Elementary Teachers' Knowledge and Practices in Teaching Science to English Language Learners

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UNIVERSITY OF MIAMI

ELEMENTARY TEACHERS’ KNOWLEDGE AND PRACTICES IN TEACHING SCIENCE TO ENGLISH LANGUAGE LEARNERS

By
Alexandra O. Santau

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Coral Gables, Florida

June 2008
UNIVERSITY OF MIAMI

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

ELEMENTARY TEACHERS’ KNOWLEDGE AND PRACTICES IN TEACHING SCIENCE TO ENGLISH LANGUAGE LEARNERS

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Efforts to improve education – more concretely science education – by creating fundamental shifts in standards for students and teachers have been launched by educators and policy makers in recent years. The new standards for science instruction address improvements in student learning, program development, assessment, and professional development for teachers, with the goal to prepare US students for the academic demands of the 21st century. The study examined teachers’ knowledge and practices in science instruction with English language learning (ELL) students. It also examined relationships among key domains of science instruction with ELL students, as well as profiles of teaching practices. The four domains included: (1) teachers’ knowledge of science content, (2) teaching practices to promote scientific understanding, (3) teaching practices to promote scientific inquiry, and (4) teaching practices to support English language development during science instruction. The study was part of a larger 5-year research and development intervention aimed at promoting science and literacy achievement of ELL students in urban elementary schools. The study involved 32 third grade, 21 fourth grade, and 17 fifth grade teachers participating in the first-year implementation of the intervention. Based on teachers’ questionnaire responses, classroom observation ratings, and post-observation interviews, results indicated that (1)
teachers’ knowledge and practices were within the bounds of the intervention, but short of reform-oriented practices and (2) relationships among the four domains existed, especially at grade 5. These findings can provide insights for professional development and future research, along with accountability policies.
To my mother Lucia,
for her tough love and endless sacrifice
Acknowledgements

My deepest gratitude goes to my advisor Professor Okhee Lee, who patiently guided me toward becoming a scholar. Thank you for pushing and challenging me, while giving me countless opportunities for personal and professional growth. The best advice you have ever given me – to make myself valuable – will accompany me for the rest of my career.

I would like to express my thanks and appreciation to my committee members. Dr. Cory Buxton, thank you for always being positive and for the invaluable advice with the job search. Dr. Walter Secada, thank you for always pushing me to own my research. Dr. Randy Penfield, thank you for your support and patience with my methodology.

The most sincere “thank you” goes out to my family, for your unconditional love and support from thousands of miles away. Thank you to my mother, Lucia Pasere, for your kind and encouraging words of wisdom. Thank you to my father, Ioan Santau, for never doubting me. Thank you to my aunt, Lavinia Eberhardt, for giving me hope when there seemed to be no light at the end of the tunnel. Thank you to my grandmother Silvia Pasere, for tirelessly praying for me.

Thank you to my best friend Dr. Yasemin Hocaoglu. You have been the most magnificent friend ever. Endlich Übertritt ins Berufsleben!

Thank you to Wayne Wasserberg for encouraging me, supporting me, and putting up with me during my doctoral study. You have been wonderful to me.

Thank you to Dr. Jagdeep Sodhi, for not accepting any less of me.

Thank you to my friends in Munich, Chicago, and Miami. You all gave me the balance to pull through.
Thank you to Jaime Maerten-Rivera for all your help and advice. Thank you to the P-SELL team for working with me and making work fun.
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CHAPTER I

Introduction

In recent years, policymakers and educators have launched efforts to improve education by creating fundamental shifts in standards for students and teachers. The new standards for science instruction – based on recommendations made during the past decade by the American Association for the Advancement of Science (1989, 1993) and the National Research Council (1996, 2000) – address improvements in student learning, program development, assessment, and professional development for teachers. This reform movement simply stems from the belief that U.S. science instruction is neither suitable nor sufficient to equip students with the scientific concepts and skills needed for the 21st century (Romberg et al., 2005). Therefore, the success of the reform depends on the qualifications and effectiveness of teachers, which makes teacher professional development a major focus of systemic reform initiatives (Corcoran, 1995).

Appending to the changes prompted by the science reform movement, further pressures are added by increased expectations for high academic achievement by all students, as embodied in the No Child Left Behind Act (NCLB) of 2001 (PL 107-110). This act redefines the responsibilities of teachers, as accountability systems place a great deal of pressure on teachers to implement well articulated curriculum, instruction, and assessment systems that foster the academic growth and development of an increasingly diverse student population.

Teaching science in the era of reform has become a comprehensive endeavor to be undertaken by today’s teachers. While teachers are expected to possess the adequate science content knowledge, reform suggests that teaching for science literacy and
therefore understanding through employing practices that encourage scientific inquiry lies at the heart of the science standards. In addition, special considerations have to be given to students of diverse cultural and linguistic backgrounds, including English language learners or ELL students. However, research literature suggests that what is currently happening in science classrooms may not have reached the expected level of reform-based science teaching with regard to knowledge of science content, scientific understanding, scientific inquiry, and English language and literacy with ELL students, as described next.

In order to create an environment that promotes science literacy, teachers need to develop a deep understanding of the scientific content appropriate to the instructional level at which they teach. Teachers should have knowledge of the science topics being taught, the relationship to the content prior to and beyond the instructional level of students, the ways in which students reason and understand scientific content, and the nature of mathematical and scientific processes (Romberg et al., 2005). Moreover, teachers are required to have the ability to communicate basic knowledge and to develop advanced thinking and problem-solving skills among their students (Loucks-Horsley et al., 1998). In the midst of the requirements of science reform, elementary teachers must be prepared to improve their knowledge of science content and understanding of scientific inquiry (Garet et al., 2001; Kennedy, 1998).

In reality, literature suggests that teachers have relatively weak understandings of science, whether it is substantive knowledge of science content, the nature of science, or science inquiry (Davis et al., 2006). Moreover, teachers often possess the same
misconceptions as their students, and frequently compensate for inadequacies with science teaching strategies that are not in concordance with reform guidelines.

Both the American Association for the Advancement in Science (1993) and the National Research Council (1996) stress science literacy as the primary goal for reform in science teaching. Science literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity (NRC, 1996, 2000). Therefore, the ultimate purpose of science instruction should involve students’ understanding of scientific concepts and skills, as well as their ability to apply scientific phenomena to real world situations. Scientific understanding can not be confused with scientific knowledge, however. Scientific knowledge refers to facts, concepts, principles, laws, theories, and models. Scientific understanding requires the acquisition of a complex structure of many types of knowledge, including the ideas of science, the relationships between ideas, reasons for these relationships, ways to predict natural phenomena, and ways to apply them to other events (NRC, 1996). Science literacy does not merely involve learning the concepts and procedures of scientific domains, but also how to use these ideas in previously un-encountered situations or how to solve non-routine problems, similar to acquiring fluency in a foreign language (Romberg et al., 2005). Reform classroom practices should give students the opportunity to target science literacy and experience how scientists develop conjectures about the world and how they justify assertions and a base from which to reason and model data they encounter in real life.

Scientific inquiry, as suggested by the Science Standards, is a way of exploring science in a “hands-on and minds-on” manner, rather than as a process through which
students learn skills such as observing and experimenting. Scientific inquiry is a way of developing knowledge and understanding of science content. By means of scientific inquiry, students learn how to ask questions and use evidence to answer them, similar to professional scientists. In the process of becoming familiar with the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions. Therefore, in order to ultimately raise scientific understanding, teachers need to develop teaching practices in order to engage students in scientific inquiry and develop arguments based on evidence, along with their students (NRC, 2000).

Similar to the situation concerning teacher science content knowledge, the current classroom practices of teachers concerning scientific understanding and scientific inquiry are not in concordance with the practices set forth by science reform. Because many teachers have not had the opportunity to learn how to teach for understanding and for inquiry, they often tend to amalgamate conventional teaching strategies with reform ones, ultimately standing in the way of promoting science literacy (Lee et al., 2004).

Ample knowledge of science content and inquiry practices to promote student scientific understanding is yet not sufficient in today’s reform-oriented world, especially as the school-age population in the U.S. is becoming increasingly diverse. Teachers have the added responsibility to recognize these students’ unique learning needs – culturally, linguistically, and socioeconomically – consequently leading to a complex situation that contributes to persistent achievement gaps in content areas, particularly science.

However, many teachers are not prepared to meet the learning needs of students from varied backgrounds. Many teachers lack knowledge of how best to work with
students who are from diverse cultures or who are learning English as a new language (Bryan & Atwater, 2002; National Center for Education Statistics, 1999). While ELL students must learn science and English language and literacy simultaneously, the research traditions and teacher education programs have kept these two issues largely separate (Lee, 2005).

In addition to exploring teacher knowledge and practices in the context of reform-based science, as described above, it is critical to investigate whether there are relationships among the four domains described above, and between which domains these relationships exist. For example, the science standards consistently discuss scientific understanding and scientific inquiry as closely intertwined and as dependent on teacher knowledge and practices, along with most studies on scientific inquiry, which presume that scientific inquiry will enhance scientific understanding. Despite such conjectures conceptually, empirical studies on these relationships are limited.

The reality of current science practices calls for professional development that addresses these issues individually as well as collectively. In order for teachers to gain more mastery of the science content they are expected to teach, this study can provide a baseline for shaping professional development that focuses on improving teachers’ science content knowledge. By means of examining how teaching practices for scientific understanding and scientific inquiry compare to the reform standards, this study can further give insights as to how professional development can be designed in order to address these issues. In examining teacher practices for English language development, this study then can reveal how – if at all – teachers deal with this important issue. The findings can subsequently be used to advance professional development in addressing the
necessity of English language development. Based on findings of classroom practices in general, professional development can be shaped according to the areas that need improvement, while capitalizing on strong points.

Additionally, this study has the potential to provide initial insights through revealing statistical relationships into how a connection may exist between what teachers know about the science content, their classroom practices to promote students’ understanding and inquiry, along with their practices to support ELL students’ English language development. Based on these findings, professional development can be designed with the consideration of these relationships. Once undergoing professional development specifically tailored to address these domains, teachers can be expected to develop classroom practices closer to reform standards, and to build consistency among the four constructs. Furthermore, teachers will learn that it is important to incorporate all four constructs into their science instruction.

Purpose of the Study

The study took place during the first three years of a larger 5-year research and development project focused on implementing curriculum units and teacher professional development workshops. The intervention is aimed at promoting science and English literacy achievement of ELL students in urban elementary schools at a time when science is becoming a part of accountability policies in the U.S. The larger project involves teachers and students in grades 3 through 5 at 14 elementary schools in a large urban school district. All these schools enroll high proportions of ELL students and students from low socioeconomic status (SES) backgrounds, and have traditionally performed poorly according to the state’s accountability plan.
As part of the larger research project, this particular study involved 32 third grade, 21 fourth grade, and 17 fifth grade teachers during their respective first-year implementation of the professional development intervention. This study examined two sets of questions about teachers’ knowledge and practices in teaching science to ELL students. The four domains under investigation included: (1) teachers’ knowledge of science content, (2) teaching practices to support scientific understanding, (3) teaching practices to support scientific inquiry, and (4) teaching practices in science to support English language development.

The first set of questions examines how teachers’ science knowledge and practices compare to the standards of science reform. Do practices for scientific understanding and inquiry meet the requirements of the science reform, do they fall below, or do they exceed? Furthermore, science content knowledge of teachers is examined, in revealing how well teachers know the content they are expected to teach. The last examined variable is how teachers incorporate English language development into their science lessons during instruction with ELL students.

The second set of questions examines relationships among key domains of science instruction with ELL students based on third, fourth, and fifth-grade teachers’ survey-based self-reports of their science content knowledge and classroom practices, third-party observations of those knowledge and practices, and post-observation interviews. These strategies are employed to establish relationships among what teachers think/say they do, what teachers are observed doing during their science instruction, and what teachers perceive they did during their instruction subsequent to teaching a science lesson.
In the context of science reform and accountability policies, it is important to investigate teacher practices in promoting scientific understanding and inquiry in their classrooms, along with their science content knowledge. Further examining how the relationships among these domains are interrelated provides insight into whether relationships exist and to what extent. This study uses mixed methods including teacher surveys, classroom observations, and interviews with teachers, giving rise to the following research questions:

1. What are elementary teachers’ knowledge and practices in each of the four domains of teaching science to ELL students during the teachers’ first-year participation in the intervention?
   a. Description of patterns of teacher knowledge and practices.
   b. Illustration of the patterns with classroom examples.

2. What are the relationships among the four domains?
   a. Description of the relationships among the four domains.
   b. Illustration of the profiles of teaching practices.

The findings of this study can add to the knowledge base of developing effective professional development by shaping it according to areas needing improvement, while building on existing strengths. (RQ1). Furthermore, professional development can be refined in how to address the relationships among the constructs (RQ2).
CHAPTER II

Literature review

In the past century, teachers’ science content knowledge was rigorously tested through exams administered to teachers, strongly emphasizing the recollection of scientific facts. Teachers were assessed by the ability to define terms and concepts such as “specific gravity” or “adhesion” (Shulman, 1986). Today’s standards, in contrast, have stirred away from the mechanistic approach of testing teachers, and are now stressing that a teacher’s capacity to teach is of essence, which gives science teaching a new silhouette: strong science content knowledge, along with teaching practices to promote scientific understanding and inquiry to an increasingly culturally, linguistically, and socioeconomically diverse student body. The first section of the following literature review examines what research on classroom practices and professional development says about the four domains of interest in this study – teachers’ science content knowledge, practices for scientific understanding and inquiry, and practices for English language development – in more depth. The second part of the review focuses on existing literature concerned with relationships thus far examined among these constructs.

*Teachers’ Knowledge and Practices in Teaching Science to ELL Students*

With regard to the four domains of teachers’ knowledge and practices examined in this study, the discussion focuses on the goal of reform-oriented practices, as compared to the current status of elementary teachers’ knowledge and practices reported in the literature. The discussion then highlights emerging literature on professional development interventions.
Teacher Knowledge of Science Content

Reform-oriented practices. In general, the science reform agrees that in order for teachers to be able to teach science to students, they should have knowledge of the subject they are required to teach, along with content-specific teaching strategies (Kennedy, 1998). Teachers should have deep and complex understandings of science concepts, be able to make connections among science concepts or topics, and be able to apply science concepts to explain natural phenomena or real world situations (Lee et al., 2007).

Teachers should develop an understanding of the Nature of Science (NOS), which is an important component of science reform efforts and is considered an essential component of science literacy. It is defined as the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge and understanding (Abd-El-Khalick et al., 1998; NRC, 2000). Teachers must have knowledge and understanding of NOS in order to be able to teach it, along with strong pedagogical practices and other components, such as teachers’ comfort with their understanding of NOS, their ability to assess students’ conceptions of NOS, and their knowledge about how to locate resources to teach NOS (Abd-El-Khalick et al., 1998). These skills then have to be translated into instructional practices (Abd-El-Khalick et al., 1998).

Kennedy (1998), in her review of literature on educational reform and subject matter knowledge, concludes that it is imperative for teachers to possess science subject content knowledge. She expands the idea of content knowledge by adding dimensions of knowledge. First, she mentions the idea of quantity vs. quality of knowledge. Especially
in science, students often ask questions far beyond the curriculum, and therefore a large quantity of content knowledge should be in place. This knowledge should be of high quality, meaning that it goes farther than the mere recitational subject matter knowledge, reaching into understanding. Second, conceptual knowledge should be emphasized as a) a sense of proportion (by being able to visualize to students the size of abstract entities); b) understanding the central ideas (how the concept relates to the big picture); c) seeing relationships among ideas (that concepts do not exist in isolation of each other; d) elaborated knowledge (including a variety of examples and details); and e) reasoning ability (developing arguments about phenomena, solving real problems, and justifying one’s solutions). Third, pedagogical content knowledge enables teachers to translate complex or difficult ideas into concepts that students can relate to and grasp, and which in turn depends heavily on the conceptual dimensions of knowledge.

Some argue that even in the event of exemplary science content knowledge, it is not enough to achieve a high quality learning environment. Pedagogical content knowledge (PCK), defined as the knowledge of the representations, analogies, and strategies useful for teaching a particular topic, as well as knowledge of students’ ideas about a topic, is an essential component of science teaching (Shulman, 1986). It is now assumed that subject matter knowledge and teaching experience are prerequisite to PCK (Cochran & Jones, 1998).

The development of PCK, which combines science content knowledge and knowledge of pedagogy, has indeed been shown to connect teachers’ knowledge of NOS and science content knowledge (Schwartz & Lederman, 2002; Tobin et al., 1994). The main point Schwartz and Lederman (2002) make is as follows:
Subject-matter knowledge alone, NOS knowledge alone, or pedagogical knowledge alone will not suffice. For teachers to successfully address NOS, attention must be given to the development of “traditional” subject-matter knowledge, NOS knowledge, and pedagogy, as well as the interaction among these domains. (p. 232)

Although it is now known what instructional strategies promote teacher learning and what components constitute teacher knowledge (Cochran & Jones, 1998; Shulman, 1986), some argue that the cognitive mechanisms behind the teachers’ learning have been neglected with traditional ways of measuring teacher knowledge. Davis (2004) claims that knowledge integration involves applying knowledge integration processes (identifying weaknesses in knowledge, adding new ideas to the knowledge repertoire, and linking and distinguishing ideas) to scientific principles, real-world experiences, and classroom-based experiences in order to develop robust understandings. These components seem to play an important role in the acquisition of science content knowledge.

Current practices. Teachers’ knowledge of science content affects science instruction and student learning. Newton and Newton (2001) found that teachers with incomplete subject content knowledge tended to interact less with their students, ask them fewer questions overall, and ask them fewer questions about causational issues. These teachers tended to emphasize descriptions and facts much more than discussion and inquiry. The opposite was found in teachers with a better understanding of science topics, who tended to ask more causal questions and interact more with their students. Overall, the results suggest that teachers with stronger science content knowledge have an advantage in facilitating or enabling content-related discourse.
Ackerson (2005) investigated two enthusiastic elementary teachers who – while aware of their limited science content knowledge – considered science important and therefore invested effort into teaching it. The findings revealed that these teachers, who designed their own astronomy unit, focused on discussion of ideas rather than on a prescriptive lesson plan. These teachers paid attention to their students’ views, questions, and misconceptions about astronomy, while researching and reading about the subjects to improve their content knowledge. They also used trade books to make a connection between the students’ levels of understanding and the difficult scientific concepts. However, despite the fact that these teachers went to great lengths to maximize their teaching and subject area knowledge, they still recognized that they had weaknesses in their understanding of the astronomy content, which in turn impeded their ability to teach the concepts more effectively.

Adding to the lack of adequate science content preparation and ability to teach reform-oriented science, teachers may have their own ideas of scientific concepts that may not be in sync with accurate scientific ideas (Stoddart et al., 1993). Because most elementary teachers learn science content at the same time they are learning how to teach science, they often have the same misconceptions or alternative frameworks about science as their students (Abd-El-Khalick et al., 1998; Davis, 2004; Lonergan, 2000). These findings are not surprising, considering that elementary teachers are not specialists in science, and thus their content knowledge can be incomplete (Ackerson, 2005). This insufficient content knowledge, in turn, causes elementary teachers to lack confidence to teach scientific concepts (Borko, 1993). Accurate subject content knowledge may increase a teacher’s confidence and fluency when leading discussions, providing
examples and explanations, and generating problems for practice, whereas incomplete subject content knowledge would lead to lower confidence and less emphasis on discussion (Smith & Neale, 1989). Even the most enthusiastic elementary science teachers, who can effectively teach scientific concepts in which they are knowledgeable, have difficulty teaching other science topics because of incomplete science knowledge (Abell & Roth, 1992).

Due to their discomfort in teaching science, elementary teachers have been found to use a variety of coping strategies in order to compensate for lacking science content knowledge (Harlen, 1997). A general pattern of teaching as little as possible of unfamiliar science concepts and teaching more biology than physical science, as well as relying on outside-developed lessons like kits and step-by-step work cards, emerged. Teachers also have a tendency to emphasize expository teaching and underplay discussions while avoiding all but the simplest hands-on activities. These current practices are in dissonance with the guidelines set by the science reform standards, which promote the constructivist learning perspective. The coping strategies teachers use as anchors for science teaching are a mere representation of traditional science teaching.

Some scholars consider subject content knowledge unimportant, or secondary to other aspects of teaching. Qualter (1999) argues that the absence of content knowledge is not necessarily a problem, because the teacher can acquire the necessary knowledge along the way. What ultimately makes a difference, he claims, is that there is a quality interaction between teacher and learner where there is a negotiation of meaning. He asserts that teachers who have “too much” subject content knowledge tend to adopt a transmission-reception approach to teaching.
Professional development. Lowery (2002) showed that skills that are in accordance with reform practices can be acquired given the adequate pre-service preparation. A study of 31 pre-service teachers experiencing a standards-based, rather than textbook-based, mathematics and science methods course with access to immediate field experience revealed that the collaborative environment of the university system and the school system gave birth to a third system, the “Cohort of Learners system,” which ultimately provided the arena for situated learning. Situated learning occurred from teacher, from children, from the methods course and instruction, and from self, peers, and others. These frameworks created a baseline for teachers’ subject content knowledge and pedagogical content knowledge, which repeated themselves continuously and existed as separate entities. Overall, the findings confirmed the acquisition of subject content knowledge and pedagogical content knowledge of mathematics and science among the pre-service teachers, as they were exposed to situated learning environments and learning venues. In a situation like this, a road for success is paved by pre-service education. With adequate in-service training along the same lines, teachers could get closer to fulfilling the expectations of the science reform.

A qualitative study by Schwartz and Lederman (2002) provides insights about how two beginning teachers’ teaching of NOS was affected by their depth of NOS understanding, subject content knowledge, and the relationship between NOS and subject content knowledge. One of the teachers had a more extensive science background than the other, and therefore deeper content knowledge. This teacher was able to effectively incorporate his knowledge into teaching NOS, whereas the teacher with limited content knowledge was inhibited from incorporating relevant NOS topics within traditional
science content. The authors conclude that the differences between these two teachers’
levels of understanding NOS could and likely do correspond with differences in
knowledge of science content (Schwartz & Ledermann, 2002). This study provides
insight into designing professional development with a focus on science content
knowledge.

Most elementary teachers need continuing opportunities – i.e., in-service
professional development – to develop science content knowledge as well as content-
specific teaching strategies in order to be able to identify student misconceptions and
construct collective meanings among students (Kennedy, 1998; Loucks-Horsley et al.,
1998). Professional development designed to apply generically across subject areas has
proven relatively unsuccessful in promoting changes in teachers’ science content
knowledge and teaching practices, whereas training focusing on teachers’ knowledge on
specific science content and their understanding of how students learn that content has
been more effective (Kennedy, 1998; Fennema & Franke, 1992). Professional
development activities involving small numbers of volunteer teachers committed to their
professional growth have shown to produce fundamental changes in their science content
knowledge and teaching practices (Kennedy, 1998). However, large-scale professional
development interventions are impeded by limited funding and resources (Garet et al.,
2001).

Scientific Understanding and Inquiry

Reform-oriented practices. Traditionally, scientific concepts and procedures were
mistakenly viewed as a collection of established facts that merely required memorization.
Both teaching and learning were simplistically designed based on this outlook, with the
assumption that memorization and repetition would lead to learning or understanding (Romberg et al., 2005). Upon the realization that these strategies neither promoted learning with understanding, nor provided U.S. students with the scientific skills comparable to the rest of the world, the science reform movement is geared toward students becoming scientifically literate. Acquiring science literacy involves the arduous task of revamping epistemology about the learning of science, as well as a shift in teaching practices for scientific understanding. This shift must veer away from traditionally judging student understanding in terms of memorizing facts and following step-by-step procedures, and instead more in terms of student ability to scientifically address problem situations (Romberg et al., 2005).

What is scientific understanding, and when do we know that understanding has occurred? Today’s teachers must shift the conception of science instruction from the “assembly-line” metaphor consistent with the views of the 19th century to a conception of science literacy based on “exploring a domain”, consistent with the views of the modern technological world (Romberg et al., 2005). This means that traditionally, scientific concepts were considered a collection of facts that were put together piece by piece, and in a systematic order, until a bigger picture arose. Today’s perception is that students understand science concepts best when they are encouraged to explore scientific ideas and draw conclusions based on what they observe, along with applying them to new situations or problems, in the context of a big picture, or a “domain.” Greeno (1991), using a “domain-based” metaphor, compares scientific understanding to an environment with resources at various places in the domain. In this metaphor, knowing is knowing your way around in the environment and knowing how to use its resources. This includes
knowing what resources are available in the environment as well as being able to find and use those resources for understanding and reasoning by exploring the territory and how its various components interact.

More concretely, Shafer and Romberg (1999) state:

Understanding in a domain develops as new relationships among pieces of existing knowledge are sought, tested, and realized, or as new information is connected to and integrated with existing knowledge. As understanding grows, the facts, relationships, and procedures in a domain become resources that aid reasoning in solving ordinary problems in routine ways and in generating insights for making sense of unfamiliar situations. This growth in understanding in a domain occurs intermittently and sporadically in periods of progression and regression, rather than in linear increments or stages (pp. 159-160).

If scientific understanding were to be quantified, a distinction between shallow and deep understanding must be made. Students develop deep understanding of science concepts when they are able to use complex understandings and newly produced knowledge in connecting science concepts to one another, applying them to explain natural phenomena or real world situations. Instead of merely reciting fragmented pieces of information, students understand when they build up systematic, integrated, and holistic understandings of the science content. This is apparent when students can understand problematic and incomplete information and are able to make reasoned and well-supported arguments. Scientific understanding is shallow, on the other hand, when scientific concepts exist in isolation from related ideas, real world situations, and personal experiences, such as when fragmented ideas are unconnected to other knowledge. This can result in students not being able to use knowledge to make clear distinctions, build arguments, solve problems, or develop more complex understandings of other related phenomena (Newman et al., 1995).
With the inherent vastness of science, it becomes a challenge in deciding what science concepts and topics our students should understand in order to reach science literacy. Traditionally, science has been divided up into common general topics, such as biology, chemistry, and physics. Romberg et al. (2005) support Greeno (1991) in that while targeting science literacy, the domain approach focusing on the problem areas or big ideas is more effective. In focusing on ideas stemming from problem areas, students can gradually acquire the concepts and skills in a domain as a consequence of solving problems, be able to relate those ideas to one another, and be able to use those ideas in new problem situations. This requires teachers to learn not only what to teach but also in what order to teach it, while developing meaningful connections toward fostering students’ scientific understanding. The sequence in which these concepts are presented should follow a variety of paths along a “learning corridor,” since the learning for understanding perspective sees students progressing from informal ideas in a domain to more formal ideas over time, consequently reconfiguring their knowledge and developing strategies and models to understand why and how concepts and skills are important.

Consistent with the notion that memorization of scientific facts is no longer the preferred method of today’s science classrooms in order to promote scientific understanding, the terms “inquiry” and “hands-on” are dominating reform-oriented literature. The National Science Education Standards (NRC, 1996) define scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p.
Several considerations lie at the heart of this definition: a) children interact with their environment from an early age, asking questions and seeking ways to answer those questions; b) scientific inquiry reflects how scientists come to understand the natural world, which we ultimately aim for in our students; and c) understanding science content is significantly enhanced when ideas are anchored in inquiry experiences, as they are the core of how students learn (NRC, 1996, 2000).

Scientific inquiry often goes hand in hand with exploration and discovery, generating a sense that guidance and structure is lacking when inquiry is taking place in science classrooms. Coming back to the domain-based metaphor, a collection of problem situations is needed to engage students in exploring the environment of a domain in a structured manner (Romberg et al., 2005). First, in order to make certain that students take on meaningful inquiry activities, domains must be well mapped, so that the new linkages that form through inquiry are still within the bounds of the content. Second, activities that encourage students to explore the domain need to be identified and organized in a structured manner that allows for understanding, rather than leading nowhere.

Scientific inquiry in a classroom occurs when students ask questions about events in the environment which can be answered through scientific observation, data collection, and interpretation (NRC, 1996, 2000). A science lesson rich in inquiry involves students planning and designing authentic scientific investigations, making predictions about outcomes, and searching for patterns to justify inferences with evidence through communicating findings and scientific argumentation. These aspects of scientific inquiry interact in complex ways and are not mutually exclusive. A science lesson poor in
scientific inquiry involves activities in which students follow scripted sets of procedures that do not require them to use any of the skills described above.

   The science standards treat scientific understanding and inquiry as closely intertwined. By definition, “inquiry refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (NRC, 1996). This implies that inquiry is central to science learning, and scientific inquiry is a main tool ensuring that scientific understanding has occurred. To facilitate student engagement in scientific inquiry, educators must recognize how students’ prior knowledge, particularly misconceptions, shapes their scientific understanding. Through utilizing students’ existing scientific knowledge and knowledge of the natural world, teachers should enable students to recognize problematic and incomplete information, make reasoned and well-supported arguments, justify solutions based on evidence, and negotiate ideas and construct collective meanings about science (NRC, 2000, 2007). However, even while employing inquiry practices and allowing for exploration and investigation, it is crucial that in the case that student conclusions are erroneous, they are corrected and tied together with accurate scientific versions.

   As part of developing scientific understanding through inquiry, argumentation – the ability to articulate ideas – is a tool suggested by reform standards (NRC, 2007). Communication of knowledge, whether verbal, written, or through visual aids, is central to developing understanding of scientific ideas. Scientific argumentation builds on students’ previous experiences, along with disagreements and explanations. If encouraged in the science classroom, argumentation will lead to the establishment of
norms of behavior conducive to achieving consensus through comparing solutions, challenging explanations, and requiring others to defend their positions (Stewart et al., 2001). Ultimately, students are acculturated into classroom communities of practice in which they create and internalize their own understanding of complex scientific concepts through argumentation. Stewart et al. (2001) argue:

. . . with opportunities provided for students to engage in argumentation related to the need for and the adequacy of various types of explanations…Argumentation occurs when students interact with one another, often in ways carefully orchestrated by teachers, around diverse but high-stakes issues associated with the generation and validation of scientific claims. For us, argumentation in science classrooms is simply the public face of the activities of inquiry, modeling, and, particularly, explanation. (pp. 12-13)

An emerging approach to promote scientific inquiry and therefore central to students’ scientific understanding is through models and modeling. Models – scientific, explanatory, or causal in nature – can be used as representational tools that describe a set of ideas and questions to communicate scientific concepts to others. Lehrer and Schauble (2004) found that students learned how to reason about natural variation through revising models of data recorded during a science experiment on plant growth. For example, instead of being provided with conventions on representation of data, students were encouraged to invent their own representational conventions, which translated into significant educational value. Nonetheless, the idea of models can be a double-edged sword: without sufficient knowledge of how to build a model, existing models can be misinterpreted as pre-set information that is not expandable, therefore failing to utilize models as a tool for inquiry and jeopardizing learning for understanding. When applied in a meaningful way, models can provide students with an idea of how scientists arrive to their conclusions. For example, models can help retest, revise, and expand existing
models, as well as predict more sophisticated and complicated patterns based on observations (Romberg et al., 2005; NRC, 2007).

**Current practices.** Teachers generally support the high standards for teaching and learning, although they are not able to implement reform-oriented teaching practices due to insufficient preparation (Garet et al., 2001). Elementary teachers generally have inadequate knowledge of science content. In many cases, teachers place heavy emphasis on memorizing facts, without emphasizing deeper understanding of subject knowledge (Darling-Hammond & McLaughlin, 1995). They often miss the opportunity to facilitate student scientific understanding because they do not know the extent to which they can guide, listen, discuss, prompt, question, and clarify scientific concepts as students engage in building models and argumentation (Romberg et al., 2005). Furthermore, orchestrating reform-based instruction targeting scientific understanding is complex, and many teachers have not embraced the essence of this mode of learning in which students begin to “think” scientifically (Fradd & Lee, 1999).

It has been tradition to teach science as a succession of unrelated topics (e.g., weather, rocks and minerals, the rain forest). Lehrer and Schauble (2005), however, see no reason why scientific concepts can not be taught for understanding; coherently and cumulatively around important core ideas, as suggested by the science standards (NRC, 1996). In addition, the gap between research and practice may contribute to the disparity between intended reform-oriented curricula and classroom practices (Crawford, 2000).

These issues give rise to the additional challenge that inquiry practices, which are thought to enhance scientific understanding, are new to teachers. Many teachers misconstrue the scientific method as a collection of content-free skills. However, in order
to adapt to the modern inquiry-driven philosophy, the teaching practices for scientific inquiry need to shift to an “environmental” approach, in which the roles of the student and the teacher become complementary (Romberg et al., 2005).

Despite the ongoing debate regarding inquiry approaches in science classrooms, researchers concur that facilitating inquiry-based activities is a difficult task for teachers (Barab & Luehmann, 2003; Sadler et al., 1999) and that schools and teachers fail to understand the central features of scientific inquiry (Chinn & Malhotra, 2002). Chinn and Hmelo-Silver (2002) claim that “many inquiry activities found in schools fail to capture important characteristics of authentic scientific inquiry” (p.171). Furthermore, the term “inquiry” is often falsely simplified by the term “hands-on”, where teachers provide students with a series of hands-on activities that are often unconnected to substantive science content and are not authentic inquiry (Crawford, 2000). In addition, due to the open-ended nature of inquiry, it has become increasingly challenging for teachers to “succeed” in their classrooms, since they are expected to be flexible to students’ individual needs, unpredictable classroom situations, and scientific explanations beyond the bounds of the lesson (Chinn & Hmelo-Silver, 2002).

In an authentic inquiry classroom, the teacher plays multiple roles: motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, mentor, collaborator, and learner (Anderson & Helms, 2001). The ideal situation of initiating and sustaining inquiry is impeded by multiple barriers present in teachers’ daily classroom lives: a) lack of time to design and teach both content and process knowledge about inquiry; b) conflicts between the ideal standards and the realities of the science classes; c) tensions between emerging teachers’ roles in inquiry classes and the typical school culture; d) the
“preparation ethic” in which teachers feel responsible for making students ready for the next level (p. 6); and e) the challenges of assisting students of different levels to focus on higher level problems (Anderson & Helms, 2001).

Studies have also shown that reform-based enactments for inquiry are more successful when teachers actively participate in designing inquiry-oriented curricula, implementing innovations, and reflecting collaboratively on their beliefs and teaching practices in science (Lynch, 1997). However, teachers’ unfamiliarity with what inquiry entails, along with lacking scientific experience – exposure to laboratory experiments for science majors – prior to teaching, limits teachers’ ability to partake in designing inquiry-based curricula and the quality and frequency of inquiry-based classroom activities. Teachers who had substantive scientific experience prior to teaching successfully implemented inquiry activities in their science instruction, whereas those who lacked practical scientific experience were less successful (Windschitl, 2002).

*Professional development.* In order to adapt teaching practices to promote scientific understanding and inquiry to the specifications of science reform, professional development is essential in addressing and guiding this adoption, especially if this did not occur during pre-service education. There is broad consensus among teacher learning research that “reform-oriented” professional development tends to be more effective than traditional professional development in fostering reform-oriented teaching practices (Loucks-Horsley et al., 1998). Reform-oriented professional development activities include being mentored or coached, participating in a committee or study group, or engaging in an internship, which, unlike traditional workshops, allow teachers to explore new concepts and teaching practices in sufficient depth (Little, 1993). We are just now
beginning to learn what impact teacher professional development has on teacher outcomes (Garet et al., 2001; Supovitz & Turner, 2000) and student outcomes (Lee et al., in press).

Loucks-Horsley and Matsumoto (1999), in their review of literature of the effectiveness of professional development for mathematics and science teachers, concluded that there are indeed important relationships among quality professional development and changes in classroom practice. Professional development can produce multiple outcomes, including teacher learning of new knowledge and teaching skills, changes in classroom practice, and leadership development. Change in teacher knowledge and teaching practices can consequently add to improved student learning. Kennedy (1998) also concluded that professional development programs helping teachers learn how their students learn science content are more successful in improving student achievement. By learning how students learn the science content, teachers better learned the content themselves, learned how to recognize if and how students are learning, and learned ways to teach the specific content.

A qualitative study by Rosebery and Puttick (1998) investigated the experiences and practices of a beginning elementary science teacher undergoing teacher professional development that engaged teachers in learning and viewing science as a socially and historically sense-making practice. In this professional development, practicing science teaching itself was approached as a sense-making constituent. Not only did the nature of the professional development shape this teacher’s own understandings of scientific ideas and practices, but she developed a view of how science could be transmitted to students in order to develop scientific understanding through making sense of the concepts. Upon
reflection of her teaching practices by viewing videotapes of her lessons, the teacher was able to identify gaps in her students’ scientific understandings and revisit them appropriately in subsequent lessons.

A large-scale study of 454 teachers engaged in an inquiry science program revealed that along with reform-oriented professional development, giving teachers time to plan for implementation, helping them integrate the materials into their curriculum, and providing them with specialized equipment needed to conduct science experiments proved effective in aiding teachers to implement scientific inquiry in their classrooms (Penuel et al., 2007). However, other studies have shown that even after being engaged in professional development, teachers often blend reform-oriented practices with traditional/conventional practices (Cohen & Hill, 2000; Knapp, 1997). For example, they may engage students in hands-on activities or ask the students to pose questions, but they are not likely to help students make sense of the data collected or to ask for explanations based on evidence.

**English Language Development**

*Reform-oriented practices.* Reform documents in the U.S. state three goals for ELL students at all age levels: (1) use English to communicate in social settings, (2) use English to achieve academically in all content areas, and (3) use English in socially and culturally appropriate ways (Teachers of English to Speakers of Other Languages, 1997). ELL students need to develop English language and literacy skills in content areas in order to achieve at the same level as their English-speaking peers. Ideally, content area instruction should provide a meaningful learning environment for English language and literacy development, while improving English skills provide the medium for
understanding academic content, such as science (Amaral et al., 2002; Buxton, 1998; Fathman & Crowther, 2006; Lee & Fradd, 1998).

An emerging literature highlights the integration of science with English language and literacy for ELL students (Fathman & Crowther, 2006; Lee, 2005). For example, “science talk” includes more than just grammatical structures and lexicons (Lemke, 1990). Science talk includes knowledge of various sub-registers representing specific disciplines. It also employs non-technical terms that have meanings unique to scientific contexts (e.g., matter, force, energy, space) that may differ from their everyday use. Additionally, it requires ways of communicating specific to science disciplines, as students engage in science inquiry by formulating hypotheses, designing investigations, collecting and interpreting data, drawing conclusions, and communicating results (NRC, 2000).

An array of strategies conducive to better catering to ELL students has been identified. First, teachers of ELL students need to create classroom environments that promote development of general and content-specific academic language (Wong-Fillmore & Snow, 2002). Second, teachers should view language from a human development perspective and formulate developmentally appropriate expectations about language comprehension. Third, teachers should apply this knowledge to the teaching of academic content areas. Consequently, teaching practices that engage students of all levels of English proficiency in academic language learning will emerge, offering multiple points of entry for students of differing levels of English proficiency and providing multiple modes for students to display their science learning.
Research on second language immersion programs shows that contextualized, content-based instruction in students’ second language can enhance the language proficiency of English language learners with no detriment to their science learning (Stoddart et al., 2002). The science content provides a meaningful context for the learning of language structure and functions, whereas context-reduced or decontextualized language occurs when there is no context to aid the spoken language in providing information (Stoddart et al., 2002). Especially during inquiry instruction, teachers should place high emphasis on connecting language activities to contextualized science activities, such as hands-on experimentation and naturally occurring events in the environment, to which students can relate (Lee & Fradd, 1998).

**Current practices.** The unique needs of culturally diverse students and ELL students in learning science require significant consideration, given that the student population is becoming increasingly diverse. With the new expectations of science reform, along with being overwhelmed with the stresses of high-stakes testing and accountability, many elementary teachers have additional difficulties teaching science to ELL students.

Teachers are largely unaware of cultural and linguistic influences on science learning, and simply assume that ELL students must acquire English before learning science. Due to this lack of awareness, teachers often do not consider “teaching for diversity” their responsibility, frequently overlook linguistic differences, and accept inequities as a given condition (Bryan & Atwater, 2002; Rodriguez & Kitchen, 2005).

Furthermore, most teachers are unacquainted with teaching strategies that cater to ELL students, and they do not know how to incorporate English language and literacy
This is because traditionally, teacher education programs did not place emphasis on the integration of the linguistic and cultural components of the student population during science instruction (Fradd & Lee, 1999). In order to integrate language development with reform-based science instruction, teachers must learn the characteristics of this new area of expertise, which is a challenge given that most teachers assume that English language learners must acquire English before learning the subject matter (Garcia, 1999; Stoddart et al., 2002).

Most states have shifted toward English-only policies, which disregard the development of students’ home language, as science instruction for most English language learners is conducted in English. Students learn science in a language they are still acquiring, and are often deemed English proficient well before they have reached adequate proficiency for learning science. Furthermore, elementary teachers tend to focus on ELL students’ acquisition of English and fail to take advantage of ELL students’ oral and written proficiencies in their home language (Lee et al., 2007).

Professional development. Teachers can be made aware of English language development strategies through effective professional development that highlights the essence of the special attention that needs to be paid to this issue. An emerging body of literature examines the impact of professional development on teachers’ knowledge and practices in promoting science learning of ELL students.

In recent years, studies have focused on hands-on, inquiry-based science with ELL students (Amaral et al., 2002; Lee et al., 2005). First, hands-on activities through collaborative inquiry foster authentic communication about science knowledge and
practice. Second, hands-on activities are less dependent on formal mastery of the language of instruction, consequently reducing the linguistic burden on ELL students. Third, inquiry-based science promotes students’ communication of their understanding in a variety of formats, including written, oral, gestural, and graphic.

Other studies focused on how teachers enabled ELL students to learn the discourse of science (Merino & Hammond, 2001; Rosebery et al., 1992). Kelly and Breton (2001) examined how two bilingual elementary school teachers guided their students to engage in science inquiry through particular ways of framing problems, making observations, and engaging in spoken and written discourse. The teachers provided specialized discourse of science by engaging students in conversations through questioning, reframing ideas, varying use of languages, making reference to other classroom experiences, and devising interactional settings for students to “talk science” under a range of conditions.

In Lee, Hart, Cuevas, and Enders (2004), third and fourth grade elementary teachers participated in an intervention that consisted of curriculum units and teacher workshops over the course of the school year. During classroom observations in fall and again in spring, teacher knowledge and practices were generally within the bounds of the lesson content provided in the intervention and fell short of reform-oriented practices. In contrast, on the questionnaire at the end of the school year, teachers reported enhanced knowledge of science content. Furthermore, during focus group interviews, they related more expanded strategies to promote science understanding and stressed their efforts to foster student initiative and student-centered inquiry.
Stoddart, Pinal, Latzke, and Canaday (2002) involved elementary school teachers of predominantly Latino ELL students. After their participation in a five-week summer professional development program, the majority of teachers showed a change from a restricted view of the connections between inquiry-based science and English language development to a more sophisticated understanding about the various ways in which the two could be integrated.

Similar results were obtained by Hart and Lee (2003), who provided professional development to elementary school teachers serving diverse student groups. Both quantitative and qualitative results indicated positive changes in teachers’ perceptions and practices simultaneously. As teachers expressed a broader and more integrated conceptualization of literacy in science instruction, they integrated reading and writing in science instruction more systemically and extensively and provided more effective linguistic scaffolding to enhance students’ scientific understanding.

Lee et al. (in press) implemented a teacher professional development intervention with elementary teachers who worked with culturally and linguistically diverse students, including ELL students, in urban schools. The intervention provided teachers with professional development workshops and new instructional materials. The approach promotes scientific understanding and inquiry while fostering English language and literacy development of ELL students. The results with approximately 800 third-graders showed that students displayed a statistically significant increase in science achievement from the beginning to the end of the school year on a project-developed science test. Significant increases were also recorded for ELL students. Finally, nearly 1,000 treatment students scored significantly higher on a statewide mathematics test,
particularly on the measurement strand, than nearly 1,000 students in a comparison group. The results indicated that teacher professional development programs helped elementary school students, including ELL students, learn to think and reason scientifically while performing well on high-stakes achievement tests.

**Relationships amongDomains of Science Instruction with ELL Students**

In addition to exploring teacher knowledge and practices in the context of reform-based science with ELL students, it is critical to investigate whether there are relationships among the four domains described above, and between which domains these relationships exist. Among domains of science instruction, teachers who possess subject matter expertise and the ability to represent the subject matter to their students are more likely to engage in inquiry-based activities that facilitate scientific understanding, whereas teachers with weak subject matter knowledge are more likely to rely heavily on the textbook as the primary source of subject matter content (Carlsen, 1991; Tobin & Fraser, 1990). Additionally, scientific inquiry provides teachers with opportunities to develop students’ inquiry skills and to enrich their understanding of science concepts through an interconnection of inquiry strategies (NRC, 2000).

With ELL students, English language and literacy development is integral to subject area instruction, such as science (Fathman & Crowther, 2006; Lee, 2005). Subject area instruction provides a meaningful learning environment for English language and literacy development, while improving English skills provides the medium for understanding academic content, such as science (Amaral et al., 2002; Lee & Fradd, 1998; Stoddart et al., 2002). Especially some studies examine how ELL students benefit from hands-on, inquiry-based science (Lee, 2002; Rosebery et al., 1992).
Although relationships among domains of science instruction are surmised, systematic investigations of these relationships are limited to non-existent. Additionally, although an emerging literature highlights the integration of subject area instruction, such as science, with English language and literacy for ELL students, no studies thus far have examined relationships between domains of science instruction and English language and literacy with ELL students. Since teachers play pivotal roles in reform-oriented classrooms, researchers have stressed the need for examining relationships between teacher knowledge and beliefs in learning and teaching, their classroom practices, and student learning (Bryan, 2003). Thus, this study has the potential to provide initial insights into how connections may be present between what teachers know about the science content and their classroom practices for scientific understanding and inquiry, along with their practices for English language development, with ELL students.

The presence and magnitude of relationships can have a meaningful impact on designing pre-service education, professional development, and science curricula with ELL students. If domains of teacher knowledge and practices are related, teachers can then be informed that it is important to incorporate related domains concurrently and that treating them in isolation of each other may impede the overall quality of science instruction.
CHAPTER III

Method

Research Setting

This study was conducted in a large school district located in the Southeastern U.S. The district is composed of a linguistically and culturally diverse student population. During the 2004-2005 school year (the first year of the study), the student population in the school district was 60% Hispanic, 28% Black (including Haitian and Caribbean Islanders), 10% White Non-Hispanic, and 2% Asian or Native American. Across the district, 72% of elementary students participated in free or reduced price lunch programs, and 24% were categorized as limited English proficient (LEP) according to the state definition.

In May 2004, schools were invited to participate in a five-year research and development project based on three criteria: (a) percentage of ELL students (predominantly Spanish or Haitian Creole-speaking students) above the district mean at the elementary school level (24%), (b) percentage of students on free or reduced price lunch programs above the district mean at the elementary school level (72%), and (c) poor school performance (i.e., school grades of primarily C or D) according to the state’s accountability plan since its inception in the 1998-1999 school year. Of the 206 elementary schools in the district, 33 schools met these criteria and 15 schools expressed a desire to participate in the research. Based on a set of criteria, seven schools were assigned to the treatment group and eight schools to the comparison group. One treatment school dropped at the start of the second year. Thus, the study involved six treatment schools which continued their participation during the three years of the study from 2004
through 2007. Table 1 provides the demographic makeup of the students in the six
treatment schools.

Table 1

| Student Demographics in Six Treatment Schools during 2004 – 2007 |
|----------------------|---------------|---------------|---------------|
|                      |                | n (%)       | n (%)      | n (%)      |
| Gender               | Male           | 453 (50)    | 384 (49)   | 383 (47)   |
|                      | Female         | 444 (50)    | 402 (51)   | 423 (53)   |
| Ethnicity            | Hispanic       | 369 (41)    | 334 (43)   | 356 (44)   |
|                      | Black (including Haitian and Caribbean immigrants) | 486 (54) | 411 (52) | 409 (51) |
|                      | White Non-Hispanic | 34 (4) | 30 (4) | 30 (4) |
|                      | Other          | 8 (1)       | 13 (1)     | 11 (1)     |
| Socioeconomic Status | Free or reduced lunch price programs | 806 (90) | 692 (88) | 692 (86) |
| Exceptional Student Education (ESE) | Exceptional students (not including gifted students) | 134 (15) | 110 (14) | 118 (15) |
| English to Speakers of Other Languages (ESOL) | ESOL levels 1 through 4 | 151 (17) | 79 (10) | 85 (10) |
|                     | ESOL level 5 (exited from ESOL within 2 years) | 298 (33) | 205 (26) | 433 (54) |
|                     | Non-ESOL (exited from ESOL over 2 years or never in ESOL) | 448 (50) | 502 (64) | 288 (36) |

Teacher Participants

For our school-wide initiative, all third, fourth, and fifth grade teachers in each
treatment school were invited to participate in the professional development intervention,
described below. Only those teachers who participated for the entire school year and who
completed data collection activities were included in the study. Based on these criteria,
the study involved 32 out of the 45 third grade teachers, 21 out of the 27 fourth grade
teachers, and 17 out of the 22 fifth grade teachers, a total of 70 out of the 94 teachers.

Table 2 presents the demographic and professional backgrounds of these teachers. The
majority of teachers identified themselves as members of racial/ethnic nonmainstream
groups. Many of the teachers reported earning graduate degrees. Based on demographic
data from our previous studies, we assert that the majority of the teachers had a degree or
endorsement in English to Speakers of Other Languages (ESOL), considering that they
teach a highly diverse student body high in ESOL students.

Table 2

Teacher Demographics during First Year of Participation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Demographic Groups</th>
<th>Grade 3</th>
<th>Grade 4**</th>
<th>Grade 5**</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
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<td>2 (10)</td>
<td>7 (41)</td>
<td>13 (19)</td>
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<tr>
<td></td>
<td>Female</td>
<td>28 (87)</td>
<td>18 (90)</td>
<td>10 (59)</td>
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<tr>
<td>Ethnicity</td>
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<td>6 (30)</td>
<td>3 (19)</td>
<td>16 (23)</td>
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<tr>
<td></td>
<td>Black Non-Hispanic</td>
<td>15 (47)</td>
<td>7 (35)</td>
<td>7 (44)</td>
<td>29 (42)</td>
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<tr>
<td></td>
<td>White Non-Hispanic</td>
<td>5 (16)</td>
<td>5 (25)</td>
<td>3 (19)</td>
<td>13 (19)</td>
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<tr>
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<td>Haitian</td>
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<td>2 (10)</td>
<td>2 (12)</td>
<td>6 (9)</td>
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<tr>
<td></td>
<td>Asian</td>
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<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (3)</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>1 (6)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Native Language</td>
<td>English</td>
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<td>13 (65)</td>
<td>11 (74)</td>
<td>50 (72)</td>
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<td>5 (25)</td>
<td>2 (13)</td>
<td>11 (16)</td>
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<td>Haitian Creole</td>
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<td>1 (5)</td>
<td>2 (13)</td>
<td>4 (6)</td>
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<td>1 (5)</td>
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<td>2 (3)</td>
</tr>
<tr>
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<td>11 (55)</td>
<td>9 (53)</td>
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<td></td>
<td>Master’s</td>
<td>13 (41)</td>
<td>8 (40)</td>
<td>5 (29)</td>
<td>26 (38)</td>
</tr>
<tr>
<td></td>
<td>Specialist</td>
<td>1 (3)</td>
<td>1 (5)</td>
<td>2 (12)</td>
<td>4 (6)</td>
</tr>
<tr>
<td></td>
<td>Ph.D. or Ed.D.</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (6)</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

* Multiple categories could be selected.

** Demographic information is missing for one teacher in Grade 4 and Grade 5.

Professional Development Intervention

The intervention was comprised of (a) curriculum units, including student
booklets, teachers’ guides, and science supplies and (b) teacher workshops throughout the
school year. The curriculum units and workshops were designed to complement and
reinforce each other for the improvement of teachers’ knowledge and practices in science instruction along with English language development of ELL students.

Curriculum Units

A series of curriculum units has been developed to constitute the entire science curriculum for grades 3 through 5 as mandated by the State of Florida science content standards and also recommended by the National Science Education Standards (National Research Council, 1996). Special consideration has been given to the State content standards (Florida Curriculum Framework, 1996) and science test item specifications (Florida Department of Education, 2002) to ensure thorough alignment between each curriculum unit and benchmarks that are tested by the State assessment in science.

The three 3rd grade units were developed during a previous research project and further refined based on teacher feedback, classroom observations, and student assessment results during Year 1 of the current research. The three 4th grade units were tested during Year 2 and have been finalized during Year 3 (in summer and fall of 2006). The three 5th grade units were tested during Year 3 and have been finalized during Year 4 (in summer and fall of 2007).


4th grade: Energy, Force and Motion, Processes of Life

5th grade: Nature of Matter, Earth Systems, Synthesis

For all three grades, the introduction in the teachers’ guide for each unit begins with an explanation of: (a) how to progress along the continuum of teacher-explicit to student-initiated science inquiry for students with various levels of experience of school science (Lee, 2002; Lee & Fradd, 1998), (b) how to promote students’ understanding of
key science concepts and “big ideas” (patterns of change, systems, models, and relationships) to explain natural phenomena, (c) how to incorporate English language and literacy development as part of science instruction, and (d) how to incorporate mathematics as part of science instruction. For each lesson, the teachers’ guide includes (a) specific correlations with state content standards in science, language arts, and mathematics; (b) key vocabulary terms in English, Spanish, and Haitian Creole; (c) glossary of science vocabulary; (d) a list of materials for each hands-on activity; and (e) transparencies of pictures, drawings, tables, graphs, and charts. Additionally, the teachers’ guide offers suggestions for writing prompts, field trips, and trade books or literature related to the science topics.

Science. Student booklets are designed to promote standards-based, inquiry-driven science learning. Science inquiry involves such conventions as control of variables, multiple trials, and accuracy of measurement. Students also learn about independent and dependent variables and constants. To promote science inquiry with students who may be less familiar with scientific practices, the units are designed to move progressively along the continuum of teacher-explicit to student-initiated inquiry. Units gradually progress to higher levels of complexity in terms of both science concepts and the level of inquiry required from students. Teachers’ guides offer suggestions on how teachers may provide scaffolding to promote science inquiry, depending on students’ prior experience with school science and the demands of specific science tasks. The teachers’ guides also offer suggestions about how to set up and implement hands-on activities, along with cautions about what may go wrong and how to respond to such situations.
Within the context of science inquiry, student booklets emphasize key science concepts and big ideas. Following inquiry activities, each lesson provides science background information that explains the question under investigation and related natural phenomena. The units also highlight common misconceptions and potential learning difficulties. To enrich the science content in the student booklets, teachers’ guides provide science background information and explanations for the questions posed in the student booklets, with particular emphasis on students’ common misconceptions and learning difficulties. Furthermore, they offer suggestions for extension activities, assessment activities, and homework assignments.

*English language and literacy.* Student booklets highlight activities or strategies to foster general literacy (i.e., reading and writing) in English for all students. For example, the booklets use specific comprehension questions about inquiry activities, strategies to enhance comprehension of science information in expository text at the end of each lesson, and various language functions (e.g., describing, explaining, reporting, drawing conclusions) in the context of science inquiry. Teachers’ guides also provide suggestions to promote literacy development. For example, students engage in authentic communication through the use of hands-on tasks, narrative vignettes, and expository texts related to everyday experiences. Students write expository paragraphs describing the scientific process under investigation, explanations and conclusions of science experiments conducted in class, or responses to the writing prompts provided as supplementary materials. Trade books or literature related to the science concepts under investigation are incorporated.
All units specifically address the needs of ELL students by providing explicit guidance to promote their English proficiency. For example, science terms in Spanish and Haitian Creole are provided to support communication and comprehension. Language load for students at varying levels of English proficiency is increasingly demanding from grades 3 through 5. The units introduce key vocabulary in the beginning and encourage students to practice the vocabulary in a variety of settings to enhance their understanding throughout the lesson and over the course of the unit. Additionally, the units use multiple modes of communication and representation (verbal, gestural, written, graphic) to enhance students’ understanding of science. Teachers’ guides also emphasize the importance of linguistic scaffolding to promote ELL students’ comprehension and understanding of science. For example, extensive graphic materials are included in transparencies (e.g., graphic organizers, Venn Diagrams, pictures of measurement instruments, drawings of experimental set-ups, data tables, graphs, charts). Teachers are encouraged to engage students in a variety of group formations, so that students learn to communicate independently, in small groups, and with the whole class.

Teacher Workshops

The workshops focus on improving teachers’ knowledge and practices in science instruction along with English language development for ELL students. During the teachers’ first-year participation in the intervention, the intervention focused on improving teachers’ knowledge and practices in science, with a secondary focus on improving teachers’ knowledge and practices in English language development. In subsequent years, the intervention would gradually give more emphasis on English language development. Third grade teachers attended five full-day workshops throughout
the school year during Year 1 of the project (2004-2005), fourth grade teachers attended six full-day workshops including three day summer workshops during Year 2 of the project (2005-2006), and fifth grade teachers attended seven full-day workshops including three-day summer workshops during Year 3 of the project (2006-2007).

Science. During the first year of teachers’ participation, the workshops focused on familiarizing teachers with the science content, hands-on activities, common student misconceptions, and potential learning difficulties in each lesson. These issues were discussed in relation to the state science content standards and statewide science assessments.

Inquiry-based science is the primary goal of science teaching and learning in this intervention. While engaging in inquiry tasks in the curriculum units at each grade level, teachers discuss conventions of science inquiry including control of variables, multiple trials, and accuracy of measurement. Project personnel present inquiry tasks outside the curriculum, and engage teachers in discussion of experimental designs, procedures for gathering data, multiple ways of displaying the data, and conclusions based on data and evidence. Additionally, teachers discuss how to promote student initiative in conducting inquiry as they gradually reduce their level of guidance. They discuss the notion of the teacher-explicit to student-initiated continuum in providing instructional scaffolding to promote science inquiry. Effective inquiry instruction requires a balance of teacher guidance and student initiative, as teachers make the decisions about when and how to foster student responsibility. Teachers discuss how to move away from teacher-explicit instruction and encourage students to take the initiative and assume responsibility for their own learning.
As teachers engage in science inquiry during the workshops, they discuss science concepts and big ideas on major science topics presented in the curriculum, connect science concepts or topics to one another, and apply science concepts to explain natural phenomena or real world situations. Particularly, workshops highlight students’ common misconceptions and learning difficulties.

The state science content standards are emphasized as a backbone of the workshops. Project personnel describe how the curriculum units from grades 3 through 5 align to the state science content standards. For each curriculum unit at each workshop, project personnel demonstrate how the unit corresponds to specific science benchmarks. Teachers are introduced to the state-defined content clusters including those benchmarks that are annually assessed as well as those assessed every three years. Teachers become familiar with the benchmark clarifications for those standards that are assessed at grade 5. Teachers also become aware of assessment item formats and the probable impacts of high-stakes science test results on school grades according to the state’s accountability system. Especially, project personnel help teachers recognize how students’ science inquiry and reasoning abilities can enhance performance on statewide science assessment.

_English language and literacy._ Project personnel present various strategies for developing literacy (reading and writing) for all students. Science learning and literacy development reinforce each other in a reciprocal process. Teachers discuss various literacy strategies embedded in the curriculum and how they can reinforce these strategies in their instruction. Some of these strategies include:

- activation of prior knowledge,
• comprehension of expository science texts,
• language functions (e.g., explain, compare, contrast, report) in relation to science process skills,
• scientific genres of writing, graphic organizers (e.g., Venn diagrams, concept maps),
• multiple forms of representation (oral, written, graphic),
• trade books, and
• writing prompts.

Project personnel also describe how to provide linguistic scaffolding for ELL students. The discussion focuses on how teachers:

• recognize students’ varying levels of language proficiency,
• adjust the language load required for their participation (e.g., slower rate, enunciation),
• use language that matches students’ levels of communicative competence in length, complexity, and abstraction (e.g., reducing difficult language to key vocabulary or using shorter utterances and simplified sentence structures), and
• communicate at or slightly above students’ levels of communicative competence (comprehensible input).

Teachers also discuss the use of language support strategies with ELL students to enhance comprehension of academic content and to develop English language proficiency:

• use realia (demonstration of real objects or events),
• use hands-on inquiry,
• use multiple modes of communication and representation through non-verbal (gestural), oral, graphic, and written communication,
• introduce key vocabulary in the beginning of lessons and encourage students to practice the vocabulary in a variety of contexts, and
• use language in multiple contexts (e.g., introduce, write, repeat, highlight).

**Instruments, Data Collection, and Coding**

Data collection occurred via questionnaire, classroom observations, and post-observation interviews to examine the four constructs summarized in Table 3. The three instruments were adapted from previous research on science instruction (Lee, Hart, Cuevas, & Enders, 2004; Newmann, Secada, & Wehlage, 1995) and English language and literacy development in science instruction (Hart & Lee, 2003), as well as relevant literature. Data collection from these three sources was conducted by a team of researchers (principal investigators of the project, post-doctoral associates, research associates, and doctoral students) who came from the disciplines of science education, mathematics education, and ESOL/bilingual education.

**Table 3**

*Constructs Examined through Three Data Sources*

<table>
<thead>
<tr>
<th></th>
<th>Teacher knowledge of science content</th>
<th>Scientific understanding</th>
<th>Scientific inquiry</th>
<th>Teacher support of English language development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
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<tr>
<td>Classroom Observations</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Post-observation Interviews</td>
<td>N/A</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>
Questionnaire

Based on relevant literature, previous research, and extensive pilot-testing in the fall of 2004, a questionnaire was developed to measure teachers’ self-reported knowledge and practices in teaching science to ELL students. The questionnaire includes the following scales to measure latent constructs:

1. *Teacher knowledge of science content scale* measures teachers’ reported knowledge in teaching science topics according to the state science content standards at their grade level. The eight science topics include nature of matter, energy, force and motion, processes that shape the earth (i.e., earth science), earth and space, processes of life, environment, and nature of science.

2. *Practice in scientific understanding scale* measures teachers’ reported practices in teaching science for understanding. The scale consists of five items:
   a. discuss students’ prior knowledge or experience related to the science topic or concept,
   b. explain the reasoning behind an idea,
   c. use students’ mistakes to generate class discussion,
   d. apply science concepts to explain natural events or real world situations, and
   e. talk about things students do at home that are similar to what they do in science class (e.g., measuring, boiling water, freezing water).

3. *Practice in scientific inquiry scale* measures teachers’ reported practices in teaching science for inquiry. The scale consists of five items:
   a. use science process skills (e.g., hypothesize, organize, infer, analyze, evaluate, describe patterns, make models or simulations),
b. use basic measurement tools (e.g., ruler, thermometer, scale/balance, timer, graduated cylinder),

c. use everyday, household items (e.g., plastic cups or containers, food coloring, light bulbs, batteries),

d. analyze relationships using tables, charts, or graphs, and
e. write about what was observed and why it happened.

4. **Practice in English language development scale** measures teachers’ reported practices in using ESOL strategies or ELL students' home languages to support English language and literacy in science instruction. The scale for ESOL strategy use includes four items:

   a. revise science materials in English to make them accessible to ESOL students,
   b. reduce difficult language to key science vocabulary in English with ESOL students,
   c. talk with an ESOL student one-on-one in English to assess his or her communication of science ideas, and
   d. purposefully create small groups of English proficient and ESOL students to work together in science class.

The scale for ELL students’ home language use includes four items:

   a. use science vocabulary in ESOL students’ home language,
   b. allow ESOL students to discuss science using their home language,
   c. encourage small groups of bilingual and ESOL students to use their home language in science class, and
d. allow ESOL students to write about science ideas or experiments in their home language.

To help teachers think about their classroom practices and guard against rushed responses, the questionnaire items were framed in terms of specific time periods (such as “in the last month”) and were focused on practices that teachers engaged in for sustained periods of time (such as “for at least 10 minutes”). The teachers completed the questionnaire for 30-45 minutes during the final teacher workshops each year.

The questionnaire items used a four-point rating system. To measure the extent to which teachers reported their own knowledge of science content at their grade level, the questionnaire items used a 4 point rating system (1 = not knowledgeable; 2 = somewhat knowledgeable; 3 = knowledgeable; 4 = very knowledgeable). Similarly, to measure the extent to which teachers reported practices for scientific understanding, scientific inquiry, and English language development in their own teaching, the items used a 4 point rating system (1 = never or almost never; 2 = some lessons; 3 = most lessons; 4 = every lesson).

Classroom Observations

The classroom observation scales measured teachers’ observed teaching practices during specific lessons, whereas the questionnaire scales measured teachers’ self-reported teaching practices broadly. The classroom observation guideline provides detailed descriptions of the scales and criteria for ratings:

1. *Teacher knowledge of science content* – This scale measures the extent to which the teacher has an accurate and comprehensive grasp of the science content of the lesson. A high rating on this scale indicates when the teacher responds to students’ questions with relevant information beyond that included in the lesson,
enriches the lesson by providing deeper knowledge of the phenomena, or links the
lesson content to other phenomena or experiences known to students. In contrast,
a low rating indicates multiple inaccuracies in the information that the teacher
transmits to students.

2. *Scientific understanding* – This scale measures the extent to which students
demonstrate a deep understanding of science. Scientific knowledge is deep when
students develop relatively complex understandings of the lesson’s concepts,
produce new knowledge when they connect science concepts or topics to one
another, and apply science concepts to explain natural phenomena or real world
situations. In contrast, scientific knowledge is shallow, thin, or superficial when
concepts have been taught in isolation from related ideas, personal experiences, or
real world phenomena, providing students with only a surface acquaintance with
meaning.

3. *Scientific inquiry* – This scale measures the extent to which students engage in
scientific inquiry related to the practice of science. A lesson is high in scientific
inquiry when students engage in the practice of science as they generate
questions, design investigations and plan procedures, carry out investigations,
analyze and draw conclusions, and report findings. In contrast, a lesson is low in
scientific inquiry when inquiry activities are limited to following a scripted set of
procedures that does not require them to engage in the practice of science, or
students do not engage in an inquiry activity at all.

4. *Teacher support of English language development* – This scale measures the
extent to which the teacher supports students’ English language development. A
high rating indicates that the teacher appropriately structures activities to reduce the language load required for participation (e.g., slower rate, enunciation), communicates at and slightly above students’ levels of communication (comprehensible input), uses language support strategies (e.g., key terms and meanings, multiple modes of representation through non-verbal and written communication, language in multiple settings), and uses ELL students’ home language or encourages ELL students to use their home language. In contrast, a low rating indicates that the teacher fails to use such strategies successfully so as to support students’ English language development.

The teacher knowledge of science content and teacher support of English language development scales focus on teacher practices, whereas the scientific understanding and scientific inquiry scales measure the instructional environment that the teacher and students create jointly. Each observation scale uses a five-point rating system. The classroom observations included quantitative ratings of the observation scales, justifications for these ratings, and narrative field notes. Field notes provided classroom discourse and contextual information in rich detail, so that project members who were not the observers of the particular lessons could come up with the same ratings and justifications.

Prior to classroom observations, project members participated in reliability training using videotaped lessons from previous research. The members used the observation scales to rate these lessons and to discuss our ratings and justifications. These members continued training by observing lessons in real time and rating them on the scales until they established inter-rater agreement of over 90%. Prior to conducting the
second round of observations in the spring, the observers repeated the same training procedures using additional videotaped lessons from previous research.

Each teacher of each grade level was observed once in fall and once in spring. For third grade, fall observations were generally conducted during the Measurement unit, and spring observations during the Water Cycle and Weather unit. For fourth grade, fall observations were generally conducted during the Energy unit, and spring observations during the Processes of Life unit. For fifth grade, fall observations were generally conducted during the Earth Systems unit, and spring observations during the Synthesis unit. Each observation typically lasted from 45 minutes to an hour.

All observers followed standard conventions for the format of the field notes. Field notes were color-coded for episodes that illustrated reform-oriented practices for each of the four scales under investigation. For each scale in each lesson, a rating was given ranging from 1 (lowest) to 5 (highest) based on two criteria: (a) the frequency or intensity of reform-oriented practices and (b) the percentage of students who were engaged in such practices. In addition to the ratings, justifications were provided based on the evidence in the field notes of the lesson. Small groups or pairs of observers cross-validated the complete corps of the classroom observation data to ensure reliability.

Post-observation Interviews

The primary purpose of the post-observation interviews was to examine teachers’ reflections on their practices during the observed lessons. A secondary purpose was to use interview responses in triangulating classroom observations and questionnaire
responses. The interview protocol includes opening questions followed by probes in the following areas:¹

1. Scientific understanding and inquiry – This area includes the following opening questions:

   a. I’d like to know about the strategies that you use to teach science.

   To the interviewer: Address both scientific understanding and inquiry as relevant to the lesson. Choose an important teaching strategy from the lesson and ask the teacher to explain her conceptions of how that strategy works and what makes it a good (or important) strategy to teach science. If you do not get much from the first strategy that you select, discuss a second example.

   b. How much or little do you think your students understood the science topic in today’s lesson?

   To the interviewer: Address both scientific understanding and inquiry as relevant to the lesson.

Probes:

How can we tell whether your students understood the science topic?

¹ It was not feasible to assess teachers’ knowledge of the science content of the lessons being observed during the post-observation interviews. The primary reason was that direct assessment of teachers’ science knowledge could be perceived as an affront to professionalism, thus hampering our relationships which were to continue for another four years as part of the larger research project. Other reasons involved the difficulties in constructing an instrument to assess teachers’ science knowledge and the need for conducting interviews within reasonable time limits.

In addition to the questions addressing scientific understanding and inquiry and support for English language development, the interview protocol addressed other questions that are not parts of this study.
What learning difficulties, if any, did you notice with your students?

2. **Support for English language development** – This area includes the following opening questions:

   a. I’d like to know about the strategies that you use to promote students’ English language development.

   b. Do you have ESOL students in your class? I’d like to know about the strategies that you use to promote ESOL students’ English language development.

During the training on the classroom observation guideline, the project members who conducted classroom observations reviewed the interview protocol. After conducting the first several interviews following the classroom observations in real time, these members reviewed the interview audiotapes, provided feedback for each other, and ensured consistency for interview procedures.

Half of all observed teachers in each grade were randomly selected for the interviews in fall, and the remaining half of teachers were interviewed in spring. On the days of classroom observations, teachers participated in post-observation interviews at their school sites. By combining the observation and interview during a single visit, the research could examine teachers’ practices (through observations) and reflections (through interviews) regarding what happened during the lesson. To situate the interview in relation to the lesson, both the interviewer/observer and the teacher used examples of salient events during the lesson. Prior to the interview, the interviewer reviewed the classroom observation notes and selected examples for probing questions. The interviewer also asked the teacher to provide examples from the lesson. Although specific
examples differed among the observed lessons, the interviewers followed standard procedures to elicit teachers’ responses using the same opening and probing questions. Each interview lasted at least 30 minutes. The interviews were audiotaped and transcribed.

Although the interviewers asked specific questions pertaining to scientific understanding and inquiry and English language development, teachers often volunteered responses related to these issues throughout the interviews. As a result, interviews were used in their entirety for analysis, rather than specific sections pertaining to specific questions. For the preliminary analysis framework, the initial descriptive codes were developed based on the questionnaire and the classroom observation guideline. As teachers’ responses were coded, new codes began emerging. The final analysis framework combined the overlapping codes based on the questionnaire and the classroom observation guideline, on the one hand, and the emerging codes from the interviews, on the other hand (Bogdan & Biklen, 2003). Several closely related codes were merged.

Once the coding system was established, 4 project members read a small set of transcripts in their entirety and analyzed teachers’ responses across the entire list of codes. After the inter-rater agreement reached 90%, three members analyzed all transcripts together. One member worked with the other members to maintain consistency among the three members. Each coder analyzed a set of the transcripts and verified the coding of the other for another set of the transcripts. Cross-validation of the complete corps of the data was employed to ensure reliability. As each coder read the entire transcript, the teacher’s responses with respect to relevant codes were analyzed. If a teacher gave the same response multiple times, it was counted as one response.
Data Analysis

Data analysis was based on 32 third grade teachers, 21 fourth grade teachers, and 17 fifth grade teachers who participated for the entire school year and who completed data collection activities, a total of 70 teachers. The entire data base for analysis in this study included 70 questionnaire responses, 140 classroom observations, and 70 post-observation interviews. The study employed mixed methods including both quantitative and qualitative approaches for data analysis. The three data sources allowed triangulation of results.

Teachers’ Knowledge and Practices

Descriptive statistics. To examine teachers’ knowledge and practices during the first year of their participation in the intervention (Research Question 1A), the means and standard deviations of questionnaire results and observation results were obtained.

First, the questionnaire items were grouped together to form scales on teacher knowledge of science content, practices for scientific understanding, practices for scientific inquiry, and practices for English language development. The score for each scale was computed using the average of the responses to the items that comprised the scale. Use of the average item response, as opposed to the summated score, ensured that missing responses would not lead to a systematic negative bias of the scale scores. A scale score was computed only for those respondents who had valid responses for at least 75% of the items in the scale. If someone answered fewer than 75% of a scale’s items, the respondent’s scale score was set to be missing and omitted from that particular scale. Internal consistency reliability estimates for the scale scores using Cronbach’s alpha (\(\alpha\)) ranged from .64 to .94. Most estimates were within an acceptable range, with the
exception of the Grade 3 scientific understanding estimate, which was slightly below.

The reliability estimates for each construct and for each grade are displayed in Table 4.

Table 4
*Reliability Estimates for Questionnaire Scales (Cronbach’s \( \alpha \))*

<table>
<thead>
<tr>
<th>Teacher knowledge of science content</th>
<th>Scientific understanding</th>
<th>Scientific inquiry</th>
<th>Teacher support of English language development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 3</td>
<td>.91</td>
<td>.64</td>
<td>.76</td>
</tr>
<tr>
<td>Grade 4</td>
<td>.88</td>
<td>.72</td>
<td>.79</td>
</tr>
<tr>
<td>Grade 5</td>
<td>.88</td>
<td>.81</td>
<td>.86</td>
</tr>
<tr>
<td>Combined grades</td>
<td>.90</td>
<td>.72</td>
<td>.80</td>
</tr>
</tbody>
</table>

Second, the classroom observation ratings were obtained from the coded transcripts. Consistent with the questionnaire, the four constructs on teacher knowledge of science content, practices for scientific understanding, practices for scientific inquiry, and practices for English language development were included. At each grade level, means of the ratings for the four constructs were computed for fall and spring observations separately. The data were not collapsed because there may be differences between fall and spring based on different content taught at those particular observation times; these differences would be ignored if the two time points are collapsed.

Finally, the post-observation interview ratings were obtained from the coded transcripts. For each construct, there was a maximum number of codes each teacher can mention during the interview. For example, if there were 13 possible codes for scientific understanding, each teacher could mention any number of codes up to the 13 set codes (e.g., 7 out of 13 codes). The same approach was employed for the constructs of scientific understanding and English language development. For each construct, the number of
teachers mentioning each code was counted, and the most frequent responses are reported.

In order to examine differences between grade levels, questionnaire scales, fall observation ratings, and spring observation ratings were analyzed separately using analysis of variance (ANOVA) methods. Levene’s tests were performed to detect possible violations to homogeneity within the samples. If this assumption was violated, the significance levels were reduced to 0.01. If this assumption was not violated, the significance levels were set at 0.05. In addition, partial $\eta^2$ effect size magnitudes were computed (Cohen, 1988, pp. 284-288). Post-hoc comparisons were performed to determine grade level differences.

Illustrations. To exemplify teachers’ knowledge and practices during science instruction to ELL students and teacher reflections on the observed lesson (Research Question 1B), vignettes from classroom observations followed by post-observation interviews were provided.

In order to exemplify classroom observation ratings, two approaches were used. First, an entire lesson was chosen to illustrate typical patterns in teachers’ knowledge and practices (i.e., modes of the classroom observation ratings for the four constructs across all observed lessons). In addition to description of the typical lesson, the ratings for each domain in this particular lesson were described and justified. Second, an entire lesson was chosen to illustrate reform-oriented practices (i.e., classroom observation ratings of 4 or 5 for the four constructs). Again, in addition to description of the reform-oriented lesson, the ratings for each domain in this particular lesson were described and justified.
**Relationships**

*Description of relationships.* To examine the relationships among the four constructs under investigation, as well the relationships between perceptions and practices of participating teachers (Research Question 2A), Pearson correlations are reported. Three types of relationships were examined:

First, to examine the relationships among the four domains of teachers’ perceptions, the questionnaire scales were intercorrelated using Pearson correlations. Both the coefficients and significance levels are reported. Scatterplots were examined for variables that were significantly correlated to visually inspect the data for a linear trend.

Second, Pearson correlations were conducted to examine the relationships among the four domains of teachers’ practices. The classroom observation ratings from the fall were intercorrelated, and those from the spring were intercorrelated. Both the coefficients and significance levels are reported. Scatterplots were examined for variables that were significantly correlated to visually inspect the data for a linear trend.

To examine whether other potential variables might account for relationships between teacher knowledge and practices, multiple regression analyses were conducted. The scales for the four constructs were used as dependent variables: a) practices for understanding; b) practices for inquiry; c) science content knowledge; and d) English language development. For classroom observations, analyses were conducted for fall and spring separately. Teacher background predictor variables were based upon teachers’ self-reported information. For both questionnaire responses and classroom observations, three predictor variables were included: a) the number of years they had been teaching; b) the number of science courses they had taken in six different science disciplines with the
highest categories of science classes collapsed together (this value could range from 0 to 36); and c) the highest degree of education earned.

 Profiles of teaching practices. To identify patterns of relationships of the four constructs that might be prevalent among teachers, profiles of teaching practices were constructed using classroom observation ratings. In order to determine whether patterns among domains existed and what those patterns were, a manual profile analysis of teaching practices was performed (Research Question 2B). To facilitate the formation of profiles, observations for all third, fourth, and fifth grade teachers were included in this analysis, and attention was paid to potential differences between fall and spring.

For the profile analysis of teaching practices, the original classroom observation ratings (ranging from 1 to 5) were further categorized into denominations of high (H), medium (M), and low (L). Ratings of 4 and 5 were grouped into the high denomination, ratings of 3 into the medium denomination, and ratings of 1 and 2 into the low denomination. For each of the four constructs – teacher content knowledge, scientific understanding, scientific inquiry, and English language development – a denomination was assigned based on the rating. These denominations counted together allow for profiles to emerge that may give rise to patterns. For a visual hypothetical representation, see Table 5.
Table 5

*Hypothetical Profiles of Teaching Practices*

<table>
<thead>
<tr>
<th>Teacher knowledge of science content</th>
<th>Teacher understanding of content</th>
<th>Scientific inquiry</th>
<th>Scientific language development</th>
<th>Profile</th>
</tr>
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<tr>
<td>1</td>
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(continued)
CHAPTER IV

Results

Results on teachers’ self-reported knowledge and practices, as well as observed practices and reflections on their practices, are presented. The results are based on mixed methods for statistical and qualitative analysis of questionnaire responses, observation ratings, and post-observation interview responses.

*Elementary Teachers’ Knowledge and Practices in Science Instruction with ELL Students*

*Questionnaires*

The results of questionnaire responses are reported in Table 6. The questionnaire responses for the teacher knowledge of science content scale were based on a 4-point rating system. The mean for this scale was 2.87 for third grade, 2.85 for fourth grade, and 3.12 for fifth grade. These means indicate that teachers reported they were generally knowledgeable of science topics at their grade level. The questionnaire responses for teaching science for the understanding, inquiry, and English language development scales were also based on a 4-point rating system. The mean for understanding was 3.16 for third grade, 3.16 for fourth grade, and 3.13 for fifth grade. These means indicate that teachers reported using practices to promote students’ understanding in most science lessons. The mean for inquiry was 3.17 for third grade, 2.89 for fourth grade, and 3.13 for fifth grade. These means indicate that teachers reported using practices to promote students’ inquiry in most science lessons. The mean for English language development was 2.13 for third grade, 2.04 for fourth grade, and 2.09 for fifth grade. These
The Levene’s test did not show violations to homogeneity of variance. Therefore, the significance levels for all domains were set to 0.05. ANOVA results indicate no significant differences between grade levels for each of the four scales; analysis yielded small effect sizes (partial $\eta^2$) for each of the four scales.

Table 6
**Teacher Questionnaire Responses: Means and Standard Deviations**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Grade 3 ($n = 32$)</th>
<th>Grade 4 ($n = 21$)</th>
<th>Grade 5 ($n = 17$)</th>
<th>$F$</th>
<th>$p^b$</th>
<th>Partial $\eta^2$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Science Knowledge</td>
<td>2.87 (0.59)</td>
<td>2.85 (0.47)</td>
<td>3.12 (0.48)</td>
<td>1.51</td>
<td>.23</td>
<td>.04</td>
<td>small</td>
</tr>
<tr>
<td>Practices for Understanding</td>
<td>3.16 (0.51)</td>
<td>3.16 (0.51)</td>
<td>3.13 (0.60)</td>
<td>0.02</td>
<td>.98</td>
<td>.00</td>
<td>small</td>
</tr>
<tr>
<td>Practices for Inquiry</td>
<td>3.17 (0.51)</td>
<td>2.89 (0.58)</td>
<td>3.13 (0.70)</td>
<td>1.64</td>
<td>.20</td>
<td>.05</td>
<td>small</td>
</tr>
<tr>
<td>Practices for English Language Development</td>
<td>2.13 (0.80)</td>
<td>2.04 (0.10)</td>
<td>2.09 (0.73)</td>
<td>0.07</td>
<td>.93</td>
<td>.00</td>
<td>small</td>
</tr>
</tbody>
</table>

$^a$ The scores are based on a 4-point rating system.

$^b$ $p < .05$ is interpreted as statistically significant.

$^c$ $\eta^2 > .01$ is ‘small’ effect size; $\eta^2 > .06$ is ‘medium’, and $\eta^2 > .14$ is ‘large’

Classroom Observations

The results of observation ratings are presented in Table 7. The classroom observation guideline used a 5-point rating system for all four scales. The means of the classroom
observation ratings for teacher knowledge of science content for third grade were 2.88 in fall and 2.97 in spring. The means for fourth grade were slightly higher at 3.10 in fall and 3.33 in spring. The means for fifth grade were yet higher at 3.41 in fall and 3.71 in spring. A rating of 3 indicates that teacher knowledge is generally accurate within the bounds of the science content provided in the student booklet. A rating of 4 indicates that the teacher transmits accurate and relevant information about the content that goes beyond what is covered in the lesson.

The means for scientific understanding for third grade were 3.13 in fall and 2.97 in spring. For fourth grade, the means were slightly higher at 3.29 in fall and 3.14 in spring. The means were the highest for fifth grade at 3.24 in fall and 3.41 in spring. A rating of 3 indicates that knowledge is treated unevenly during the lesson; some scientific concepts are developed in depth but others are developed superficially.

The classroom observation ratings for scientific inquiry are noticeably lower than other scales. It is important to note that this scale was rated more conservatively than the other scales, reflecting the lower ratings. The means for third grade were 1.19 in fall and 2.28 in spring. For fourth grade, the means were 2.14 in fall and 2.19 in spring. For fifth grade, the means were 2.65 for fall and 2.47 for spring. A rating of 2 indicates that students conducted scientific inquiry (i.e., generating questions, designing and carrying out investigations, analyzing and drawing conclusions, or reporting findings) within the bounds of a scripted lesson, as they primarily received and performed routine procedures for the inquiry. A rating of 3 indicates that there is some activity involving scientific inquiry beyond the scripted lesson.

The means for teacher support of English language development for third grade were 3.25 in fall and 3.38 in spring. For fourth grade, the means were 2.81 in fall and 3.14 in spring.
For fifth grade, the mean of 3.18 was consistent for fall and spring. A rating of 3 indicates that (a) the teacher communicates at the appropriate level or mode of language to enhance students’ comprehension and to develop English language and that (b) there are minor events as diversions in which the teacher effectively uses language support strategies (e.g., multiple modes of representation using written and non-verbal communication, use of language in multiple settings, and use of ELL students’ home language as needed).

The Levene’s test showed violations to homogeneity of variance. Therefore, the significance levels for all domains were reduced to 0.01. ANOVA results indicated significant differences in teachers’ science knowledge between grade levels in spring ($F = 4.60, p < 0.01$). Analysis yielded medium effect magnitudes in spring. Post-hoc comparisons indicated significant differences between grades 3 and 5 in spring. ANOVA results in Table 4 indicated significant differences in scientific inquiry between grade levels in fall ($F = 21.57, p < 0.01$), and analysis yielded a large effect magnitude (partial $\eta^2$). Post-hoc comparisons for scientific inquiry indicated that in the fall, there were significant differences between grades 3 and 4 and between grades 3 and 5, but not between grades 4 and 5. It is important to note that these results may reflect that the measurement unit for the third grade in fall was taught primarily as basic skills or tool use as a means for engaging in science inquiry, which was emphasized in all the subsequent units from grades 3 through 5. In spring, there was no significant difference in scientific inquiry between grade levels. With regard to scientific understanding, there was no significant difference between grades in fall or spring. With regard to English language development, there was no significant difference between grades in fall or spring.
### Table 7

**Observation Ratings: Means and Standard Deviations**

<table>
<thead>
<tr>
<th>Construct</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
<th>F</th>
<th>P</th>
<th>Partial $\eta^2$ (effect size)</th>
<th>$\eta^2$ (magnitude)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Science Knowledge</td>
<td>Fall</td>
<td>.32</td>
<td>.21</td>
<td>.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>2.88 (0.55)</td>
<td>3.10 (0.63)</td>
<td>3.41 (0.87)</td>
<td>3.66</td>
<td>.03</td>
<td>.10</td>
<td>medium</td>
</tr>
<tr>
<td>Spring</td>
<td>2.97 (0.90)</td>
<td>3.14 (1.01)</td>
<td>3.41 (1.33)</td>
<td>0.99</td>
<td>.38</td>
<td>.03</td>
<td>small</td>
</tr>
<tr>
<td>Practices for Understanding</td>
<td>Fall</td>
<td>.79</td>
<td>.64</td>
<td>1.30</td>
<td>.22</td>
<td>.81</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>3.13 (0.79)</td>
<td>3.29 (0.64)</td>
<td>3.24 (1.30)</td>
<td>0.22</td>
<td>.81</td>
<td>.01</td>
<td>small</td>
</tr>
<tr>
<td>Spring</td>
<td>2.28 (0.73)</td>
<td>2.19 (0.68)</td>
<td>2.47 (1.13)</td>
<td>0.55</td>
<td>.58</td>
<td>.02</td>
<td>small</td>
</tr>
<tr>
<td>Practices for Inquiry $^d$</td>
<td>Fall</td>
<td>.47</td>
<td>.85</td>
<td>1.12</td>
<td>21.57</td>
<td>.00 $^e$</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>1.19 (0.47) $^e$</td>
<td>2.14 (0.85)</td>
<td>2.65 (1.12)</td>
<td>21.57</td>
<td>.00</td>
<td>.39</td>
<td>large $^e$</td>
</tr>
<tr>
<td>Spring</td>
<td>2.28 (0.73)</td>
<td>2.19 (0.68)</td>
<td>2.47 (1.13)</td>
<td>0.55</td>
<td>.58</td>
<td>.02</td>
<td>small</td>
</tr>
<tr>
<td>Practices for English</td>
<td>Fall</td>
<td>.72</td>
<td>.60</td>
<td>0.81</td>
<td>2.58</td>
<td>.08</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>3.25 (0.72)</td>
<td>2.81 (0.60)</td>
<td>3.18 (0.81)</td>
<td>2.58</td>
<td>.08</td>
<td>.07</td>
<td>medium</td>
</tr>
<tr>
<td>Spring</td>
<td>3.38 (0.87)</td>
<td>3.14 (0.79)</td>
<td>3.18 (0.95)</td>
<td>0.55</td>
<td>.58</td>
<td>.02</td>
<td>small</td>
</tr>
</tbody>
</table>

---

$a$ The scores are based on a 5-point rating system.

$b$ $p < .01$ is interpreted as statistically significant.

c $\eta^2 > .01$ is ‘small’ effect size; $\eta^2 > .06$ is ‘medium’, and $\eta^2 > .14$ is ‘large’

$d$ The inquiry scale was rated more conservatively than the other scales, reflecting the lower ratings.

$e$ This result might be an artifact of the measurement unit which was taught primarily as basic skills or tool use as a means for engaging in science inquiry, which was emphasized in all the subsequent units from grades 3 through 5.
Post-observation Interviews

Post-observation interview results indicate that third, fourth, and fifth grade teachers often reflected on their practices intended to promote students’ scientific understanding during the observed lessons consistently during fall and spring. The most frequent responses for each grade are reported in Table 8.

Table 8

*Scientific Understanding Interview Responses (Percentage of Teachers Mentioning Each Code)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Grade 3 (%)</th>
<th>Grade 4 (%)</th>
<th>Grade 5 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall n = 17</td>
<td>Fall n = 9</td>
<td>Fall n = 8</td>
</tr>
<tr>
<td></td>
<td>Spring n = 15</td>
<td>Spring n = 12</td>
<td>Spring n = 9</td>
</tr>
<tr>
<td>Apply science concepts to explain natural phenomena or real world situations</td>
<td>Fall 94</td>
<td>56</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Spring 93</td>
<td>42</td>
<td>67</td>
</tr>
<tr>
<td>Relate science to other subject areas</td>
<td>Fall 0</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Spring 73</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Demonstrate understanding of the problematic nature of information OR Recognize students’ learning difficulties</td>
<td>Fall 88</td>
<td>44</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Spring 73</td>
<td>50</td>
<td>78</td>
</tr>
<tr>
<td>Engage in small group instruction, cooperative groups, or peer tutoring</td>
<td>Fall 59</td>
<td>67</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Spring 67</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>Engage in hands-on activity as means to promote understanding</td>
<td>Fall 71</td>
<td>78</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Spring 67</td>
<td>50</td>
<td>78</td>
</tr>
<tr>
<td>Use students’ mistakes to generate class discussion OR Help students with their learning difficulties</td>
<td>Fall 59</td>
<td>44</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Spring 53</td>
<td>33</td>
<td>44</td>
</tr>
<tr>
<td>Motivate students for learning or understanding</td>
<td>Fall 53</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Spring 60</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td>Explain the reasoning</td>
<td>Fall 35</td>
<td>0</td>
<td>25</td>
</tr>
</tbody>
</table>
Post-observation interview results with third, fourth, and fifth grade teachers indicate that they generally did not reflect on practices for scientific inquiry. For third grade, this result might be expected with the Measurement unit since it was taught primarily as basic skills or tool use during fall 2004. However, even during spring 2005 while most teachers taught the Water Cycle and Weather unit with a focus on scientific inquiry, they infrequently reflected on scientific inquiry. For fourth grade, this result is less expected, given that the fourth grade curriculum is more inquiry-based and student-centered. For fifth grade, this result is even less expected because of the strong emphasis on inquiry and the student-centered curriculum. The most frequent responses for each grade are reported in Table 9.

Table 9

<p>| Scientific Inquiry Interview Responses (Percentage of Teachers Mentioning Each Code) |
|-----------------------------------------------|-------------------|-------------------|-------------------|
| Time  | Grade 3 (%) | Grade 4 (%) | Grade 5 (%) |
| Fall  | Grade 3: n = 17 | Grade 4: n = 9 | Grade 5: n = 8 |</p>
<table>
<thead>
<tr>
<th>Spring</th>
<th>Grade 3: n = 15</th>
<th>Grade 4: n = 12</th>
<th>Grade 5: n = 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use measurement tools</td>
<td>Fall 59</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Spring 20</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Make predictions or hypotheses about what might be found during investigations</td>
<td>Fall 6</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Spring 27</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>Use simulations and models to construct reasonable explanations</td>
<td>Fall 0</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Spring 53</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>
Ask questions about objects, organisms, and events in the environment that can be answered through scientific observation, data collection, and interpretation

Plan and design scientific investigations, including the use of original procedures to answer questions

Use tools and techniques to gather, analyze, and interpret data

Engage in class discussion (or scientific argumentation) grounded in evaluation of data and interpretations

Hands-on activities

Use mathematics as applicable to a given investigation

Use resources (e.g. web, technology, book) to gather information

Post-observation interview results indicate that third, fourth, and fifth grade teachers often reflected on practices to support English language development during the observed lessons consistently during fall and spring. The most frequent responses for each grade are reported in Table 10.
Table 10

*Teacher Support of English Language Development Interview Responses (Percentage of Teachers Mentioning Each Code)*

<table>
<thead>
<tr>
<th>Code</th>
<th>Time</th>
<th>Grade 3 (%)</th>
<th>Grade 4 (%)</th>
<th>Grade 5 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall n = 17</td>
<td>Fall n = 9</td>
<td>Fall n = 8</td>
<td></td>
</tr>
<tr>
<td>Use multiple modes of representation using non-verbal (gestural), oral, graphic, and written communication</td>
<td>Fall 59</td>
<td>22</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 87</td>
<td>33</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Emphasize science vocabulary</td>
<td>Fall 76</td>
<td>56</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 60</td>
<td>75</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Use language in multiple settings (e.g., introduce, write, repeat, highlight)</td>
<td>Fall 76</td>
<td>56</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 47</td>
<td>58</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Communicate at and slightly above students' levels of communication (comprehensible input)</td>
<td>Fall 47</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 27</td>
<td>25</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Use key terms and definitions, or examples of these terms to support comprehension and English language development</td>
<td>Fall 47</td>
<td>0</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 27</td>
<td>0</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Engage in small group instruction or peer tutoring to enhance English language development</td>
<td>Fall 24</td>
<td>22</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 33</td>
<td>33</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Use science vocabulary in ESOL students’ home language</td>
<td>Fall 29</td>
<td>11</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 27</td>
<td>17</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Adapt the use of language for a range of English proficiency levels with ESOL students</td>
<td>Fall 24</td>
<td>11</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 27</td>
<td>0</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Structure activities to reduce language load (slower rate, enunciation)</td>
<td>Fall 6</td>
<td>11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 0</td>
<td>33</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Encourage bilingual students to work together</td>
<td>Fall 0</td>
<td>22</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 7</td>
<td>25</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>
In summary, all three data sources – questionnaire responses, observation ratings, and post-observation interview responses – indicated that teachers’ knowledge and practices were generally within the bounds supported by the intervention. In terms of differences among grade levels, while there were no significant differences in questionnaire responses, there were significant differences in classroom observation ratings. For the teachers’ science knowledge and practices for inquiry scales, the observation ratings tended to increase as the grade levels increased. In contrast, the practices for English language development scale tended to be higher at third grade than fourth or fifth grade.

A Typical Lesson

The following section describes an observed lesson that is considered “typical” of the classroom observations and post-observation interviews. This means that the lesson received ratings close to the observation rating means described in the descriptive statistics section above. For all three grades, the means for teacher knowledge of science content, practices for understanding, and practices for English language development were generally around 3, and the means for practices for inquiry were generally around 2. Therefore, a lesson receiving a rating of 3 for practices for understanding, a rating of 2 for practices for inquiry, a rating of 3 for teacher science knowledge, and a rating of 3 for practices for English language development was selected. This lesson stems from a 4th grade classroom, although any lesson with these ratings from any of the three grades could have been selected. This 4th grade classroom contained mostly Haitian-American
students. The teacher was female Caucasian who had ESOL endorsement through college, but did not speak Haitian-Creole.

*Description of the lesson.* The observed lesson was Lesson 6 – Energy and Waves – from the Force and Motion unit in spring 2006. Much of the lesson was spent reading directions of how to do the activities. There were very few opportunities for inquiry, despite the fact that two hands-on activities were performed.

The first activity involved making waves with a rope, and the second involved exploring waves with a slinky. The teacher read out of her teachers’ guide throughout the lesson, often asking students to read out loud. In the beginning, she spent some time making clear what waves were by gesticulating to explain stretch. The students exclusively followed the teacher’s and the book’s directions. At the end of the activity, the teacher systematically proceeded to answering questions on what the students observed about the movement of the rope, and prompted them to record their observations. At this point, there was not much evidence that understanding took place, as the students were merely describing what they saw, as for example the up and down movement of the rope. This was mostly reflected by the written student responses, and not by oral discussion.

The second activity was performed similarly to the first one, and it involved making waves with a slinky. This activity called for releasing the slinky upon holding different numbers of coils before letting go. Again, the teacher followed the script entirely, giving the students step by step instructions about how to proceed. Following this activity, the teacher prompted the class to complete a table provided in the lesson and draw conclusions. Here, students displayed some scientific understanding, despite the
fact that there was no information on the topic provided to them beforehand. For example, students were able to make the connection that when holding a larger number of coils of the slinky, more waves were produced because of the increased force. In general, students came up with the conclusion that energy increased as the number of waves increased, which displays understanding.

*Ratings of the lesson for each of the four domains.* The teacher’s knowledge of science content seemed generally accurate but within the bounds of the lesson content provided in the student booklet. There was no additional information provided beyond the bounds of the lesson by offering deeper knowledge and enriching the discussion with the students, which justifies this domain receiving a rating of 3. One instance in which the teacher stated that “energy is force” in response to a student statement that “as energy increases, it makes more force”, was not substantial enough to receive a higher rating. At the same time, the teacher did not display any inaccuracies, which prevented the lesson from receiving a lower rating.

Students’ scientific understanding was uneven throughout the lesson. The first part of the lesson covering the first activity with the rope did not display any scientific understanding, as the students were merely executing the activity, observing, and writing about their observations. During the second activity with the slinky, however, several students displayed understanding of the science content that was beyond mere observation. The students were able to make the connection between force and energy, which was evident through statements such as “as energy increases, the number of waves increases”. Due to the uneven nature of understanding being displayed during the whole lesson, this domain received a rating of 3. This domain would have received a higher
rating in the case of deep understanding as students provide information, arguments, or reasoning that demonstrates complexity of one or more ideas. This domain would have received a lower rating in the case of consistent superficial understanding.

Scientific inquiry activities during this lesson were within the bounds of the scripted lesson. The students primarily recited, received, and performed routine procedures as outlined in the student booklet. Therefore, this domain received a rating of 2. This domain would have received a higher rating if the teacher had structured the lesson so that there was at least one significant activity beyond the scripted lesson in which the students engaged in scientific inquiry. This domain would have received a lower rating if no inquiry activities at all had taken place.

The teacher’s support of English language development was at the appropriate level of students’ language development and comprehension. Minor strategies such as the use of realia, word definitions, or word hints were employed, and this domain received a rating of 3. This domain would have received a higher rating if there had been one or two significant events in which the teacher used varied language support strategies. This domain would have received a lower rating if the teacher had failed to communicate at the appropriate level and mode of language to enhance students’ comprehension and to develop English language.

*A Reform-oriented Lesson*

The following section describes an observed lesson that is considered reform-oriented. This means that the lesson consistently received high ratings for all four domains. Therefore, a lesson receiving a rating of 5 for practices for understanding, practices for inquiry, teacher science knowledge, and practices for English language
development was selected. This lesson stems from a 5th grade classroom, although any lesson with these ratings from any of the three grades could have been selected. This 5th grade classroom contained mostly Haitian-American students and no ESOL students. The teacher was male Caucasian who did not have ESOL endorsement through college, and did not speak Haitian-Creole.

*Description of the lesson.* The observed lesson was Lesson 1 – Introduction to Earth Systems – from the Earth Systems unit. The teacher began the lesson by reviewing the term “system” and allowing students to connect to biological systems in order to explain its meaning. The systems hydrosphere, atmosphere, and lithosphere were reviewed as well, with many definitions and relevant examples. Shortly after this vocabulary review, a discussion on whether Mars had an atmosphere arose. This discussion was not teacher-centered, but was focused on students hypothesizing on reasons why there may or may not be gases on the planet. A transition to the term “cycle” followed, and the teacher connected it to “re-cycle”. Throughout, the students displayed understanding, since many were able to describe cycles in several situations. Upon a question about photosynthesis from a student, the teacher allowed for a brief discussion on decomposition, along with providing relevant additional examples.

The teacher made a transition into the day’s topic by asking the students how old they were, a strategy to introduce the Earth’s age. Along with the introduction, the teacher used this opportunity to connect to math, and performed some multiplication exercises. While explaining the Earth’s age, the teacher again allowed for a supplementary discussion on possible explanations for gaps in the earth’s crust,
consistently defining words for English language development. Further discussions followed about fossil records.

An inquiry activity on the Earth’s age for which the teacher took the class outside the classroom followed. In this activity, students – with the basic knowledge of football and the timeline of the Earth’s formation – were encouraged to hypothesize where certain points on the line would be by physically placing themselves in a particular spot. This activity was presented in the book in the context of a football field, but the teacher enriched it creatively.

_Ratings of the lesson for each of the four domains._ There are several important characteristics that rendered this lesson reform-oriented. First, the teacher made several connections to other subjects such as mathematics and biological science, while tying in the concepts of the lesson. Second, the teacher used numerous age- and culturally appropriate examples from real life that applied to the content of the lesson. Third, the teacher allowed and encouraged hypothesizing and discussing situations, taking advantage of every opportunity that presented itself throughout the discourse of the lesson. Fourth, the teacher consistently and effectively used English language development strategies.

The teacher’s knowledge of science content was well beyond the bounds of the lesson, giving the lesson a rating of 5. He used every opportunity to supply additional information by offering deeper knowledge and enriching the discussion with the students, while connecting this information to the lesson content. For example, relevant connections on recycling were made to students’ every day lives, and links to mathematics were intertwined with computing the Earth’s age. He was able to address
student questions by providing correct answers and supplementing them with additional thoughts pertaining to the topic. For example, when asked by a student, he explained whether humans could survive on carbon monoxide.

Students’ scientific understanding was consistently deep because the teacher successfully structured the lesson so that most students (50%-90%) were able to sustain a focus on a significant topic for a period of time, demonstrate understanding of the connections between concepts and between these and personal experiences or real world phenomena, demonstrate understanding of the problematic and incomplete nature of information, and demonstrate understanding by making reasoned and well-supported arguments. Most students displayed understanding by explaining and justifying the science content, but also by applying scientific situations to real life examples. This domain received a rating of 5.

Scientific inquiry activities during this lesson were numerous and far beyond the bounds of the scripted lesson. Most students, for most of the time, engaged in scientific inquiry beyond the scripted lesson. The teacher created a supportive environment, with the use of humor, which allowed students to feel comfortable asking questions, making predictions, using math in appropriate ways, and communicating their explanations in a manner that their peers could understand. For example, there were extended discussions on whether or not Mars had an atmosphere, and possible explanations for the disappearance of fossil evidence. This domain received a rating of 5.

The teacher communicated at the appropriate level to enhance students’ comprehension and to develop English language. He used varied language support strategies throughout the lesson. There were several significant events in which the
teacher effectively used language support strategies. For example, he consistently defined science vocabulary and asked students to give him additional examples for certain terms. The most striking example was the introduction of the term “anachronism”, which the teacher considered important in the discussion of determining the Earth’s age. Furthermore, the physical arrangement of students as a representation of the Earth’s age served as an essential visual strategy in this lesson. This domain received a rating of 5.

Relationships among Domains of Science Instruction with ELL Students

Relationships among Domains of Teachers’ Perceptions

The results of the intercorrelations among the questionnaire scale scores for grades 3, 4, and 5 are presented in Table 11. The sample size for each of the correlations computed is shown in the table. There were missing data for some of the scales causing the sample size to decrease. The magnitude of correlations was determined as low ($r < .40$), moderate ($r = .40 – .80$), and high ($r > .80$), (Cohen, 1988).

For grade 3, there were two statistically significant correlations. The practices for understanding scale was significantly correlated with both the practices for inquiry ($r = .55$) and practices for English language development ($r = .41$) scales. Both correlations are positive and moderate in size. For grade 4, there were no statistically significant correlations. For grade 5, there was one statistically significant correlation. The practices for understanding scale was significantly correlated with the practices for inquiry scale ($r = .82$). This is a positive, high correlation. Overall, except for scientific understanding being related with scientific inquiry in grades 3 and 5 and with English language development in grade 3, teacher perceptions for the four scales were generally not related across grade levels.
Table 11

*Intercorrelations among Questionnaire Responses*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSK</td>
<td>PU</td>
<td>PI</td>
</tr>
<tr>
<td>Teacher science knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices for understanding</td>
<td>-.06</td>
<td>-.27</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>(32)</td>
<td>(21)</td>
<td>(17)</td>
</tr>
<tr>
<td>Practices for inquiry</td>
<td>.24</td>
<td>.55**</td>
<td>-.15</td>
</tr>
<tr>
<td></td>
<td>(31)</td>
<td>(21)</td>
<td>(17)</td>
</tr>
<tr>
<td>Practices for English language development</td>
<td>-.09</td>
<td>.41*</td>
<td>.20</td>
</tr>
</tbody>
</table>

Values in parentheses represent the number of teachers for each correlation.
* *p < .05  ** *p < .01

*Relationships among Domains of Teachers’ Practices*

Tables 12 and 13 below show the intercorrelations among the observation ratings for grades 3, 4, and 5. The tables show intercorrelations for fall and spring observations separately. For grade 3, the practices for understanding domain was related to (1) teachers’ science knowledge in the spring \((r = .52)\) by a positive, moderate correlation; (2) practices for inquiry in the fall \((r = .45)\) by a positive, moderate correlation, and in the spring \((r = .51)\) by a positive, moderate correlation; and (3) practices for English language development in the fall \((r = .51)\) and in the spring \((r = .51)\) by a positive, moderate correlation.

For grade 4, the practices for understanding domain was related to (1) teachers’ science knowledge in the spring \((r = .66)\) by a positive, moderate correlation and (2) practices for English language development in the fall \((r = .54)\) and in the spring \((r = .52)\) by a positive, moderate correlation. Additionally, the teachers’ science knowledge
domain was related to practices for English language development in the fall \((r = .58)\) and in the spring \((r = .52)\) by a positive, moderate correlation.

For grade 5, all four domains were related to one another by positive and moderate to high correlations, with the exception of teachers’ science knowledge and English language development.

In summary, except for the relationships between the practices for understanding scale and the practices for inquiry scale, teacher perceptions using questionnaire responses were not related to one another across the grade levels. In contrast, teaching practices using observation ratings were often related to one another across all three grade levels. Across the grade levels, the practices for understanding domain was generally related to the other three domains in both fall and spring. For grade 5, all four domains were related to one another in both fall and spring. The findings highlight the essential role of scientific understanding in science instruction with ELL students through both teachers’ perceptions and observations of teaching practices. The findings also indicated grade level differences in the relationships among domains, with all four domains being related to one another at grade 5.
Table 12

**Intercorrelations among Fall Observation Ratings**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Grade 3 (n = 32)</th>
<th>Grade 4 (n = 21)</th>
<th>Grade 5 (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSK</td>
<td>PU</td>
<td>PI</td>
</tr>
<tr>
<td>Teacher science knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices for understanding</td>
<td>.33</td>
<td>.18</td>
<td></td>
</tr>
<tr>
<td>Practices for inquiry</td>
<td>-.03</td>
<td>.45**</td>
<td></td>
</tr>
<tr>
<td>Practices for English language development</td>
<td>.32</td>
<td>.51**</td>
<td>-.05</td>
</tr>
</tbody>
</table>

* p < .05  ** p < .01

Table 13

**Intercorrelations among Spring Observation Ratings**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Grade 3 (n = 32)</th>
<th>Grade 4 (n = 21)</th>
<th>Grade 5 (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSK</td>
<td>PU</td>
<td>PI</td>
</tr>
<tr>
<td>Teacher science knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices for understanding</td>
<td>.52**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices for inquiry</td>
<td>.27</td>
<td>.51**</td>
<td></td>
</tr>
<tr>
<td>Practices for English language development</td>
<td>.23</td>
<td>.51**</td>
<td>.03</td>
</tr>
</tbody>
</table>
The results of the regression analyses from questionnaires and classroom observations predicting teacher science knowledge, practices for understanding, practices for inquiry, and practices for English language development are presented in Tables 14 and 15. The regression model for the questionnaire showed that the three predictor variables (i.e., the number of years of teaching, the number of science courses taken, and the highest degree of education earned) explained a statistically significant proportion of the variance in the practices for understanding scale, $R^2 = .16, F[3, 53] = 3.41, p = .024$. The predictors account for 16% of the variance in this scale. In the model, the number of science courses taken was a significant predictor of the teacher practices for understanding scale; the unstandardized coefficient was -0.03, $t[53] = -2.75, p = .008$.

Except for this scale, none of the other predictor variables showed statistical significance.

Table 14

Regression Analysis for Questionnaire Responses

<table>
<thead>
<tr>
<th>Scale</th>
<th>Coefficient</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
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<td>Teacher science knowledge</td>
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<td>0.22</td>
<td>12.54</td>
</tr>
<tr>
<td></td>
<td>TEACHYRS</td>
<td>0.05</td>
<td>0.01</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>COURSES</td>
<td>0.02</td>
<td>0.01</td>
<td>1.88</td>
</tr>
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<td>HIDEG</td>
<td>-0.04</td>
<td>0.16</td>
<td>-0.26</td>
</tr>
<tr>
<td>Practices for understanding</td>
<td>Intercept</td>
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<tr>
<td></td>
<td>TEACHYRS</td>
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<td>0.01</td>
<td>-0.94</td>
</tr>
<tr>
<td></td>
<td>COURSES</td>
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<td>0.01</td>
<td>-2.75</td>
</tr>
<tr>
<td></td>
<td>HIDEG</td>
<td>0.24</td>
<td>0.15</td>
<td>1.60</td>
</tr>
<tr>
<td>Practices for inquiry</td>
<td>Intercept</td>
<td>3.18</td>
<td>0.24</td>
<td>13.04</td>
</tr>
<tr>
<td></td>
<td>TEACHYRS</td>
<td>-0.01</td>
<td>0.01</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td>COURSES</td>
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<td>0.01</td>
<td>-0.48</td>
</tr>
<tr>
<td></td>
<td>HIDEG</td>
<td>-0.01</td>
<td>0.18</td>
<td>-0.04</td>
</tr>
<tr>
<td>Practices for</td>
<td>Intercept</td>
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<td>0.37</td>
<td>5.46</td>
</tr>
<tr>
<td>Scale</td>
<td>Time</td>
<td>Coefficient</td>
<td>SE</td>
<td>t</td>
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</tr>
<tr>
<td>Teacher</td>
<td>Intercept</td>
<td>Fall</td>
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<td>0.28</td>
</tr>
<tr>
<td>science</td>
<td></td>
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<tr>
<td>TEACHYRS</td>
<td>Fall</td>
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<td>0.01</td>
<td>0.14</td>
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<td>1.38</td>
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<tr>
<td>COURSES</td>
<td>Fall</td>
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<td>0.73</td>
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<td>Spring</td>
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<td>0.02</td>
<td>0.94</td>
</tr>
<tr>
<td>HIDEG</td>
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<td>0.21</td>
<td>-1.15</td>
</tr>
<tr>
<td></td>
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<td>0.28</td>
<td>-1.34</td>
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<tr>
<td>Scientific</td>
<td>Intercept</td>
<td>Fall</td>
<td>2.92</td>
<td>0.38</td>
</tr>
<tr>
<td>understanding</td>
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<td></td>
</tr>
<tr>
<td>TEACHYRS</td>
<td>Fall</td>
<td>0.03</td>
<td>0.02</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-0.00</td>
<td>0.02</td>
<td>-0.03</td>
</tr>
<tr>
<td>COURSES</td>
<td>Fall</td>
<td>-0.02</td>
<td>0.02</td>
<td>-0.67</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-0.01</td>
<td>0.03</td>
<td>-0.30</td>
</tr>
<tr>
<td>HIDEG</td>
<td>Fall</td>
<td>0.12</td>
<td>0.28</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
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<td>-0.35</td>
</tr>
<tr>
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<td>Intercept</td>
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<td>inquiry</td>
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</tr>
<tr>
<td>TEACHYRS</td>
<td>Fall</td>
<td>0.00</td>
<td>0.02</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-0.00</td>
<td>.02</td>
<td>-0.42</td>
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<tr>
<td>COURSES</td>
<td>Fall</td>
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<td>0.03</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-0.00</td>
<td>0.02</td>
<td>-0.33</td>
</tr>
<tr>
<td>HIDEG</td>
<td>Fall</td>
<td>-0.12</td>
<td>0.33</td>
<td>-0.36</td>
</tr>
</tbody>
</table>

Table 15

*Regression Analysis for Classroom Observation Ratings*
Profiles of Teaching Practices

The following section describes profiles of teaching practices for grades 3, 4, and 5. Although many profiles emerged at each grade level, only the five most frequently occurring profiles are reported. As a reminder, the high, medium, and low denominations were obtained in the following domain order: teacher science knowledge, scientific understanding, scientific inquiry, and English language development. The five most frequently occurring profiles for each grade are displayed in Table 16.

Table 16
Profiles of Teaching Practices

<table>
<thead>
<tr>
<th>Profile</th>
<th>Grade 3 (n = 32)</th>
<th>Grade 4 (n = 21)</th>
<th>Grade 5 (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>MMLM</td>
<td>13 (41)</td>
<td>10 (48)</td>
<td>6 (35)</td>
</tr>
<tr>
<td>MMLH</td>
<td>7 (22)</td>
<td>6 (29)</td>
<td>5 (29)</td>
</tr>
<tr>
<td>MHLH</td>
<td>5 (16)</td>
<td>4 (19)</td>
<td>4 (19)</td>
</tr>
<tr>
<td>LLLLL</td>
<td>4 (13)</td>
<td>3 (14)</td>
<td>3 (14)</td>
</tr>
<tr>
<td>MLLL</td>
<td>4 (13)</td>
<td>2 (10)</td>
<td>3 (14)</td>
</tr>
</tbody>
</table>

* only occurring in grade 4
** only occurring in grade 5
For the 32 third grade teachers, a total of 25 profiles emerged. The most frequently occurring profile was MMLM, which means that teachers with this profile received a medium denomination for teacher science knowledge, a medium denomination for scientific understanding, a low denomination for scientific inquiry, and a medium denomination for English language development. A total of 13 out of 32 third grade teachers fell into this profile. The second most frequently occurring profile for grade 3 was MMLH, which means that teachers with this profile received a medium denomination for teacher science knowledge, a medium denomination for scientific understanding, a low denomination for scientific inquiry, and a high denomination for English language development. A total of 7 out of 32 third grade teachers fell into this profile. The third most frequently occurring profile for grade 3 was MHLH, which means that teachers with this profile received a medium denomination for teacher science knowledge, a high denomination for scientific understanding, a low denomination for scientific inquiry, and a high denomination for English language development. A total of 5 out of 32 third grade teachers fell into this profile. The fourth and fifth most frequently occurring profiles were LLLL and MLLL, respectively. In general, the frequency of profiles was consistent between fall and spring. A total of 3 teachers fell into the same profile for fall and spring.

There are several noteworthy patterns about teaching profiles for grade 3. First, scientific inquiry was consistently low for the five most frequently occurring profiles. This means that little to no inquiry was performed during the lessons, a possible result of the more teacher-centered nature of the third grade curriculum and the more skill-oriented nature of the measurement unit. Second, scientific understanding ranged from low to
medium to high, but remained medium for the two most frequently occurring profiles. This could be explained by a range of difficulty of the science concepts during a particular lesson. Third, teacher science content was medium for four of the five most frequently occurring profiles, and low for one. This means that teachers generally transmitted the information provided in the curriculum but did not go beyond. Fourth, English language development was either medium or high for the three most frequently occurring profiles, which may be due to the emphasis on reading in grade 3 according to the state accountability system. Overall, the results were consistent with the classroom observation means obtained for grade 3: the low inquiry rating and the relatively high English language development rating.

For the 21 fourth grade teachers, a total of 18 profiles emerged. Five of these did not emerge in grade 3. The most frequently occurring profile for grade 4 was MMLM, as it was for grade 3. This means that teachers with this profile received a medium denomination for teacher science knowledge, a medium denomination for scientific understanding, a low denomination for scientific inquiry, and a medium denomination for English language development. A total of 10 out of 21 fourth grade teachers fell into this profile. The second most frequently occurring profile for grade 4 was MHLM, which means that teachers with this profile received a medium denomination for teacher science knowledge, a high denomination for scientific understanding, a low denomination for scientific inquiry, and a medium denomination for English language development. A total of 6 out of 21 fourth grade teachers fell into this profile. The third most frequently occurring profile for grade 4 was MMMM, which means that teachers with this profile received a medium denomination for teacher science knowledge, scientific
understanding, scientific inquiry, and English language development consistently. A total of 4 out of 21 fourth grade teachers fell into this profile. The fourth and fifth most frequently occurring profiles were HMLM and MLLM, respectively. In general, the frequency of profiles was consistent between fall and spring. A total of 3 teachers fell into the same profile for fall and spring.

As for grade 3, there are several noteworthy patterns about profiles for grade 4. First, scientific inquiry was low for four of the five most frequently occurring profiles for grade 4. Although the fourth grade curriculum is designed to be more student-centered and less teacher-centered than the third grade curriculum, the limited inquiry observed may be a result of teachers’ unawareness of how to promote scientific inquiry. Second, scientific understanding ranged from low to medium to high, but was medium or high for four of the five most frequently occurring profiles. This range, as in grade 3, could be explained by a range of difficulty of the science concepts during a particular lesson. Third, teacher science content was medium for four of the five most frequently occurring profiles, and high for one. This means that teachers generally transmitted the information provided in the curriculum or went beyond. Fourth, English language development was consistently medium for the most frequently occurring profiles, which may be explained by the emphasis on writing in grade 4 according to the state accountability system. Overall, the results were consistent with the classroom observation means obtained for grade 4: with the exception of scientific inquiry, which was low, most domains were within a medium range.

For the 17 fifth grade teachers, a total of 16 profiles emerged. Three of these profiles did not emerge either in grade 3 or grade 4. The most frequently occurring profile
for grade 5 was HHHH, a profile not present in grade 3 or grade 4. Teachers with this profile received a high denomination for teacher science knowledge, scientific understanding, scientific inquiry, and English language development. A total of 6 out of 17 fifth grade teachers fell into this profile. The second most frequently occurring profile was HHMM, which means that teachers with this profile received a high denomination for teacher science knowledge, a high denomination for scientific understanding, a medium denomination for scientific inquiry, and a medium denomination for English language development. A total of 5 out of 17 fifth grade teachers fell into this profile. The third most frequently occurring profile for grade 5 was MLLM, which means that teachers with this profile received a medium denomination for teacher science knowledge, a low denomination for scientific understanding, a low denomination for scientific inquiry, and a medium denomination for English language development. A total of 4 out of 17 fifth grade teachers fell into this profile. The fourth and fifth most frequently occurring profiles were MLLL and MMLM, respectively. In general, the frequency of profiles was consistent between fall and spring. None of the fifth grade teachers fell into the same profile for fall and spring.

As for grades 3 and 4, there are several noteworthy patterns about profiles for grade 5. First, unlike in grades 3 and 4, scientific inquiry was medium or high for the two of the five most frequently occurring profiles for grade 5. The fifth grade curriculum being even more student-centered than the fourth grade curriculum could provide an explanation for these denominations. The low scientific inquiry in three of the five most frequently occurring profiles may be a result of teachers’ unawareness of how to promote scientific inquiry. Second, scientific understanding ranged from low to medium to high,
but was medium or high for three of the five most frequently occurring profiles for grade 5. This range, as in grades 3 and 4, could be explained by a range of difficulty of the science concepts during a particular lesson. Third, teacher science content was high for two of the five most frequently occurring profiles, and medium for the other three. This could be explained by the more difficult nature of the scientific concepts in grade 5 and the higher demand for science content knowledge. Furthermore, the fact that fifth grade teachers are often departmentalized in participating schools may render them more knowledgeable of science. Fourth, English language development was medium for three of the most frequently occurring profiles. Overall, the results were consistent with the classroom observation means: scientific inquiry and teacher science knowledge were higher in grade 5 than in grades 3 and 4, and the other two domains were within a medium range as in grades 3 and 4. This may be explained by the emphasis on science in grade 5 according to the state accountability system.

In summary, teaching profiles indicated that teachers’ knowledge and practices were generally within the bounds supported by the intervention. In terms of differences by grade level, scientific inquiry was low in grades 3 and 4, but higher in grade 5. Teacher science knowledge was higher in grade 5 than in grades 3 and 4. Scientific understanding and English language development were medium, consistent across the three grades.
CHAPTER V
Discussion and Implications

This study describes urban elementary teachers’ knowledge and practices during their first-year participation in a professional development intervention comprised of curriculum materials and teacher workshops. The first research question described and illustrated teachers’ knowledge and practices in four domains: (1) teachers’ knowledge of science content, (2) teaching practices to promote scientific understanding, (3) teaching practices to promote scientific inquiry, and (4) teaching practices to support English language development during science instruction. The second research question described and illustrated the relationships among these four domains. These research questions were investigated using teacher questionnaires, classroom observations, and post-observation interviews.

Conclusions

One key finding regarding the first research question, based on questionnaires, classroom observations, and post-observation interviews was that teachers’ knowledge and practices were within the bounds of the intervention. This finding might reflect the fact that since this was the first year of participation in the intervention, teachers’ knowledge and practices might reflect beginning stages of science teaching as “prescribed” by the intervention. Teachers may not yet be familiar with reform-oriented practices and may not be aware of how far beyond the curriculum they could extend their science instruction.

Another key finding regarding the first research question was that classroom observation ratings indicated a significant difference in teachers’ science knowledge
between grades 3 and 5 (and practices for inquiry in fall, although this finding should be interpreted with caution). Observation ratings for teachers’ science knowledge tended to increase as the grade level advanced. In contrast, practices for English language development tended to be higher in third grade than in fourth and fifth grade, as this result approached statistical significance. These differences among grade levels might be attributed to the state’s accountability policy where the statewide science assessment is administered at grade 5. In response to this accountability policy in science, fifth grade teachers might recognize the importance of knowing science content and using reform-oriented practices to stress scientific inquiry. In contrast, third grade teachers might emphasize English language development in response to the accountability policy retaining third grade students based on statewide reading assessment test scores. Furthermore, the science content expectations among the three grade levels differed substantially, as the difficulty of science concepts increased with advancing grade levels. This might explain the higher ratings for teachers’ science knowledge in grade 5 as compared to grade 3.

With regard to the second research question, one key finding was the essential role that practices for understanding played in the teaching of science with ELL students. The practices for understanding scale was related to the other three scales across both sets of instruments, across grade levels, and across times (fall and spring observations)—an important replication. This finding suggests that scientific understanding was essential for science instruction with ELL students both as perceived by the teachers and as observed during classroom practices.
Another key finding regarding the second research question involved differences in relationships across grade levels. Based on classroom observations, all four scales were related to one another at fifth grade, whereas only the practices for understanding scale was related to the other three scales at third and fourth grades. Additionally, the magnitude of relationships was larger at the fifth grade level than at the third or fourth grade level. This finding might be related to accountability policies. While fifth grade teachers must focus on statewide science assessment by incorporating all four domains into their instruction, third and fourth grade teachers might not feel this pressure and thus incorporate some domains sporadically. Furthermore, the difficulty of science content at the fifth grade level as compared to third and fourth grade levels might require fifth grade teachers to incorporate all science domains as well as English language development for effective science instruction with ELL students.

While teaching profiles were intended as a part of the second research question, they confirmed the results of the first question. Teaching profiles for teacher science knowledge and scientific inquiry were higher for grade 5 than grades 3 and 4. In contrast, teaching profiles for English language development tended to be higher in grade 3 than in grades 4 and 5. Teaching profiles for scientific understanding were generally medium across grades. These results from teaching profiles were consistent with the results from classroom observation ratings and post-observation interviews.

Limitations of the Study

Despite extensive efforts to ensure methodological rigor, limitations of this study should be considered. One limitation concerns the fact that although the constructs on the questionnaire and classroom observation guideline are comparable, the ratings are
different. Despite such differences, readers may be tempted to compare the two sets of ratings on these instruments as one-to-one correspondence.

A second limitation concerns the classroom observation ratings on the practices for inquiry scale, for which the ratings appeared considerably lower than the ratings of the other three scales. It is important to note that the inquiry scale was rated more conservatively than the other scales, reflecting the lower ratings. This scale needs to be modified, so that the four scales for classroom observations are comparable to one another.

Finally, the results need to be interpreted within the context of the first-year implementation of the intervention. As stated earlier, causal claims about the effect of the intervention in the absence of baseline data are not made about how the teachers in the treatment group had performed prior to the intervention or data from the teachers in the comparison group.

Discussion

The literature has traditionally examined science instruction and ESOL instruction separately, although they are integral to ELL students who are learning science while also acquiring English. The first research question examined elementary teachers’ knowledge and practices in teaching science while supporting English language development of ELL students simultaneously. The findings confirm the existing literature that elementary teachers’ knowledge and practices in teaching science to ELL students fell short of reform expectations in science (Cohen & Hill, 2000; Davis et al., 2006; Kennedy, 1998) and ESOL (Teaching English to Speakers of Other Languages, 1997). The findings were
especially apparent in practices for inquiry, even though inquiry-based science has been proposed as particularly effective with ELL students (Lee, 2002; Rosebery et al., 1992).

The second research question examined relationships among the four domains. Although empirical evidence is virtually non-existent, there is an underlying assumption of links among these domains. For example, scientific inquiry is viewed as a conduit for developing scientific understanding (NRC, 2000). Teachers with strong science content knowledge are more likely to engage in scientific inquiry (Carlsen, 1991; Tobin & Fraser, 1990). Furthermore, inquiry-based science has been proposed with ELL students (Lee, 2002; Rosebery et al., 1992). Through empirical evidence, the findings of this study indicated relationships among the four domains. Especially, the findings highlight the essential role of scientific understanding in reform-oriented teaching of science with ELL students. These findings are consistent with Romberg and colleagues’ (2005) rhetorical title (and the book’s chapters that present five-plus years of evidence in support of the claim) that understanding science matters.

In addition to contributions to the literature conceptually, the study also contributes methodologically. The questionnaire items were grouped together to form scales based on underlying constructs. Both the questionnaire and classroom observation guidelines were designed to address the same constructs to measure reform-oriented practices in science and ESOL. As a result, these two instruments enabled examination of teachers’ knowledge and practices to promote science learning and English language development of ELL students simultaneously.
Implications for Professional Development

The results from the first-year implementation of the intervention offer insights for our ongoing professional development as well as other similar efforts. The project’s first-year of implementation focused on guiding teachers through the lessons and activities, while concurrently improving their science content knowledge. Both the questionnaire responses and observation ratings indicated that teachers’ knowledge and practices were within the bounds of lesson content supported by the intervention.

One way to design ongoing professional development is to build on the strengths and limitations of teachers’ knowledge and practices (based on the findings for the first research question). Through classroom observations and teaching profiles, fifth grade teachers showed stronger science content knowledge than third or fourth grade teachers. In contrast, third grade teachers tended to support English language development more than fourth or fifth grade teachers. Future professional development needs to help teachers recognize their strengths and enable them to capitalize on such strengths while improving their areas of limitations. Helping teachers become aware of their relative strengths and limitations is particularly important, since their questionnaire responses did not show significant differences across the three grade levels, despite significant differences through classroom observations.

Another way to design ongoing professional development is to focus on teaching practices that will support student understanding of science (based on the findings for the second research question). Professional development should then relate practices for student understanding to practices for student inquiry and practices for English language development of ELL students, as well as teachers’ knowledge of science content. Our
findings suggest that these sets of teachers’ knowledge and practices will co-emerge, as related to understanding. In the case of ongoing professional development in our intervention, it may focus on shifting teachers’ perceptions and practices from curriculum implementation to student understanding and enabling the teachers to fully realize the intentions of the curriculum by utilizing it as a scaffold to promote student reasoning (the notion of “educative curriculum materials” by Davis & Krajcik, 2005). Practices to promote understanding, in turn, may strengthen teachers’ knowledge and practices in the other domains.

Implications for Future Research

The results of the study raise major questions for future research. One area concerns change in teachers’ knowledge and practices over time (Supovitz, 2001). This study reports results from the first-year implementation of our multi-year professional development intervention. With the continuation of the intervention, its impact on change (or lack thereof) with teachers over three years of the intervention and one year of sustainability will be examined. Teacher change, in turn, may have cumulative effects on student achievement over the years. In addition to examining the impact of the intervention on teacher change and student achievement, future research needs to examine the relationship between teacher change and student achievement as a result of the intervention (Fishman, Marx, Best, & Tal, 2004). The results from the project’s longitudinal research with teachers and their students will contribute to the emerging knowledge base in designing effective professional development programs that can improve both science and English literacy achievement of ELL students.
Another area of future research concerns the influences of accountability policies on teachers’ knowledge and practices. The findings of this study indicated differences in teachers’ knowledge and practices through classroom observations across the three grade levels. Fifth grade teachers, possessed with stronger knowledge of science content, might focus on all domains of science concurrently in response to high-stakes science assessment administered at fifth grade. In contrast, third grade teachers might focus on English language and literacy in response to high-stakes reading assessment determining student retention at third grade. Since science has not been a part of accountability policies until recently, the literature is very limited (Settlage & Meadows, 2002). The findings of the study highlight this topic as a fertile area for future research.

Still another area of future research concerns the relationships between teachers’ perceptions and practices. Although this study did not examine teachers’ perceptions and practices in a systematic manner, the results between perceptions measured through questionnaires and practices measured through classroom observations were distinctly different. In general, there were no or little significant differences between perceptions and practices using questionnaire responses, whereas there were often significant differences using observation ratings. These findings could be attributed to several reasons. One possible explanation is that there were actual differences between what teachers thought they did and what they actually did in their teaching. Another possible explanation is that it might be difficult to observe during a single lesson what the teachers reported as taking place over a month’s time (recall that many questionnaire items asked how many times teachers engaged in an activity during the previous month for a minimum of ten minutes). Still another possible explanation is that our observers might
have been using more stringent criteria than those the teachers used to rate themselves. Finally, the two instruments—self-report surveys and analytic observation scales—might tap into different aspects of their respective constructs. Future research may examine alternative explanations about the relationships between teachers’ perceptions and practices more systematically.

A primary motivation for this research involves how to improve science achievement of ELL students, especially in the context of high-stakes assessment and accountability policies in science. The results, based on school-wide implementation of the intervention with grades 3 through 5 teachers and their students in urban elementary schools, will provide insights about professional development designed to promote reform-oriented practices within the evolving policy context of the *No Child Left Behind* Act. Additionally, the ongoing intervention and longitudinal research will lead to better understanding about teachers’ knowledge and practices to promote science and English literacy achievement of all students, including ELL students and students from low SES backgrounds in urban schools.
References


