language development strategies were explicitly highlighted as part of effective science instruction. The interdisciplinary approach also connected elementary science to more comfortable and familiar areas, e.g., language arts. Our investigation inquired into how this approach affected PSTs' knowledge and self-confidence.

Theory: Learning in a Scientific Classroom Discourse Community

A social cognitive learning perspective (Lave &Wenger, 1991; Vygotsky, 1986) undergirds scientific community norms and practices, as scientists work in research teams and co-construct new knowledge. However, teachers do not always use inquiry-based instruction and default to rote learning. The argument for integrating science and literacy tools invites interdisciplinary connections between science and language arts. Hand et al. (2003) stated, "language is an integral part of science and science literacy—language is a means of doing science and to constructing science understandings" (p. 608). This insight is a conceptual cornerstone for SCDCs that empower teachers to meet the demands of "the basics" as well as promote meaningful science education. For example, Morrison (2008) studied PSTs' use of science notebooks, and at the beginning of their methods course, they viewed it as simply another assignment, but at the end, they saw it as a place to explore and document their learning.

By engaging PSTs in SCDCs, we can also use applied social cognitive learning theory to model classrooms that are equitable places for diverse students. With an interdisciplinary instructional model that better supports academic language development through talking and writing in science, PSTs can directly address the challenges that language minority students face on a daily basis (Lee & Fradd, 1998), as well as optimize instructional time and meet a broad range of academic standards. Authentic language use within scientific inquiry supports both science learning and further language development and literacy for all children.

Instructional Framework

The instructional framework of an SCDC for the elementary science methods course in this study included four key aspects: (a) constructivist learning through inquiry-based science using the 5E instructional model (Bybee, 1997; Hanuscin & Lee, 2008; Lawson, Abraham, & Renner, 1989), (b) learning principles (Bransford et al., 2000) (e.g., accessing students' prior knowledge), (c) opportunities to talk and write about science, and (d) academic language development strategies. Although differing opinions about what constitutes inquiry-based instruction exist, our study identifies inquiry in accor-

Table 1. Science Methods Course Design Modeling a Scientific Classroom Discourse Community

Aspect of a Scientific Classroom Discourse Community	Example Course Foci, Activities, & Assignments
Scientific inquiry	• Learning the 5E instructional model • Types of inquiry (e.g., Exploratorium activity) • Nature of science (e.g., using Tricky Tracks activity) • Lesson study project ◦ Plan and teach 1st lesson ◦ Use formative assessment to revise lesson ◦ Teach 2nd lesson
Oral discourse	• Pairs or small group 5E science activities • Reading discussions with focused prompts • Final lesson study presentation
Written discourse	• Science notebooks ◦ Collecting and analyzing data ◦ Writing claims with evidence and reasoning • Metacognitive essays • Final lesson study report • Science teaching philosophy paper
Academic language development	• Use of gestures, pictures, animations, and manipulatives (i.e., realia) during science lessons to support language development
Learning principles (Bransford et al., 2000)	• Accessing students' prior knowledge (e.g., KWL [Know-Want to Know-Learned]) • Placing facts within a conceptual framework (e.g., concept mapping) • Metacognition (e.g., learning logs)

dance with the Biological Science Curriculum Study (BSCS) 5E instructional model (Bybee, 1997). Since the late 1980s, the BSCS's 5E instructional model has become increasingly popular in the science education community in an effort to improve curriculum by creating cohesive lesson sequences. The 5E model involves a learning cycle approach (Abraham, 1998) that incorporates scientific inquiry and modeling. Each of the five phases has a specific purpose. They are: (a) Engagement, to assess prior knowledge and purposefully create connections between past and present learning experiences; (b) Exploration, to allow students to generate new ideas, explore questions, and design and conduct investigations; (c) Explanation, to make sense of the phenomenon; (d) Elaboration, to use new experiences to challenge, apply, and deepen understanding; and infused throughout the model, (e) Evaluation, to use assessment throughout the entire learning sequence.

Hanuscin and Lee (2008) showed that using a learning cycle model in teaching elementary science methods helps teachers understand the 5E model, encouraging them to "develop a deeper understanding of powerful ways to select and sequence learning activities for their own instruction" (Hanuscin & Lee, 2008, p. 59). Thus, to reflect a social cognitive learning approach using inquiry-based science in this study, all class activities used a variety of discourse structures (e.g., pair-share, small group discussion, jigsaw, reporting to the whole group).

The SCDC research-based framework was originally developed by Baker et al. (2009) through a National Science Foundation grant, the Communication in Science Inquiry Project (CISIP) (in the interests of space, see Baker et al., 2009, for a more thorough literature review). In an ancillary study, in-service 5th- and 6th-grade teachers participated in PD summer seminars and on-going monthly Saturday workshops throughout the academic year to develop school-based teacher teams to support building SCDCs with students (Lewis et al., 2011). Because the PD program was shown to help upper elementary and middle level in-service teachers learn how to teach science in an interdisciplinary fashion, the lead author of this study designed a science methods course that used key elements from this model to reframe and augment regular course activities and assignments (Table 1). Our investigation examined PSTs' learning about SCDCs, views of the purpose of science education, goals for children's science learning, awareness of inquiry-based instruction, and confidence in teaching science precourse and postcourse.

Research Context

This study focused on a five-week, summer elementary science methods course at a large university in a

Southwestern U.S. urban center. The course was part of a typical undergraduate elementary education program for 16 PSTs; however, the summer course was paired with a separate mathematics methods course and shared a daily practicum placement in an inner-city summer school program through a partnership grant with that school district. The accelerated summer course met three times a week, for three hours each meeting, and was designed as a 1:1 replacement for the regular 15-week semester offering that met once a week for three hours. The lead author of this study designed and taught the summer course, having also taught it as a regular semester-long course. The summer session program replaced one semester of coursework and practica so that the PSTs could student-teach sooner, in the fall semester.

Preservice Elementary Science Methods Course

For the elementary science methods course, the lead author used the interdisciplinary SCDC framework. Alignment of course foci, activities, and assignments is presented in Table 1. The paired practicum was specifically designed to provide PSTs with clinical experiences with diverse K-8 students. The summer practicum placement was held in a low socioeconomic status (SES), inner-city school district with a minority-majority, in this case Latino, population. The K-8 eight-week summer school program included all core academic subject areas and provided supplementary academic instruction to the elementary students. The focus in the science methods course on the needs of English Language Learners (ELLs), and academic language development in general, was particularly important because ELLs constituted a large portion of their K-8 students. During their placements, the PSTs taught two science lessons as the basis of their major project, a lesson study (Lewis, 2002), for the methods class. Most of the PSTs worked with a partner and designed a science lesson using the 5E model of inquiry-based instruction, collected student artifacts, engaged in peer critique sessions, redesigned their lesson, and re-taught using formative assessment practices to adjust their instruction. Like Varella and Veronesi (2004), students also summarized their teaching philosophy in a formal assignment that included metacognitive reflections concerning what they learned about teaching science.

Throughout the course, the PSTs were required to use science notebooks to organize all of their in-class activities. The purpose of having PSTs engage in the use of science notebooks was to support and model scientific inquiry activities, scientific practices, and writing in science during small group conversations and activities as a learning tool. As had been observed in the CISIP PD, having teachers use science notebooks facilitated a better understanding how to use them with students during science activities. Therefore, like Morrison (2008), modeling how to use science notebooks was a key activity for the PSTs in this course.

Research Questions and Methods

This study was exploratory and the following research questions were investigated:

1. What perspectives about teaching science did the PSTs hold before and after the science methods course?
2. Did the course help the PSTs gain confidence in teaching science?
3. What were the most-valued concepts and strategies for teaching science that the PSTs learned (e.g., potential enduring knowledge)?
4. How did the PSTs view teaching elementary science at the end of the course, and what did they identify as necessary to their future PD?

We investigated PSTs' ideas precourse (May 25, 2007) and postcourse (June 29, 2007) with a questionnaire (in Appendix) to explore their perspectives and not limit responses with forced choices on a survey instrument. A course assessment, a final paper (June 28, 2007), was collected to perform a content analysis of the PSTs' exiting philosophies of teaching science. Findings were connected with a focus group interview (July 6, 2007) conducted with five PSTs after grades were submitted.

The lead author designed and taught the science methods course. She designed the questionnaire and course assignments, and collected these artifacts, and after the course was completed, she conducted the focus group interview. The other authors were doctoral students in education at another university with experience with other elementary PSTs; they assisted with the data analysis and interpretation of the findings. All authors were familiar with the tenets of qualitative research (Creswell, 2007) and how to analytically develop themes through constant comparison of data (Erickson, 1986). The multiple sources of data from the PSTs' precourse and postcourse questionnaires, final papers, and focus group interview were analyzed, triangulated using a qualitative procedure of theme development. Questionnaire responses were tallied and grouped by similar responses and reported as percentages in rank order of most to least frequent. Beliefs about teaching science in the final papers were analyzed, categorized, and tallied. We triangulated findings from PSTs' precourse and postcourse questionnaires, final papers, and the focus group interview. By implementing triangulation, which included gathering data through several strategies, we obtained evidence at different times, participants, and situations. By combining multiple materials, we overcome potential bias from single data sources, improving our understanding of the phenomenon of PST learning to teach science.

The majority (n = 10, 63%) of the 16 undergraduate elementary PSTs wanted to teach the youngest of elementary students, K-4th grade. The PSTs were mostly typical undergraduates in their senior year of college, aged 21–22 years old, with a few nontraditional older students who had returned to school to become teachers. All PSTs were female, and 15 were of Western European descent and one was of Asian descent.

Results

Research Question 1: What Perspectives About Teaching Science Did the PSTs Hold Before and After the Science Methods Course?

Initially, PSTs stated multiple purposes of elementary science education, including the most frequently mentioned, to (a) develop and support critical thinking, (b) foster students' ownership of learning, (c) build students' understanding of the process of science and become scientifically literate, (d) help students develop inquisitive minds, and (e) teach the importance of science. These ideas persisted throughout the course and remained consistent with one purpose that increased "to understand the process of science" (+18.75%). This reflects the course emphases on the nature of science and how to teach science process skills. Thus, the majority of PSTs connected how to teach science with their understanding of goals of science education, which were aligned with course learning objectives.

In response to the question, "What might be some productive ways to introduce a new science concept to students?," there were three strategies that increased the most from precourse to postcourse: (a) pose a question (+50%), (b) access prior knowledge (verbally or in written form) (+37.5%), and (c) engage in whole class discussion (+12.5%). Thus, the PSTs recognized some specific instructional approaches to find out what students knew prior to instruction during the engage phase of the 5E model, thus better positioning students to attend to a new idea. In response to "What can you do as a child's teacher to address language level/literacy?," we found that the PSTs could also identify effective ELL and language-based learning strategies to support all students in learning science; the three strategies that increased most were: (a) using visuals (+31.25%), (b) partnering students (+18.75%), and (c) offering alternate ways to communicate understandings (+18.75%). By addressing the dual challenges of engaging students using inquiry-based science instruction and making science instruction comprehensible and accessible to all students, PSTs learned such practical instructional strategies through the SCDC framework, specifically the focus on academic language development. Even though the PSTs had taken a course on language literacy and learning as part of their program, they gained a greater appreciation of the value of employing ELL strategies within teaching science.

Finally, the PSTs demonstrated a greater awareness of the 5E model to teach science. The analysis of PSTs' responses in the precourse and postcourse questionnaire indicated the largest increases in identifying inquiry-based methods were both specific, e.g., using the Elaborate phase (+37.5%) to reinforce learning, and general, e.g., using the 5E model (+25%). This indicated a range of understanding among the PSTs; while some offered a more nuanced description, others appeared to be less adept with the 5E approach although they could name it.

Research Question 2: Did the Course Help the PSTs Gain Confidence in Teaching Science?

We also asked "How much experience have you had with science?," and 56% PSTs reported a low level of experience. One-third of respondents indicated a medium level of science experience (e.g., Zoey, "I have a pretty good science base, initially starting my college career I wanted to be a biology major"). Only 13% mentioned having a high level of experience with science. To better understand their current attitudes toward science before the methods course, we asked: "What is your comfort level with science?" Forty-four percent reported a high to high-medium comfort level, and 56% a low or low-medium comfort level with science. We established these four categories through reading the PSTs' precourse writings, for example:

Low (19%): e.g., Ashley, "I am not good at science in any way, so very uncomfortable."

Low-medium (37%): e.g., Morgan, "Although I like science I have not had much experience with it so my comfort level is not very high."

High-medium (25%): e.g., Calley, "I am pretty comfortable with science; I really enjoy learning new things. I think science is a lot of fun when taught the right way."

High (19%): e.g., Emma, "I am very comfortable with science, the scientific method, genetics, and just about everything else. I am interested and passionate about science."

In general, these perspectives align with other studies that reflect a minimal content exposure to science

Table 2. Postcourse Survey Question 2: "What Is Your Comfort Level with Science?"

Comfort Level	Number of Teachers	% of Teachers
Small improvement	10	62
Maintained	3	19
Large improvement	3	19
Comfort with science content		
Not mentioned	12	75
Feel better	3	19
Worried	1	6
Comfort with teaching science		
Learned how to teach science	13	81
Not mentioned	3	19

(Appleton, 2007), but the additional qualitative statements demonstrate that not all elementary PSTs are as fearful of science as is typically assumed.

It was evident from the postcourse questionnaire and focus group interview that the methods course design, curriculum, and instruction helped the PSTs increase their comfort level with teaching science. After the course about 62% of the PSTs stated that they had experienced a small improvement in their comfort level with science, about 19% maintained their prior level, and about 19% mentioned a large improvement. Additional evidence about the PSTs' comfort level with how to teach science indicated that after the methods course the majority (81%) reported that they understood how to teach science better (Table 2).

Research Question 3: What Were the Most-Valued Concepts and Strategies for Teaching Science That the PSTs Learned (e.g., Potential Enduring Knowledge)?

In our analysis of the focus group interview and final papers, PSTs frequently stated that the most effective instructional approach for teaching science was inquiry-based. Evidence from the interview suggested that the PSTs recognized the difference between traditional, solely hands-on, and inquiry-based 5E lessons. Content analyses identified four key elements of inquiry-based teaching from the methods course. First, inquiry-based instructional approaches engage students with a variety of critical thinking skills. For example, Lucy wrote in her final paper, "through inquiry-based lessons students learn skills for observing, questioning, hypothesizing, predicting, investigating, and interpreting." And Ashley explained the benefits of inquiry-based approaches in that these instructional practices, "[let] students explore the subject by planning and conducting investigations … [and that] students should really learn from their own research."

A second theme that emerged was that an inquiry-based approach teaches students to self-regulate their own learning. Lucy and Zoey wrote, respectively, that "students take ownership and accept responsibility in an inquiry-based lesson" and "inquiry-based science encourages students to formulate their own ideas and questions to be tested … students are also given more control over their own learning." Overall, responses reflected an understanding of current science education standards and integrated important features of learning principles (e.g., self-regulation of learning, metacognition) within inquiry-based science instruction. Similar to their learning of ELLs, these PSTs had also completed a stand-alone course in human development and cognition as part of their certification coursework, but through the SCDC framework, they were able to apply cognitive theory to the 5E science lessons they taught.

Third, PSTs, using inquiry-based instruction, reimagined teachers' role as facilitators of learning through questioning, discovering, and designing opportunities to explore science concepts. Lucy commented, "in inquiry-based science the teacher's role is to lay a foundation for the students … throughout the lesson the teacher's role is to facilitate and guide the students." Finally, the PSTs also became aware of how-inquiry lessons engaged students. For example, Charlotte described how important it is to "engage the students in a lesson first so … to learn about a new object or idea." These statements reflected a shift in PSTs' understanding of teacher and student roles in the classroom during science lessons. These PSTs embraced the role of facilitator as it also released them from the pressure of having to be an expert in science content.

In summary, through their own learning experiences in the course and associated practicum, the PSTs learned how to use inquiry to teach science. They specifically identified how an inquiry-based instructional approach encouraged the development of critical thinking skills, science process skills, and a greater awareness and self-regulation of one's own learning.

Research Question 4: How Did the PSTs View Teaching Elementary Science at the End of the Course and What Did They Identify as Necessary to Their Future PD?

In response to our final research question, we found that these PSTs' views on teaching elementary science postcourse were grouped according to five core findings, that PSTs: (a) planned to use various SCDC strategies and resources to teach students science, (b) recognized four major equity issues (gender, SES, ethnicity, and ELLs) and the importance of addressing them, (c) viewed teaching science as a continuous learning process, (d) changed their views of how science instruction should be enacted over the course, and (e) viewed integration of science with other subject areas as the most effective way to balance district curriculum demands and still meet science education standards. We will address each of these five findings in turn.

Planned to use various strategies and resources to teach science. Evidence indicated that most PSTs planned to use inquiry-based teaching during student teaching and later as in-service teachers. As a group, PSTs seemed to understand the value of inquiry-based science instruction and how it can provide greater access to science. Molly wrote, "[Inquiry] allows for students to use their prior knowledge/interests/curiosities to form further knowledge that matters to them about the world around them." Lucy commented, "The most important way I plan to use my science methods experiences in future classrooms is to use inquiry-based lessons based on the positive experiences I have had with them." These statements underscore the importance of modeling inquiry-based lessons in methods courses to persuade PSTs of the effectiveness of inquiry-based learning, as well as opportunities for practical application of planning and teaching their own science lessons to build confidence and a positive attitude toward teaching science.

The science notebook was one key teaching resource that was developed throughout the methods course. Initially, many of the PSTs resisted their use as they saw it as only an organizational tool rather than a learning tool, preferring a three-ring binder to organize their course materials. However, by the end of the course, the majority of the PSTs came to view their notebook as a teaching resource that mirrored elementary students' science notebooks as documentation and a product of their own science learning. In her final paper, Evelyn wrote that she intended "to use little journals" so that the students could "learn to draw pictures of their observations." And Anne reported, "I plan to use reflective journals with my students in both my student teaching and my official teaching practices. I think they provide a way for students to keep track of their progress, thoughts, observations, and questions regarding science." In addition, PSTs emphasized the importance of providing students with collaborative learning experiences to ask questions, explain and share their ideas, and become actively engaged in exploration, all of which point to the key role of oral discourse in an SCDC. One PST, Emma, stated, "Students should be learning, using, developing, gaining, discussing, journaling, questioning, problem solving and risk-taking." As a whole, these comments provide a snapshot of how PSTs came to understand the learning that could be achieved through integrating science skills with specific cognitive and language tasks.

Addressing major equity issues. Our artifact analysis revealed that PSTs recognized four major equity issues of gender, SES, ethnicity, and ELLs, and the importance of addressing each to improve students' access to science education. PSTs noted that cultural and gender issues could be addressed through classroom instruction and most planned to do so. In addition, they mentioned using visual aids, realia (i.e., manipulatives), and hands-on approaches to make content more accessible by providing comprehensible input for language minority students. Emma noted that "equity means guaranteeing fair treatment and access to resources and programs for all students. Through inquiry we can address these issues by teaching for empowerment." Ashley commented, "I want to make sure that all the students in my classroom feel equal and recognize diversity of men and women in science, because to me, all my students have the same opportunities in life." It appeared that through the course and practicum experiences with language minority and low-SES students, PSTs finished with a better awareness of how to support diverse students and translate equity from theory to practice.

Learning to teach science as a continuous process. The PSTs viewed PD as part of their overall, long-term teaching goals. The two most common PD goals mentioned by the PSTs were to continue their own education by engaging in PD in how to teach science and to improve their science content knowledge. As one PST, Elisabeth, wrote, "I definitely want to continue my professional development in science . . . attend workshops or classes that offer some techniques about teaching science to elementary students." Having broken through their initial trepidation with teaching science, the PSTs not only gained a better understanding of different ways to teach science but were also able to identify what they knew and what they needed to learn in order to teach elementary science more effectively.

PSTs as a whole agreed that deeper science content knowledge would ultimately benefit student learning, and an increase in their understanding of inquiry-based science would lead to their increased comfort level for teaching elementary science concepts. The most common ways that PSTs thought these goals could be achieved were: (a) self-education (e.g., reading and learning more about science); (b) attending seminars, conferences, and workshops; and (c) collaboration with peer teachers. As Amelia noted, "One teacher alone can make a very good lesson, but building it with new ideas from a fellow teacher makes it possible to see a great lesson that may not have come about without extra help."

Having co-taught during the course, PSTs recognized the value of planning with colleagues, and these statements seemed to be a strong indication that they would look for this type of collegiality and support in their future teaching positions.

View of science instruction. Fourth, it was evident from our analysis that PSTs' views of science instruction changed over the course. Most frequently, they mentioned that they began to view teaching science more effectively with inquiry-based instructional strategies rather than always relying upon direct instruction, as had been their initial belief. Because they had previously believed that they would have to deliver all science content themselves through direct instruction, they were uncomfortable with the prospect of teaching science, especially when most of them viewed science as an area of personal weakness. One PST, Emma, described the importance of inquiry-based teaching as "students need to discover ideas so that they are more meaningful to them and so they can apply their knowledge out of context." PSTs identified the importance of engaging students in exploration, discussion, and explanation, which were key elements of an SCDC. Moreover, many PSTs viewed the teacher as a facilitator who guides students to connect new information to prior knowledge and construct their own meaning.

The value of integrated science instruction. Lastly, findings indicated that most PSTs viewed integration of science and other subjects was an effective way to balance curricular demands. This was exemplified by Grace, who wrote, "to ensure meeting state and national science education standards in my classroom while competing with other curriculum demands, I will make effort to integrate other content areas into science and to integrate science into other content areas." Charlotte stated that her goal was to incorporate science with other subject areas because it helps students realize how much "science relates to many different subject areas." PSTs frequently mentioned concern with covering the curriculum and the lack of science lessons taught in their practicum classrooms by their cooperating teachers. As they learned more about connecting science instruction to language arts (e.g., science notebooks), they began to envision the potential integration of disciplinary content as a more empowered teaching approach.

Discussion

As the U.S. educational policy leadership advocates for 21st century skills and problem-solving, a distinct divide persists between the recommended elementary science inquiry-based instructional strategies (Achieve, Inc., 2013; AAAS, 1993; NRC, 1996) and the reality of daily classroom practices. The research reviewed here clearly indicates a deficiency in the quantity (McMurrer, 2008) and quality of science instruction currently being taught in elementary classrooms by highly qualified elementary teachers of science (Appleton, 2007). One way to bridge this gap is to address science education in teacher education programs. Despite the short duration of the science methods course in this study, all PSTs indicated positive changes in their views of science instruction. Like Richardson and Liang (2008), this finding suggests that an interdisciplinary model of teaching science can change PSTs' understanding of inquiry-based science instruction. The course design allowed PSTs to graduate feeling more confident and compelled to teach using inquiry-based instructional practices. Similarly, Schwartz and Gwekwerere's (2006) documented PSTs' shift toward inquiry-based instruction after participating in a model-centered methods course. Most PSTs valued and planned to use various SCDC instructional strategies and resources in their future classrooms. In particular, PSTs viewed interdisciplinary instruction as an ideal way to create connections between science and other subjects, as well as build a deeper conceptual understanding of science for all their future students. By recognizing that teaching science through rich inquiry activities involves oral and written discourse (Hand et al., 2003), for academic language literacy as well as scientific literacy, PSTs accepted that the SCDC model could benefit students' education and optimize limited instructional time. With opportunities to teach science to low-SES, language minority students, PSTs also gained an appreciation of how using SCDC instructional strategies can better engage diverse learners. With rising numbers of diverse students in U.S. schools, it is critical that teachers know how to meet their learning needs and encourage all children to explore and enjoy scientific activities (Lee & Fradd, 1998).

As early as the 1970s, inquiry-based science instruction was shown to effectively teach "basic" academic skills (Greenleaf, 1982). Scientific inquiry as part of a model of an SCDC that explicitly uses language arts skills may address the marginalization of science education that has been inadvertently fostered by federal NCLB accountability measures (Goldston, 2005). With the national average for elementary science instruction at a mere 56 minutes per week (McMurrer, 2008), it is imperative for education courses to model interdisciplinary instructional frameworks so that new teachers will be better armed to advocate for science education (Achieve, Inc., 2013). A framework such as the one used in this study (Baker et al., 2009) illustrates how more time for science instruction can be intentionally and authentically woven into students' academic experiences. By extension into teacher education, restructuring science methods courses to include interdisciplinary, inquiry-based instruction would allow PSTs to experience first-hand the way basic skills, such as math, reading, and writing, can be taught in conjunction with science content using a variety of oral and written discourse instructional strategies.

Literacy tools, e.g., science notebooks, incorporated into methods courses can support PSTs in articulating and sharing their understanding of science concepts through the use of language arts (Hand et al., 2003). By using an area of strength with which to learn how to teach science content, PSTs can become more comfortable with science curricula and see how science notebooks may help their future students learn not only science but also language arts. Such cross-cutting standards are in the NGSS (NGSS Lead States, 2013), but the first exposure a teacher has with them should not be on their first day as a new teacher. Teacher educators must endeavor to be more proactive in preparing elementary teachers to meet interdisciplinary learning objectives.

While there is little empirical data on the effects of field experiences (NRC, 2010), there is some evidence that PSTs find that "field experiences reinforce the material they have learned in the classroom, and that the experiences provide useful opportunities to put it into practice" (NRC, 2010, p. 52). In addition to methods instructors employing standards-inspired course objectives, we argue that complementary field experiences for the purpose of teaching science must become an integral part of PSTs' learning in order to increase science teaching self-efficacy. Unfortunately in our study, coinciding with post-NCLB national decrease of science instruction, only about two-thirds of PSTs saw even limited science lessons being taught in their host classrooms, while the other third never saw a science lesson taught by their cooperating teachers. This creates a critical gap between PST education and in-service teaching practices. By using carefully selected master science teacher practicum placements, PSTs can witness first-hand the benefits of inquiry-based instruction (Schroeder et al., 2007). Finally, in an effort to promote science education for diverse students, it is critical to provide placements that present diversity to give PSTs the opportunity to improve their capacity to teach all students.

Conclusions and Future Research

Studies of teacher learning conducted over a full semester, in addition to careful longitudinal follow-up studies, as PSTs who become classroom teachers could provide more detail about how best to use an interdisciplinary model of an SCDC to teach elementary science and provide evidence of its efficacy and effectiveness as an approach. As teacher educators, we may do a disservice to our elementary PSTs by teaching methods in segregated academic disciplines. By providing integrated methods courses over multiple semesters using a model of an SCDC, perhaps there would be a greater chance of PSTs adopting an interdisciplinary stance toward elementary education in their future classrooms. Engaging school districts as school partners in pilot studies of reformed science instruction with a model of an SCDC would allow for better alignment between teacher education programs and the PSTs' clinical experiences, as well as support standards-based professional learning communities. Such future studies would likely yield supplementary information to inform teacher educators of the effects of an interdisciplinary model. Specifically, design-based research could more precisely locate the learning activities that are critical to learning how to build an SCDC and, consequently, what positively affects PSTs' self-efficacy, knowledge, and inclination to teach science in their future classrooms.

This category of research is important because it empirically builds an understanding of elementary PSTs' perspectives about learning to teach science and their ensuing philosophies. Both professional constructs follow PSTs into their careers and ultimately affect their future students' learning experiences. It is vital that instructors of elementary science methods courses for PSTs, and those who provide PD for in-service elementary teachers, know how to teach key elements of science learning for the 21st century.

References

Abraham, M. R. (1998). The learning cycle approach as a strategy for instruction in science. In B. Fraser and K. Tobin, eds., *International Handbook of Science Education, (Part 1)* (pp. 349–362). Dordrecht, The Netherlands: Kluwer Academic Publishers.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for Science Literacy. Project 2061*. New York: Oxford University Press.

Appleton, K. (2007). Elementary science teaching. In S. K. Abel & N. G. Lederman, eds., *Handbook of Research on Science Education* (pp. 493– 535). Mahwah, NJ: Lawrence Erlbaum.

Baker, D. R., Lewis, E. B., Purzer, S., Watts, N. B., Uysal, S., Wong, S., …, Lang, M. (2009). The Communication in Science Inquiry Project (CISIP): A project to enhance scientific literacy through the creation of science classroom discourse communities. *International Journal of Environmental and Science Education*, 4(3), 259–274.

Bransford, J. D., Brown, A., & Cocking, R. (2000). *How People Learn: Mind, Brain, Experience and School*. Washington, DC: The National Academies Press.

Britner, S. L., & Finson, K. D. (2005). Preservice teachers' reflections on their growth in an inquiry-oriented science pedagogy course. *Journal of Elementary Science Education*, *17*(1), 39–54.

Bybee, R. W. (1997). *Achieving Science Literacy: From Purposes to Practices*. Portsmouth, NH: Heinemann.

Cavallo, A.M.L., Miller, R. B., & Saunders, G. (2002). Motivation and affect toward learning science among preservice elementary school teachers: Implications for classroom teaching. *Journal of Elementary Science Education*, *14*(2), 25–38.

Cone, N. (2009). Preservice elementary teachers' self-efficacy beliefs about equitable science teaching: Does service learning make a difference? *Journal of Elementary Science Education*, *21*(2), 25–34.

Creswell, J. W. (2007). *Qualitative Inquiry & Research Design, Choosing among Five Approaches*. Thousand Oaks, CA: Sage Publications.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock, ed., *Handbook of Research on Teaching* (3rd ed., pp. 119–161). New York: Macmillan.

Goldston, D. (2005). Elementary science: Left behind? *Journal of Science Teacher Education*, *16*(3), 185–187.

Greenleaf, T. (1982). Uncle Sam wants you: New federal science-improvement program aims to recruit principals. *Principal*, *62*(1), 19–21.

Hand, B. M., Alvermann, D. E., Gee, J. P., Guzzetti, B. J., Norris, S. P., Phillips, L. M., …, Yore, L. D. (2003). Message from the "Island group": What is literacy in science literacy? *Journal of Research in Science Teaching*, *40*(7), 607–615.

Hanuscin, D. L., & Lee, M. H. (2008). Using the learning cycle as a model for teaching the learning cycle to preservice elementary teachers. *Journal of Elementary Science Education*, *20*(2), 51–66.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). *A Theory of Instruction: Using the Learning Cycle to Teach Science Concepts and Thinking Skills* (NARST Monograph, Number One). National Association for Research in Science Teaching.

Lee, C. A., & Houseal, A. (2003). Self-efficacy, standards, and benchmarks as factors in teaching elementary school science. *Journal of Elementary Science Education*, *15*(1), 37–56.

Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English-language backgrounds. *Educational Researcher*, *27*(4), 12–21.

Lewis, C. C. (2002). *Lesson Study: A Handbook of Teacher-Led Instructional Change*. Philadelphia, PA: Research for Better Schools.

Lewis, E. B., Kraft, K. J., Bueno Watts, N., Baker, D. R., Wilson, M. J., & Lang, M. G. (2011). Elementary teachers' comprehension of flooding through professional development and use of self-regulation strategies. *International Journal of Science Education*, *33*(11), 1473–1512.

McMurrer, J. (2008). Instructional time in elementary schools: A closer look at changes for specific subjects. A report in the series, *From the Capitol to the Classroom: Year 5 of the No Child Left Behind Act*. Washington, DC: Center on Education Policy.

Mechling, K. R., & Oliver, D. L. (1983). *What Research Says about Elementary School Science*. Washington, DC: National Science Teachers Association.

Minger, M. A., & Simpson, P. (2006). The impact of a standards-based science course for preservice elementary teachers on teacher attitudes toward science teaching. *Journal of Elementary Science Education*, *18*(2), 49–60.

Morrison, J. (2008). Elementary preservice teachers' use of science notebooks. *Journal of Elementary Science Education*, *20*(2), 13–21.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: The National Academies Press.

National Research Council. (2010). *Preparing Teachers: Building Evidence for Sound Policy*. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: The National Academies Press.

Nichols, S. L., & Berliner, D. C. (2007). *Collateral Damage: How High-Stakes Testing Corrupts America's Schools*. Cambridge, MA: Harvard Education Press.

Oakes, J. (1986). *Keeping Track: How Schools Structure Inequality*. New Haven, CT: Yale University Press.

Park Rogers, M. A. (2009). Elementary preservice teachers' experience with inquiry: Connecting evidence to explanation. *Journal of Elementary Science Education*, *21*(3), 47–61.

Richardson, G. M., & Liang, L. L. (2008). The use of inquiry in the development of preservice teacher efficacy in mathematics and sciences. *Journal of Elementary Science Education*, *20*(1), 1–16.

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*(10), 1436–1460.

Schwartz, C. V., & Gwekwerere, Y. N. (2006). Using a guided inquiry and modeling instructional framework (EIMA) to support preservice K-8 science teaching. *Science Education*, *91*(1), 158–186.

Smith, L. K., & Gess-Newsome, J. (2004). Elementary science methods courses and the National Science Education Standards: Are we adequately preparing teachers? *Journal of Science Teacher Education*, *15*(2), 91–110.

Smith, L. K., & Southerland, S. A. (2007). Reforming practice or modifying reforms?: Elementary teachers' response to the tools of reform. *Journal of Research in Science Teaching*, *44*(3), 396–423.

Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School Science and Mathematics*, *100*(7), 374–379.

Varella, G. F., & Veronesi, P. D. (2004). Preservice teachers defining "Self-As-Teacher": The elementary science teaching rationale. *Journal of Elementary Science Education*, *16*(1), 35–48.

Varma, T., Volkmann, M., & Hanuscin, D. (2009). Preservice elementary teachers' perceptions of their understanding of inquiry and inquiry-based science pedagogy: Influence of an elementary science education methods course and a science field experience. *Journal of Elementary Science Education*, *21*(4), 1–22.

Vygotsky, L. (1986). *Thought and Language*. Cambridge, MA: MIT Press.

Appendix

Research Instruments

Pre-/post-course questionnaire. The purpose of the questionnaire was to reveal the PSTs' prior knowledge and dispositions toward science education in order to better support their learning throughout the course and to model a diagnostic assessment. The questions were designed with consideration of the research findings in elementary teacher literature concerning science education (Appleton, 2007) and the general aspects of the instructional model of a scientific classroom discourse community. With the exception of questions 1, 2a, and 3 the survey was administered again at the end of the course to gauge what, if anything, the PST's had gained in terms of awareness, revision, or new learning of teaching science had occurred.

Questions

1. What grade level do you intend to teach once you became a classroom teacher?
2. (a) How much experience you have had with science?
   (b) What is your comfort level with science?
3. What strengths and interests do you have to offer your future students?
4. What are your goals for teaching science?
5. What is the purpose of science education for elementary-aged students?
6. (a) What do you know about teaching science?
   (b) From what experience(s)?
7. From the program experiences what have you observed about teachers and students during science lessons?
8. (a) What does equity (gender, ethnicity, disability) mean to you as a teacher in terms of teaching science?
   (b) What are some ways to make your classroom an equitable learning environment?
9. How does a student's linguistic ability affect his/her learning in science?
10. How does a student's cultural perspective affect their learning experiences in science?
11. (a) What can you do as a child's teacher to address language level/literacy?
    (b) What can you do as a child's teacher to address non-Western cultural perspectives during science lessons?
12. What might be some productive ways to introduce a new science concept to students?
13. How can you deepen a student's understanding of a science concept?
14. What is the role of assessment in teaching and learning?

Focus group interview. The purpose of the focus group interview was to triangulate the findings from the questionnaire and debrief the PSTs' experience with the course. The agenda items from the interview were (* = questions that were generated as the interview took place):

1. What aspects of the course were most helpful in learning how to teach science for elementary school?
2. What would be some ways we could improve the whole notebook experience?*
3. What aspects were least helpful in learning? i.e., What could you have done without?
4. What concepts were easier to learn than others?
5. Was there any of the science content that you felt like needed more time? *
6. When you think about the course design, how much time was spent on these various concepts, what would you have liked to have learned more about?
7. In terms of time—the program, and being on the short schedule for the course, how pressed were you feeling? *
8. Was there any course material that you felt was redundant that you feel could have eliminated (e.g., that you had in another class)?
9. What strategies and/or resources are you planning on using next semester [in student teaching]?
10. How do you feel about teaching science now that you have completed a course in science methods, and how is your comfort level?