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

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ABSTRACT: This study examined urban elementary teachers' knowledge and practices in teaching science while supporting English language development of English language learning (ELL) students. As part of a larger 5-year research project in the United States, the study involved 38 third-grade teachers who participated in the first-year implementation of a professional development intervention that consisted of curriculum units and teacher workshops. The study examined four areas—teacher knowledge of science content, teaching science for understanding, teaching science for inquiry, and teacher support for English language development—through a questionnaire, classroom observations, and postobservation interviews. Results indicate that teachers' knowledge and practices were generally within the bounds supported by the intervention; however, such knowledge and practices fell short of the goal of reform-oriented practices. The results provide insights for our ongoing intervention and other similar efforts and contribute to the emerging knowledge base on science and English language and literacy with ELL students. © 2007 Wiley Periodicals, Inc. *Sci Ed* **92:**733–758, 2008

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INTRODUCTION

While immigrants represent an increasing fraction of the student population in the United States, many teachers are ill prepared to meet these students' learning needs—a complex situation that contributes to persistent achievement gaps in content areas, particularly science. Elementary teachers in the United States often lack both knowledge of science content and understanding of inquiry-based science (Garet, Porter, Desimone, Birman, & Yoon, 2001; Kennedy, 1998). They also 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).

A primary motivation for our larger research project is to improve science achievement of English language learning (ELL) students at a time when science is becoming part of accountability policies across the nation. The research implements a professional development intervention consisting of curriculum units and teacher workshops over the course of its 5-year period. The research involves teachers from grades 3–5 and their students at 15 elementary schools in a large urban school district. All the 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 policies.

As part of the larger research project, this particular study involved 38 third-grade teachers who completed the first-year implementation of the professional development intervention. The study examined the following four areas of teaching science with ELL students: (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. Specifically, the study examined the following questions:

1. What were teachers' knowledge and practices in each of the four areas of teaching science with ELL students?
2. How did the teachers' knowledge and practices compare to the goal of reform-oriented practices in teaching science with ELL students?

LITERATURE REVIEW

This study focused on teachers' knowledge and practices in teaching science while also supporting English language development with ELL students in urban elementary schools. This student population deserves special attention because these students need to learn academic content along with English language and literacy in urban schools where resources tend to be limited. Below, two areas of literature are discussed: (a) teachers' knowledge and practices in teaching science to ELL students and (b) teachers' practices in supporting English language development of ELL students in science instruction. In each area of literature, 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.

Teachers' Knowledge and Practices in Teaching Science to ELL Students

Reform-Oriented Practices. It seems self-evident that teachers need to know the subject matter they are required to teach (Kennedy, 1998). Reform documents indicate that teachers need to have deep and complex understandings of science concepts, be able to make connections among science concepts, and be able to apply science concepts in explaining natural phenomena or real-world situations (American Association for the Advancement of Science [AAAS], 1989; National Research Council [NRC], 1996). Teachers also need to be able to engage in scientific inquiry and develop arguments based on evidence (NRC, 2000).

In addition to knowledge of subject matter, teachers need to have content-specific teaching strategies. They should recognize the role of prior knowledge, particularly students' misconceptions, in shaping students' understanding. They should enable students to engage in scientific inquiry related to the practice of science (NRC, 2000). They should also 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.

Current Practices. It is a challenge for many elementary school teachers to adopt reform-oriented practices because of their inadequate knowledge of science content and content-specific teaching strategies (Garet et al., 2001; Kennedy, 1998). After being engaged in large-scale 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.

Additional difficulties interfere with teaching science to ELL students. For example, teachers are largely unaware of cultural and linguistic influences on science learning. Many assume that ELL students must acquire English before learning science, are unaware of linguistic influences on science learning, do not consider "teaching for diversity" as their responsibility, overlook linguistic differences, or accept inequities as a given condition (Bryan & Atwater, 2002; Rodriguez & Kitchen, 2005). Many teachers, regardless of background, are unaware of the linguistic and cultural knowledge that their nonmainstream students bring to the classroom (Lee, Luykx, Buxton, & Shaver, 2007). Furthermore, teachers lack opportunities to learn and reflect upon how students' minority or immigrant status may affect their educational experience (Cochran-Smith, 1995).

Professional Development. An emerging body of literature examines the impact of professional development on teachers' knowledge and practices in promoting science learning of ELL students. 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 following the intervention, they related more expanded strategies to promote science understanding and stressed their efforts to foster student initiative and student-centered inquiry.

The literature also examines the impact of professional development on ELL students' learning of science. Some studies focused on hands-on, inquiry-based science with ELL students (Amaral, Garrison, & Klentschy, 2002; Lee, Deaktor, Hart, Cuevas, & Enders, 2005). Hands-on activities are less dependent on formal mastery of the language of instruction, thus reducing the linguistic burden on ELL students. Hands-on activities through collaborative inquiry foster authentic communication about science knowledge and practice. In addition, 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, Warren, & Conant, 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.

Teachers' Practices in Supporting English Language Development of ELL Students in Science Instruction

Reform-Oriented Practices. Reform documents in the United States 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 [TESOL], 1997). ELL students need to develop English language and literacy skills in content areas to achieve at the same level as their English-speaking peers. Content area instruction should provide a meaningful learning environment for English language and literacy development. Simultaneously, English language and literacy development should provide the medium for understanding academic content, such as science (Amaral et al., 2002; Buxton, 1998; Fathman & Crowther, 2006; Lee & Fradd, 1998).

Teachers need to create classroom environments that promote ELL students' development of general and content-specific academic language (Wong-Fillmore & Snow, 2002). First, in addition to ensuring that ELL students acquire the communicative language functions used for social language, teachers should create classroom environments that promote the development of academic language. Second, teachers should view language from a human development perspective and formulate developmentally appropriate expectations about language comprehension and production over the course of learning English. Finally, teachers should apply this knowledge to the teaching of academic content areas. The amalgamation of these three knowledge sources should result in teaching practices that engage students of all levels of English proficiency in academic language learning, offer multiple points of entry for students of differing levels of English proficiency, and provide multiple modes for students to display their learning.

Current Practices. In reality, however, ELL students frequently confront the demands of academic learning through a yet-unmastered language without the instructional support they need. Most teachers are unaware of how to incorporate English language and literacy development as part of content area instruction (García, 1999). In teaching science, 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. In science education, an emerging body of research addresses teachers' beliefs and practices in supporting English language development of ELL students. Lee (2004) worked with six bilingual Hispanic teachers of fourth-grade Hispanic students at two elementary schools. Compared to the beginning of the school year, the teachers gradually began to focus on specific aspects of English language and literacy in science instruction. They adapted their literacy instruction and provided linguistic scaffolding to meet students' learning needs. They also helped students to acquire the conventions of standard oral and written English in social and academic settings. In addition, they used multiple representational formats (e.g., gestural, verbal, written, graphic) to promote both literacy and science learning.

Stoddart, Pinal, Latzke, and Canaday (2002) involved elementary school teachers of predominantly Latino ELL students. After their participation in a 5-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.

Purpose of the Study

An emerging body of literature addresses the impact of professional development on teachers' knowledge and practices in promoting science learning and English language development with ELL students. The purpose of this study was to examine teachers' knowledge and practices during the first year of their participation in our professional development intervention, as compared to the goal of reform-oriented practices. Specifically, the study examined urban elementary teachers' knowledge of science content, their practices in teaching science for understanding, their practices in teaching science for inquiry, and their practices in supporting English language development with ELL students.

The results about teachers' knowledge and practices in this study need to be interpreted in the context of the professional development intervention during its first year. By using the emerging results from our ongoing intervention, the ultimate goal is to design a professional development model that guides teachers toward reform-oriented practices in teaching science while also supporting English language development with ELL students. At the same time, we will refine our intervention based on change (or lack thereof) in teachers' knowledge and practices with grades 3–5 over the 5-year period of the project. Furthermore, the results from our longitudinal investigations will contribute to the knowledge base in designing effective professional development programs that can improve both science and literacy achievement of all students, including ELL students. These results may have particular importance in the context of the impending high-stakes testing and accountability policy in science.

While recognizing that teachers' knowledge and practices could be influenced by the intervention in this study, we are not attempting to make causal links because the study did not have baseline data about how the teachers in the treatment group performed prior to the intervention or did not collect data from the teachers in the comparison group.

RESEARCH SETTING AND PARTICIPANTS

Research Setting

The research was conducted in a large urban school district in the southeast United States with a linguistically and culturally diverse student population. During the 2004–2005 school year, the student population in the school district was 60% Hispanic, 28% Black, 10% White non-Hispanic, and 2% Asian or Native American. Across the school district, 72% of elementary students participated in free or reduced price lunch programs, and 24% were designated as limited English proficient according to the state definition.

TABLE 1
Teacher Demographics ($n = 38$)

Variables	Demographic Groups	*n*	%
Gender	Male	4	11
	Female	34	89
Ethnicity	Hispanic	9	24
	Black non-Hispanic	19	50
	White non-Hispanic	5	13
	Haitian	2	5
	Asian	2	5
	Other	1	3
Native language(s)[a]	English	32	84
	Spanish	5	13
	Haitian Creole	1	3
	French	1	3
	Dutch	1	3
	Sranang Tango	1	3
ESOL training[a]	Bachelor's or master's degree in ESOL	3	8
	ESOL endorsement through college coursework	13	34
	ESOL endorsement through school district	21	55
	Grandfathered in through teaching	3	8
	No preparation for ESOL	5	13
Degrees	Bachelor's	22	58
	Master's	15	39
	Specialist	1	3

[a]Multiple categories could be selected.

In late May 2004, schools were selected based on three criteria: (a) percentage of ELL students (predominantly Spanish or Haitian Creole speaking students) above the district average at the elementary school level, (b) percentage of students on free and reduced price lunch programs above the district average at the elementary school level, 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 the 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.

Teacher Participants

For the first year of our intervention, we invited every third-grade teacher in each treatment school to participate, resulting in an initial sample of 44 teachers. However, only those teachers who participated for the entire school year and provided complete data were included in the analyses, a total of 38 teachers. Table 1 presents the demographic and professional backgrounds of these teachers. The majority of teachers identified themselves as members of racial/ethnic nonmainstream groups. The majority of the teachers had a degree or endorsement in English to speakers of other languages (ESOL). Nearly half of the teachers reported earning graduate degrees.

Project Personnel

As a large-scale project, over a dozen project personnel were involved in the research and development efforts, including curriculum development and teacher workshops (described next). The project personnel represented both genders from a wide range of racial/ethnic and linguistic backgrounds including White, Hispanic, Haitian, and Asian-American and disciplinary backgrounds including science, science education, mathematics education, and bilingual/ESOL education.

PROFESSIONAL DEVELOPMENT INTERVENTION

The intervention consisted 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

The grade 3 curriculum is aligned with the state science content standards and also follows recommendations by the National Science Education Standards (NRC, 1996). The three units for grade 3 include measurement, states of matter, and water cycle and weather. The teachers' guide for each unit begins with an explanation of (a) how to promote students' science inquiry and understanding of key science concepts and "big ideas" (patterns of change, systems, models, and relationships) to explain natural phenomena and (b) how to incorporate English language and literacy development as part of science instruction.

Science. The student booklets are designed to promote standards-based, inquiry-driven science learning. The three units are designed to move progressively along the continuum of teacher-explicit to student-initiated inquiry. Earlier lessons provide greater structure, whereas later lessons are more open ended, thereby encouraging more student initiation and exploration. The complexity of science concepts and the degree of inquiry required from students also increase as students move through the units. Within settings that promote science inquiry, student booklets emphasize key science concepts and big ideas. Following inquiry activities, each lesson provides background information that explains the question under investigation and related natural phenomena. The lessons highlight common misconceptions and potential learning difficulties.

Teachers' guides provide content-specific teaching strategies for each lesson. They offer suggestions on how teachers may provide different levels of guidance and scaffolding depending on students' prior experience with different science topics and the demands of specific science tasks. They 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. In addition, they 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, and homework assignments.

English Language and Literacy. Student booklets highlight activities and strategies to foster reading and writing during science instruction. For example, the booklets incorporate 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) to promote 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 processes under investigation. Writing prompts support literacy development. Trade books or literature related to the science concepts under investigation are incorporated.

The units 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. Each unit introduces key vocabulary at its beginning, and students practice the vocabulary throughout each lesson and the unit. The units use multiple modes of communication and representation (verbal, gestural, written, graphic). In addition, teachers' guides 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 setups, 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

During the first year of the project, third-grade teachers in the treatment group attended 5 full-day workshops during regular school days over the course of the year. The first workshop was organized around describing the purpose of the project, obtaining teachers' consent, conducting data collection activities, and introducing the first few lessons of the measurement unit. The second workshop was organized around completing the measurement unit, the third workshop around the matter unit, the fourth workshop around the water cycle and weather unit, and the final workshop around data collection activities including teachers' reflection and feedback.

Science. 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.

One area of emphasis involved scientific inquiry. During the third workshop on the matter unit, project personnel and teachers discussed what science inquiry involves (NRC, 2000) and the teacher-explicit to student-initiated continuum (Lee, 2002). Effective inquiry instruction requires a balance of teacher guidance and student initiative, as teachers make decisions about when and how to foster student-centered inquiry. Teachers discussed how to move away from teacher-explicit instruction and how to encourage students to take the initiative and assume responsibility for their own learning. Based on this discussion, teachers worked in small groups on inquiry tasks from the matter unit. Then, given "practice" inquiry tasks outside the unit, the teachers came up with a variety of experimental designs, procedures for gathering data, multiple ways of displaying the data, and conclusions based on hypothetical evidence. Each group of teachers presented their work to the entire group and discussed various ways of conducting science inquiry. The emphasis on how to promote more student-centered and open-ended inquiry continued with the water cycle and weather unit at the fourth workshop.

Scientific reasoning was also emphasized during the workshops. During the second workshop on the measurement unit, teachers brought their own students' work samples from the measurement booklet and discussed student reasoning. At the end of the second workshop, teachers completed state-released practice items on a statewide science test. Teachers' reasoning about their test responses was one focus of the third workshop. At the fourth workshop on the matter unit, we presented our previous research on students' reasoning about designing an experiment to test the effect of surface areas on the rate of evaporation. Using segments of student interview transcripts, teachers analyzed students' capabilities and difficulties in designing the experiment. At the final workshop, project personnel presented major patterns in students' reasoning about various measurement concepts and skills from our current research. The presentation highlighted the "funds of knowledge" about measurement in students' home environments that could serve as building blocks for learning school science. Based on this presentation, teachers discussed how students made sense of home experiences and how teachers could use these home connections to promote student learning.

English Language and Literacy. The workshops also focused on incorporating English language and literacy into specific science lessons. At the second workshop, using examples in the measurement unit, project personnel described various strategies for developing students' reading and writing skills during science instruction. Project personnel also described how to provide linguistic scaffolding for ELL students. The discussion focused on how teachers (a) adjust the level and mode of communication (verbal, gestural, written, graphic) to enhance students' understanding of science, (b) recognize the diversity of students' levels of language proficiency and adjust the language load required for participation, (c) use language that matches students' levels of communicative competence in length, complexity, and abstraction, and (d) communicate at or slightly above students' levels of communicative competence. Based on this presentation, teachers engaged in a jigsaw activity regarding how to incorporate ESOL strategies. At the fourth workshop, teachers worked in small groups to incorporate ESOL strategies in selected lessons from the water cycle and weather unit. As a culminating activity, teachers made group presentations, followed by whole group discussion.

DATA COLLECTION AND ANALYSIS

The four constructs under investigation were based on the reform documents in science (AAAS, 1989; NRC, 1996, 2000) and English language and literacy (TESOL, 1997). Reform-oriented practices for these four constructs are discussed in the literature review earlier, and operational definitions are provided in three instruments including a questionnaire, classroom observations, and postobservation interviews[1] (see Table 2). These instruments were adapted from our previous research on science instruction (Lee et al., 2004; Newmann, Secada, & Wehlage, 1995) and English language and literacy development in science instruction (Hart & Lee, 2003), as well as relevant literature. We employed mixed methods including both quantitative and qualitative approaches for data analysis. The three data sources allowed triangulation of results. The first two authors of this manuscript completed the data collection, the third and fourth authors completed major portions of the data analysis, and the fifth author contributed to the conceptualization of the research procedures.

[1] The instruments along with instructions on their use are available on the project Web site http://www.education.miami.edu/psell/).

TABLE 2
Constructs Examined Through Three Data Sources

	Teacher Knowledge of Science Content	Scientific Understanding	Scientific Inquiry	Teacher Support of English Language Development
Questionnaire	√	√	√	√
Classroom observations	√	√	√	√
Postobservation interviews	N/A	√	√	√

Questionnaire

Instrument. The questionnaire measured teachers' self-reported knowledge and practices in teaching science to ELL students. The questionnaire includes scales to measure latent constructs, rather than individual items.

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.
2. *Practice in Scientific Understanding Scale* measures teachers' reported practices in teaching science for understanding.
3. *Practice in Scientific Inquiry Scale* measures teachers' reported practices in teaching science for inquiry.
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 questionnaire items used a 4-point rating system. To help teachers think about their actual classroom practices and guard against their responding impressionistically, we phrased the items in terms of specific time periods (e.g., "in the last month") and sustained periods of time during a lesson (e.g., "for at least 10 minutes").

Data Collection and Analysis. The teachers completed the questionnaire for 30–45 minutes during the final teacher workshop in May 2005. We used the questionnaire data at the end of the first-year implementation to be consistent with the other two data sources that were collected in the context of the first-year implementation of the intervention. The score for each scale was computed using the average of the responses to the items that comprised the scale. Internal consistency reliability estimates for the scale scores using Cronbach's alpha (α) ranged from .72 to .90, which were within an acceptable range. Teachers' responses on the questionnaire were analyzed in terms of the means for the scales.

Classroom Observations

Instrument. The classroom observation scales measured teachers' observed teaching practices during specific lessons. 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.
2. *Scientific understanding*: This scale measures the extent to which students demonstrate a deep understanding of science.
3. *Scientific inquiry*: This scale measures the extent to which students engage in scientific inquiry related to the practice of science.
4. *Teacher support of English language development*: This scale measures the extent to which the teacher supports 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 focus on the instructional environment that the teacher and students jointly create. Each observation scale uses a 5-point rating system. The classroom observations included quantitative ratings of the observation scales, justifications for these ratings, and narrative fieldnotes. Fieldnotes 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.

Data Collection. Prior to the classroom observations in the fall of 2004, three project members (the first, second, and fifth authors) viewed several videotapes of science lessons from our previous research. We used the observation scales to rate these lessons and to discuss our ratings and justifications. After initial discussions, the first two authors/observers continued training by observing lessons in real time and rating them on the scales until they established interrater agreement of over 90%. Prior to spring 2005 observations, the two observers conducted the same training procedures using a different set of videotaped lessons from our previous research.

Each third-grade teacher in the treatment group was observed once in fall 2004 and once in spring 2005. The fall 2004 observations were conducted while teachers taught the measurement unit. The spring 2005 observations were conducted after the statewide assessments during which time most teachers were teaching the water cycle and weather unit. Each observation typically lasted from 45 minutes to 1 hour.

Data Analysis. The two observers followed standard conventions for the format of the fieldnotes. We color-coded classroom episodes that illustrated reform-oriented practices for each of the four scales under investigation. For each scale in each lesson, we gave a rating 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. After we assigned ratings, we provided justifications based on the evidence in the narratives of the lesson.

The two observers and another member (the third author) reviewed the entire set of notes. We employed this cross-validation of the complete corps of the data to ensure reliability, especially since we were refining the research procedures during the first year of the project. For data analysis, we obtained the mean and the frequency of the ratings for each observation scale in fall 2004 and spring 2005 separately.

Postobservation Interviews

Instrument. Postobservation interviews measured teachers' reflections on their practices during the observed lessons. The interview protocol includes the opening questions below, followed by probes using key examples from the day's lesson[2]:

1. *Teaching practices to promote scientific understanding and inquiry*

   a. I'd like to know about the strategies that you use to teach science (with a focus on scientific understanding and inquiry).
   b. How much or little do you think your students understood the science topic in today's lesson (with a focus on scientific understanding and inquiry)?

2. *Teaching practices to support English language development*

   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.

Data Collection. During the training on the classroom observation guideline, the two members (the first and second authors) who conducted classroom observations reviewed the interview protocol with another member (the fifth author). After conducting the first four interviews following the first four classroom observations in real time, these two members reviewed the interview audiotapes, provided feedback for each other, and ensured consistency for interview procedures.

Half of the teachers were randomly selected for the interviews in fall 2004, and the remaining teachers in spring 2005. On the days of classroom observations, teachers participated in postobservation 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 from 45 minutes to 1 hour. The interviews were audiotaped and transcribed.

Data Analysis. Although the interviewers asked specific questions pertaining to scientific understanding and inquiry and English language development, teachers often volunteered responses related to these constructs throughout the interviews. As a result, we determined to use the interviews in their entirety for analysis, rather than specific sections pertaining to specific questions.

For the preliminary analysis framework, we developed the initial descriptive codes based on the questionnaire and the classroom observation guideline that reflect reform-oriented

[2] It was not feasible to assess teachers' knowledge of the science content of the lessons being observed during the postobservation 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 4 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.

practices. As we coded teachers' responses, we identified new codes. 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 we established the coding system, four members (the first four authors) read a small set of transcripts in their entirety and analyzed teachers' responses across the entire list of codes. After the interrater agreement reached 90%, two members (the third and fourth authors) analyzed all transcripts together. Each coder analyzed half of the transcripts and verified the coding of the other for the remaining half of the transcripts. We employed this cross-validation of the complete corps of the data to ensure reliability, since we were refining the research procedures during the first year of the project. As each coder read the entire transcript, she analyzed the teacher's responses with respect to relevant codes. If a teacher gave the same response multiple times, we counted it as one response. We analyzed the data in terms of the number of teachers who mentioned each code.

RESULTS

Since the science topics differed between fall 2004 (covering the measurement unit) and spring 2005 (primarily covering the water cycle and weather unit), we report the results separately. This decision is based on the literature indicating that teacher practices vary across science subject areas and across science topics (Carlsen, 1991; Tobin & Fraser, 1990). In addition, we present a typical lesson, along with classroom observation ratings and postobservation interview responses for this lesson.

Teacher Knowledge of Science Content

On the questionnaire, the Cronbach α for the scale score of teacher knowledge of science content was .90. The questionnaire responses are based on a 4-point rating system (1 = not knowledgeable, 2 = somewhat knowledgeable, 3 = knowledgeable, and 4 = very knowledgeable). The mean for this scale was 2.89 ($SD = 0.56$), indicating that teachers reported they were generally knowledgeable of science topics at their grade level. Teachers' responses ranged from the mean of 2.69 for the topics of both energy and force/motion to the mean of 3.28 for the topic of processes of life.

The mean of classroom observation ratings for teacher knowledge of science content was 2.89 ($SD = 0.55$) during fall 2004 and 2.97 ($SD = 0.64$) during spring 2005 (see Table 3). A rating of 3 indicates that teacher knowledge is generally accurate within the bounds of the science content provided in the student booklet. Many of the observed lessons rated a 3 during fall 2004 (68%) and spring 2005 (73%). Although teachers generally did not transmit major scientific inaccuracies once or twice (a rating of 2) or multiple times (a rating of 1) during an observed lesson, neither did most teachers transmit knowledge once or twice beyond the bounds of the lesson spontaneously or in response to students' questions (a rating of 4). No lesson was observed in which teachers demonstrated knowledge beyond the bounds of the lesson by offering deeper knowledge and enriching the discussion (a rating of 5).

Practices for Scientific Understanding

On the questionnaire, the Cronbach α for the scale score of teaching science for understanding was .72. The questionnaire responses are based on a 4-point rating system (1 = never or almost never, 2 = some lessons, 3 = most lessons, and 4 = every lesson). The

TABLE 3
Teacher Knowledge of Science Content: Classroom Observation Ratings[a]

	Fall 2004					Spring 2005				
M (*SD*)			2.89 (0.55)					2.97 (0.64)		
Ratings	1	2	3	4	5	1	2	3	4	5
%	0	21	68	11	0	5	5	76	14	0

[a]The results are based on a 5-point rating system.

TABLE 4
Scientific Understanding: Classroom Observation Ratings[a]

	Fall 2004					Spring 2005				
M (*SD*)			3.05 (0.77)					2.95 (0.87)		
Ratings	1	2	3	4	5	1	2	3	4	5
%	3	18	50	29	0	5	21	50	21	3

[a]The results are based on a 5-point rating system.

mean for the understanding scale was 3.11 ($SD = 0.56$), indicating that teachers claimed they taught science to promote students' understanding in most science lessons.

The mean of classroom observation ratings for scientific understanding was 3.05 ($SD = 0.77$) during fall 2004 and 2.95 ($SD = 0.87$) during spring 2005 (see Table 4). 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. A rating of 3 was given to 50% of the observed lessons during both fall 2004 and spring 2005. In several other lessons, knowledge was relatively deep, as many students demonstrated the complexity of one or more ideas (a rating of 4). Only in one lesson during spring 2005 was knowledge developed consistently deep, as most of the students demonstrated the complexity of one or more ideas (a rating of 5). In several lessons, on the other hand, concepts and ideas were only mentioned or covered superficially (a rating of 2). In a few lessons, concepts were taught in isolation from related ideas or real-world phenomena and students were mainly required to memorize information (a rating of 1).

Postobservation interview results indicate that teachers consistently described strategies to promote students' scientific understanding in the observed lessons during fall 2004 and spring 2005. The most frequent responses are reported in Table 5.

Practices for Scientific Inquiry

On the questionnaire, the Cronbach α for the scale score of teaching science for inquiry was .76. The questionnaire responses are based on a 4-point rating system (1 = never or almost never, 2 = some lessons, 3 = most lessons, and 4 = every lesson). The mean for the inquiry scale was 3.14 ($SD = 0.52$), indicating that teachers claimed they taught science to promote students' inquiry in most science lessons.

The classroom observation ratings for scientific inquiry are noticeably different between fall 2004 and spring 2005 (see Table 6). During fall 2004, the mean was 1.16 ($SD = 0.44$), indicating that students did not engage in scientific inquiry. A rating of 1 was given to 87% of the observed lessons. Teachers generally taught measurement as basic skills or tool use, and students rarely engaged in higher level reasoning such as estimation, prediction, posing

TABLE 5
Scientific Understanding: Interview Responses (Number of Teachers Mentioning Each Code)

	Fall 2004 ($n = 20$)	Spring 2005 ($n = 18$)	Total ($n = 38$)
Apply science concepts to explain natural phenomena or real-world situations	18	17	35
Relate science to other subject areas	16	15	31
Demonstrate understanding of the problematic nature of information OR recognize students' learning difficulties	18	12	30
Engage in small group instruction, cooperative groups, or peer tutoring	12	13	25
Engage in hands-on activity as means to promote understanding	14	10	24
Use students' mistakes to generate class discussion OR help students with their learning difficulties	13	10	23
Motivate students for learning or understanding	11	7	18
Explain the reasoning behind an idea	7	8	15

TABLE 6
Scientific Inquiry: Classroom Observation Ratings[a]

	Fall 2004					Spring 2005				
M (*SD*)	1.16 (0.44)					2.21 (0.81)				
Ratings	1	2	3	4	5	1	2	3	4	5
%	86	11	3	0	0	16	55	21	8	0

[a]The results are based on a five-point rating system.

a question, or finding a solution. During spring 2005, the mean of classroom observation ratings was 2.21 ($SD = 0.81$), indicating 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 2 was given to 55% of the observed lessons while most teachers taught the water cycle and weather unit. In several lessons, students did not engage in scientific inquiry (a rating of 1). In several other lessons, in contrast, some students engaged in scientific inquiry beyond the scripted lesson sporadically, or at least one significant activity involving scientific inquiry beyond the scripted lesson (a rating of 3). In a few lessons, there was at least one major activity involving scientific inquiry beyond the scripted lesson in which many students were engaged for a substantial portion of the class period (a rating of 4). No lesson was observed in which most of the students were engaged in scientific inquiry for most of the class period (a rating of 5).

Postobservation interview results indicate that teachers generally did not mention strategies to promote scientific inquiry during the observed lessons (see Table 7). 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.

TABLE 7
Scientific Inquiry: Interview Responses (Number of Teachers Mentioning Each Code)

	Fall 2004 ($n = 20$)	Spring 2005 ($n = 18$)	Total ($n = 38$)
Use measurement tools (ruler, thermometer, scale/balance, timer, graduated cylinder) to collect and analyze data	12	4	16
Make predictions or hypotheses about what might be found during investigations	1	10	11
Use simulations and models to construct reasonable explanations	0	9	9
Ask questions about objects, organisms, and events in the environment that can be answered through scientific observation, data collection, and interpretation	4	3	7
Plan and design scientific investigations, including the use of original procedures to answer questions	0	7	7
Use tools and techniques to gather, analyze, and interpret data	2	5	7
Engage in class discussion (or scientific argumentation) grounded in evaluation of data and interpretations	2	4	6

Practices for English Language Development

On the questionnaire, the Cronbach α for the scale score of supporting English language development was .88. The questionnaire responses are based on a 4-point rating system (1 = never or almost never, 2 = some lessons, 3 = most lessons, and 4 = every lesson). The mean for this scale was 2.02 ($SD = 0.79$), indicating that teachers reported the use of ESOL strategies or ELL students' home language to promote English language development in only some of the science lessons.

The mean of classroom observation ratings for teacher support of English language development was 3.26 ($SD = 0.69$) during fall 2004 and 3.37 ($SD = 0.88$) during spring 2005 (see Table 8). 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 nonverbal communication, use of language in multiple settings, and use of ELL students' home language as needed). A rating of 3 was given to 63% of the observed lessons during fall 2004 and 42% during spring 2005. In a number of lessons, teachers used varied language support strategies or effectively used such strategies in one or two significant events (a rating of 4). In a few lessons, teachers used varied language support strategies throughout the lesson or effectively used such strategies in several significant events (a rating of 5). In contrast, in several lessons, teachers sometimes failed to communicate at the appropriate level or mode of language and rarely used language support strategies (a rating of 2). No lesson was observed in which the teacher consistently failed to communicate at the appropriate level or mode of language or to use language support strategies (a rating of 1).

TABLE 8
Teacher Support for English Language Development: Classroom Observation Ratings[a]

	Fall 2004					Spring 2005				
M (*SD*)			3.26 (0.69)					3.37 (0.88)		
Ratings	1	2	3	4	5	1	2	3	4	5
%	0	8	63	24	5	0	16	42	32	10

[a]The results are based on a 5-point rating system.

TABLE 9
Teacher Support of English Language Development: Interview Responses (Number of Teachers Mentioning Each Code)

	Fall 2004 (*n* = 20)	Spring 2005 (*n* = 18)	Total (*n* = 38)
Use multiple modes of representation using nonverbal (gestural), oral, graphic, and written communication	13	14	27
Emphasize science vocabulary	14	12	26
Use language in multiple settings (e.g., introduce, write, repeat, highlight)	17	8	25
Communicate at and slightly above students' levels of communication (comprehensible input)	9	6	15
Use key terms and definitions, or examples of these terms to support comprehension and English language development	9	5	14
Engage in small group instruction or peer tutoring to enhance English language development	5	5	10
Use science vocabulary in ESOL students' home language	5	5	10
Adapt the use of language for a range of English proficiency levels with ESOL students	4	5	9

Postobservation interview results indicate that teachers often described strategies to support English language development during the observed lessons during fall 2004 and spring 2005. The most frequent responses are reported in Table 9.

A Typical Lesson

We describe a lesson that was typical of the classroom observations and postobservation interviews during the first-year implementation of the intervention with third-grade teachers. The observation was scored at the modes of ratings (see Tables 4, 6, and 8) and the interview was coded among frequent responses (see Tables 5, 7, and 9). Although this observation was longer than the majority of the observations, it was rather common for the observations of this particular lesson on two water cycle simulation activities. This third-grade classroom contained mostly Haitian-American students. Except for one student who was classified as ESOL level 4, the others had exited from ESOL programs. The teacher was female African-American, had ESOL endorsement through college, but did not speak Haitian Creole.

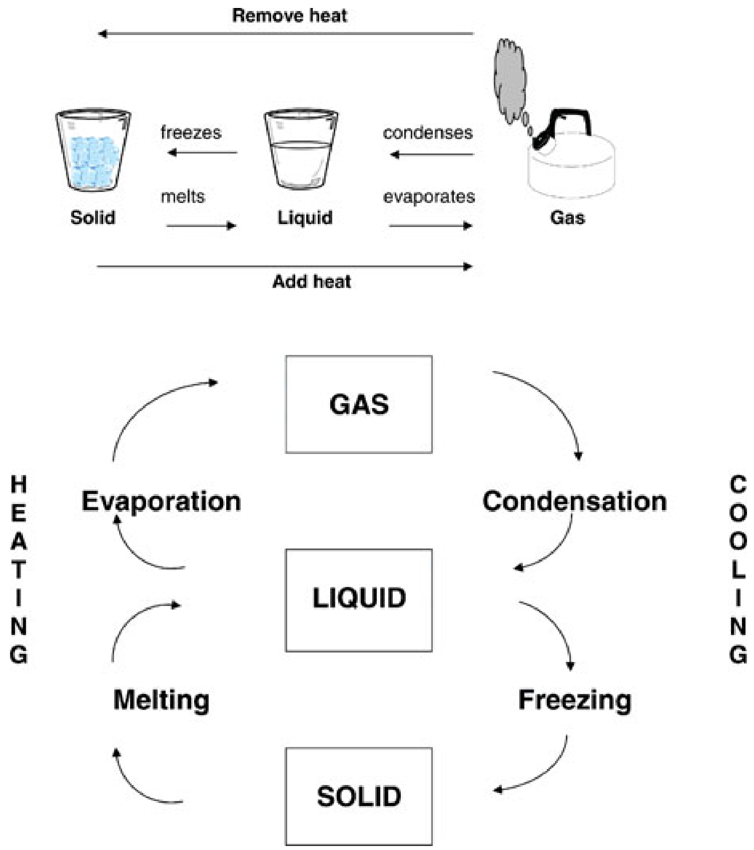

Figure 1. Drawing and graphic organizer showing the changes of states of matter. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

This was the second lesson from the water cycle and weather unit in spring 2005. In the beginning of this lesson, the class briefly reviewed the first lesson of the unit. The teacher asked for the definition of matter, the names of the three states of matter, and the changes in states during melting, freezing, evaporation, and condensation. Then, the class reviewed the drawing and the graphic organizer showing the relationships between heating/cooling and changes in states (see Figure 1). The teacher reminded students to use science vocabulary. Through the recitation style, students demonstrated generally accurate knowledge of science concepts. For example, matter has weight and takes up space, condensation is the opposite of evaporation when a gas changes to a liquid, melting occurs when a solid changes to a liquid as heat is added, and freezing occurs when a liquid changes to a solid as heat is removed.

The second lesson in the unit started with science terms in English, Spanish, and Haitian Creole, and the teacher reminded the class that they had gone over the vocabulary. She introduced the two water cycle simulations to the class while showing the graphics on the overhead projector (see Figures 2 and 3). Then, using the graphic for the boiling water activity (Figure 2), she asked students to explain the water cycle and reminded them to use science vocabulary. Through the recitation style, the teacher's questions and student responses did not progress systematically from one process of the water cycle to the next (i.e., evaporation, condensation, precipitation, and cycle), but rather jumped around the different processes. Student responses were generally accurate, although often short and

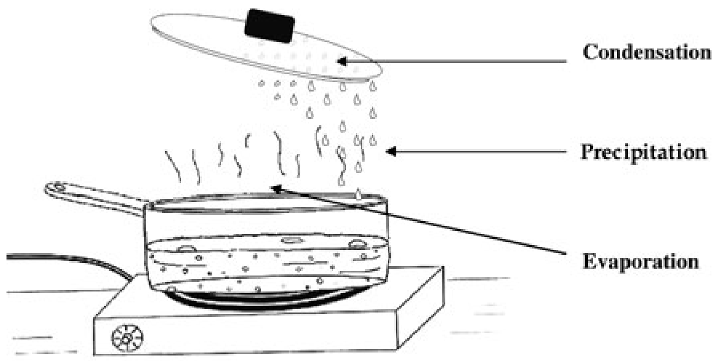

Figure 2. Water cycle simulation 1.

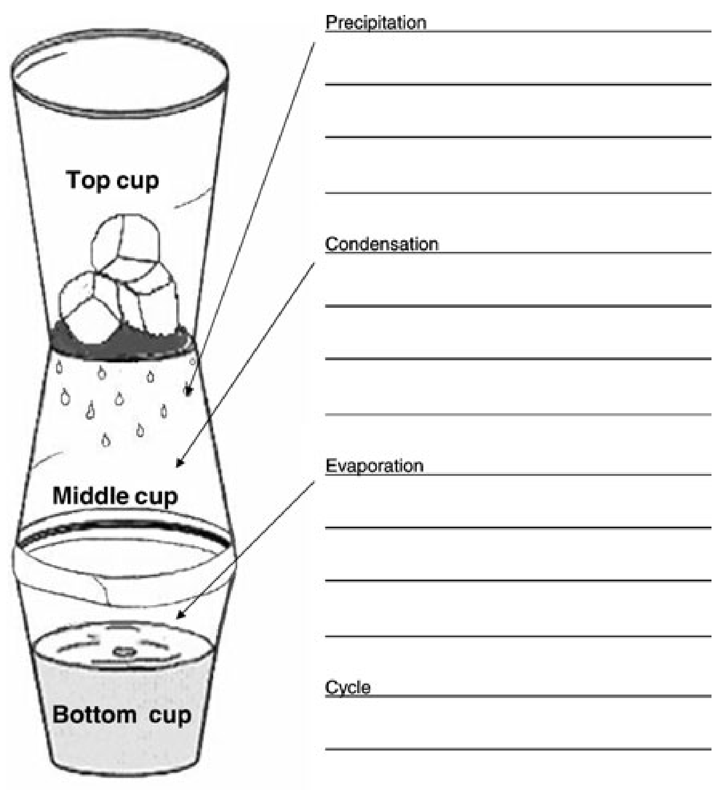

Figure 3. Water cycle simulation 2.

incomplete. For example, when the teacher asked where condensation occurred, a student said that it occurred under the lid of the glass pot. Another student said that when the water eventually fell, it was precipitation. When the teacher asked how water fell to the earth, one student gave no response, another said that it rained, and still another said that it rained when the "cloud is too full."

The teacher boiled water for the first simulation. She told half of the class to observe the simulation at her desk and the remaining half to answer the two questions in the student booklet: (1) "Describe what you observe in this activity" and (2) "Explain how this activity is like the water cycle." While students were observing the simulation, the teacher asked them which parts were evaporation, condensation, and precipitation. After the remaining half of the class observed the simulation, the entire class worked on the two questions. The teacher walked around the room and checked student answers while a few students asked her for help.

The teacher asked the class to share their answers, and students demonstrated partial understanding. For example, when the teacher asked the class, "Let's hear some of your responses," one student said "I observed foggy, condensation" and another said "the water is boiling and the bubbles." As the recitation style continued, the teacher asked students to use science vocabulary. When one student said that the simulation was like the water cycle because "the steam goes up and the water drops go down," the teacher repeated the answer but did not comment further. In contrast, when another student said "both deal with evaporation and precipitation," the teacher said "he made a very good parallel, and he mentioned about two and how they are alike." When the teacher stated that the drops became heavy enough that they fell like rain, one student commented, "You can experience this when you make spaghetti." However, the teacher did not follow up on this comment. The class concluded this simulation activity by reading about science information in the student booklet. As students took turns reading, the teacher occasionally asked questions to verify their comprehension and understanding.

The class continued with the second simulation activity (see Figure 3). The teacher formed small groups of students and described the job for each member of the group. The class followed the teacher's directions to construct the simulation setup, with safety warnings dealing with hot water. She told the class to figure out what was happening in the cups and to explain each process of the water cycle in the booklet (see Figure 3). When the teacher asked several questions, students demonstrated partial understanding. When she asked, "What is the purpose of the cup on top?" a student said, "The ice is going to melt, then it is coming out, and rain is going to be in the middle cup." The teacher did not address this misconception—that melting ice water in the top cup comes through and makes rain in the middle cup. In fact, following the directions in the lesson that were intended to counter this misconception, students put a few drops of food coloring in the top cup to show that the color of the ice water in the top cup was different from the clear water in the middle cup.

The teacher asked students to share their answers, starting from the process of precipitation, then condensation, next evaporation, and finally the cycle (see Figure 3). Students demonstrated partial understanding, and the teacher corrected inaccurate responses. After discussion of each process, the teacher gave a complete explanation before moving on to the next process. However, she did not ask students to model her explanation and give a more complete explanation in their own words. While discussing precipitation, a student raised a question, "How does the water fall? There is nothing when there is no hole in the cups." The teacher did not address this misconception, even though another student had already expressed it (see above) and the student booklet explicitly addressed it as follows:

1. What role do the ice cubes in the top cup have in the water cycle simulation?
2. Some children may think that the water drops in the middle cup come from the ice water in the top cup. Do you think this is correct or incorrect?

    a. If you think this is *correct,* how do you explain or prove your point?
    b. If you think this is *incorrect,* how do you explain or prove your point?

The teacher asked the class to write their answers for the two questions above for the rest of the class period before the end of the school day.

Next, we present the results of observation ratings and postobservation interview responses with regard to each of the four constructs under investigation.

Teacher Knowledge of Science Content. Teacher knowledge seemed generally accurate within the bounds of the lesson content provided in the student booklet (a rating of 3). Although the teacher used "sweat" for condensation, this was considered a minor inaccuracy and did not lead to a lower rating. When a student asked why the heating coil on the hot plate was not red, the teacher said that the heat was being transferred; however, this additional knowledge was not directly related to the lesson content and did not enrich it. The teacher did not demonstrate scientific knowledge beyond the bounds of the lesson by offering deeper knowledge and enriching the discussion (which could have led to a higher rating).

Scientific Understanding. The lesson was generally carried out using the recitation style. In response to the teacher's questions, students demonstrated partial understandings of the water cycle in the contexts of the two simulations and their relation to the water cycle in nature (a rating of 3). Students' understanding might have been improved (which could have led to a higher rating) if the teacher had pursued students' comments; unfortunately, she did not respond to or build on these comments. One comment about the water cycle while preparing spaghetti might have helped students to apply the lesson content to a real-world situation. Two related comments indicating a misconception about the ice water coming through the cups and becoming rain in the middle cup might have helped students to recognize the problematic and incomplete nature of their understanding and to construct more accurate understanding.

During the postobservation interview, the teacher gave responses that were categorized with the following five codes: (a) apply science concepts to explain natural phenomena or real-world situations, (b) relate science to other subject areas, (c) engage in small group instruction or cooperative groups, (d) explain the reasoning behind an idea, and (e) address various learning strategies. (Note: Responses coded as the first four were frequently mentioned by teachers, as shown in Table 5.) For example, the teacher emphasized applying science concepts to explain natural phenomena or real-world situations:

> It's important because it's what happens around them on a daily basis, so they need to know what is going on around them. Because it's not good for them to just assume that the water, it just rains, and that it's not a continual cycle. It rains, we have puddles, and the water evaporates. So it's something that they really need to be made aware of simply because it's a daily occurrence in their life.

Scientific Inquiry. Students engaged in the two simulations as inquiry activities; however, they primarily received and performed routine procedures for the inquiry within the bounds of the scripted lesson (a rating of 2). Students' inquiry might have been improved (which could have led to a higher rating) if the teacher had addressed the misconception about the ice water coming through the cups and becoming rain in the middle cup. This discussion would have supported students to justify their reasoning of opposing explanations with evidence (i.e., differences between color of the ice water in the top cup and the clear water in the middle and bottom cups), to search for patterns between the two simulations, and to relate these simulations to the water cycle in nature.

During the postobservation interview, the teacher gave responses that were categorized with the following two codes: (a) use simulations to construct reasonable explanations and (b) engage in hands-on activities. (Note: Responses coded as the first were frequently mentioned by teachers, as shown in Table 7.) For example, the teacher emphasized hands-on in her teaching of science:

> That they are not afraid to try it and that they actually learn something from it through hands-on . . . . With them having a chance to be able to see it and go through the process, the scientific process, the actual steps. "Ok, do I have all my materials? What am I observing?" And I mean that's what they lack. They lack just doing the experiments. And as you can see, if you don't pair them up the right way, it could be very difficult because they don't even get along. So I think that interaction as a group and learning how to actually do and perform experiments.

Teacher Support of English Language Development. The teacher communicated at the appropriate level and mode of language, and students demonstrated comprehension. Also, the teacher used some routine language support strategies (a rating of 3). These strategies included use of graphics, rephrases of student responses, assistance in pronouncing precipitation and condensation, and encouragement to use science vocabulary. However, the teacher did not use varied language support strategies, nor had she effectively used such strategies in significant events (which could have led to a higher rating).

During the postobservation interview, the teacher gave responses that were categorized with the following two codes: (a) use multiple modes of representation including nonverbal (gestural), oral, graphic, and written and (b) use language in multiple settings (e.g., introduce, write, repeat, highlight). (Note: Both coded responses were frequently mentioned by teachers, as shown in Table 9.) For example, the teacher emphasized using multiple modes of representation and communication to promote students' English language development:

> Again, just a different way that we instruct them. I mean make sure that we meet their needs in terms of their learning process. If they're more auditory versus tactile, and just their different learning styles, really. I don't have them so low [in English proficiency], that they can't learn in English. They do speak the language.

DISCUSSION AND IMPLICATIONS

This study examined urban elementary school teachers' knowledge and practices in teaching science while supporting English language and literacy of ELL students. Of the 44 teachers who participated in the first-year implementation of a professional development intervention, the study included those 38 teachers who provided complete data. In this section, conclusions stemming from the results are discussed, followed by implications for professional development and suggestions for further research.

Discussion

This study examined four constructs that are central to teaching science with ELL students. The study used a questionnaire, classroom observations, and postobservation interviews to measure these constructs consistently. Since the rating systems for these three data sources are not identical, the results are not directly comparable. Yet, patterns in the results seem to emerge with regard to each construct, described below.

The results were consistent with regard to teacher knowledge of science content. Teachers reported feeling generally knowledgeable about science topics at their grade level (through the questionnaire). Their knowledge of science content was generally accurate within the bounds of the lesson content in the intervention (through classroom observations).

The results were also consistent with regard to scientific understanding. Teachers reported teaching science to promote scientific understanding in most science lessons (through the questionnaire). Students were engaged in deep understanding of some scientific concepts and ideas some of the time (through classroom observations). Teachers often reflected on their practices to promote scientific understanding (through postobservation interviews).

The results were not consistent with regard to scientific inquiry. Teachers reported teaching science to promote scientific inquiry in most science lessons. In contrast, students rarely engaged in the practice of science beyond basic skills or tool use during the measurement unit or beyond the routine procedures for inquiry during the water cycle and weather unit. Also, teachers generally did not reflect on their practices to promote scientific inquiry. The results suggest that teachers perceived "hands-on" as scientific inquiry, but did not engage students in "minds-on." While highlighting hands-on activities, teachers may be less likely to engage students in intellectual work through making sense of the data collected or looking for explanations based on evidence (Cohen & Hill, 2000).

The results were also not consistent with regard to English language development. Teachers reported using ESOL strategies or ELL students' home language in only some of the science lessons. In contrast, during the observed lessons they communicated at the appropriate level or mode of language and effectively used language support strategies. Also, they often reflected on their practices to support English language development. The results suggest that the urban elementary school teachers serving ELL students in this study actually supported English language and literacy through their practices more so than their self-reports of their own practices on the questionnaire. One explanation may be that elementary teachers are adept at integrating language and literacy broadly across content areas, including science. Another explanation, specific to this study, may be that the majority of these teachers with an ESOL degree or endorsement (see Table 1) were able to support English proficiency of ELL students across content areas, including science. Still another explanation may be that teachers had embedded these practices so fundamentally that these practices were ingrained in their view of teaching and invisible to them. An alternative explanation may be that since science and English language and literacy have traditionally been treated as separate disciplines, teachers may not normally think of integration.

Despite variations across the four constructs, classroom observations indicate that teachers' knowledge and practices were generally within the bounds supported by the intervention: a rating of 3 for teacher knowledge of science content, a rating of 3 for scientific understanding, a rating of 2 for scientific inquiry (during spring 2005), and a rating of 3 for teacher support of English language development. The example lesson described in this paper illustrates typical patterns in teachers' knowledge and practices and their reflections on their observed lessons. To demonstrate reform-oriented practices, teachers should exhibit a rating of 4 or 5 for each of the four constructs. In this study, only a small fraction of the teachers exhibited reform-oriented practices in science instruction (NRC, 1996, 2000) and English language and literacy development in content area instruction (TESOL, 1997). The results suggest that teachers' knowledge and practices fell short of the goal of reform-oriented practices during the first year of the intervention.

The results of the study need to be interpreted within the context of the first-year implementation of the intervention. As stated earlier in the "Purpose of the Study" section, we do not make causal claims about the effect of our intervention in the absence of baseline data about how the teachers in the treatment group had performed prior to the intervention or data from the teachers in the comparison group.

Implications for Professional Development Intervention and Research

This study reports preliminary results from the first-year implementation of our multiyear professional development intervention. As we continue our intervention, we will examine its impact on change (or lack thereof) in teachers' knowledge and practices over the years. The results of our longitudinal research will contribute to the emerging knowledge base on science and English language and literacy with ELL students.

Professional development should enable teachers to develop deep and complex understandings of science concepts, to engage in scientific inquiry, and to develop arguments and justify their ideas based on evidence. Furthermore, professional development should support the teachers so that they can enable their students to develop scientific understanding, inquiry, and discourse (AAAS, 1989; NRC, 1996, 2000). One approach to professional development involves enabling teachers to view instruction in terms of student reasoning rather than the curriculum they are implementing. In other words, professional development focuses on shifting teachers' views and practices from curriculum coverage to student reasoning. This approach is in line with reform-oriented practices, which is the goal of our intervention. In our professional development over the course of 3 years of intervention and 1 year of sustainability, we will examine whether teachers fully realize the intentions of the curriculum and utilize the curriculum as scaffolds to promote student reasoning (the notion of "educative curriculum materials" by Davis & Krajcik, 2005).

Ongoing professional development needs to be built on the strengths and limitations of teachers. Although the teachers in this study reported that they promoted scientific inquiry, they seemed to have difficulty going beyond routine procedures for inquiry in their teaching practices. Our future intervention will focus on helping teachers recognize the distinction between hands-on and minds-on, followed by the necessary support for reform-oriented practices (NRC, 2000). The results are somewhat the opposite with regard to English language and literacy. Although teachers did not report that they used ESOL strategies or ELL students' home language, they did effectively use language support strategies in their practices. Our future intervention needs to help teachers recognize their strengths and enable them to capitalize on such strengths in the curriculum units and professional development workshops. For each of the four constructs under investigation, we will examine whether there is a relationship between teachers' perceptions and practices. We will also examine whether and how this relationship changes over the course of our intervention.

The impact of ongoing professional development can be measured in terms of change in teachers' knowledge and practices (Supovitz, 2001). Teacher change, in turn, will have cumulative effects on student achievement over the years. In addition to examining the impact of the intervention on teacher change and student achievement, respectively, future research needs to examine the relationship between teacher change and student achievement as a result of the intervention (Fishman, Marx, Best, & Tal, 2004).

Methodological strengths as well as limitations need to be considered in the interpretations of the results of this study. In terms of strengths, all three instruments are conceptually grounded on relevant literature and our ongoing research over a decade (e.g., Hart & Lee, 2003; Lee et al., 2004; Newmann et al., 1995). They measure key constructs from two academic disciplines that have traditionally remained separate: science and English language and literacy. They measure these constructs for consistency, allowing comparisons between teachers' perceptions and practices. The questionnaire includes scales to measure latent constructs, compared to most existing instruments that include individual items. In addition to these strengths in a conceptual sense, we undertook extensive efforts to establish reliability for data collection and analysis as we were refining the research procedures during the first year of this 5-year project.

Methodological limitations stem mainly from complexities in conducting large-scale research in varied educational settings. While we involved 44 third-grade teachers from the seven treatment schools during the first year of the intervention, the sample size will increase as we expand our intervention to include third-, fourth-, and fifth-grade teachers from both the treatment schools and additional replication schools during the 5-year period of the research. In a longitudinal design, we need to maintain the same procedures over the course of the research. As a result, we could afford only limited numbers of classroom observations (one each semester) and postobservation interviews (one each year) with each teacher. While it would have been desirable to observe and interview every teacher more frequently, this would require extensive additional resources and personnel. Furthermore, we could not assure a representative sample of curriculum units or lessons; rather, the observed class sessions varied with regard to the science content covered, class size, and other factors. These limitations have less to do with conceptual grounding or methodological rigor than with the inherent difficulties of conducting large-scale research. As scale-up of educational innovations is called for in recent years, trade-offs between methodological rigor and feasibility of research procedures should be carefully examined (Schneider & McDonald, 2007).

Starting from 2006–2007, the third year of our intervention, statewide science assessment at the fifth-grade level factors into school accountability in the state where this research takes place. The results, based on school-wide implementation of the intervention with grade 3–5 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 NCLB Act. In addition, our ongoing intervention and research will lead to better understanding about curriculum development, teacher professional development, and teachers' knowledge and practices as they relate to science and literacy achievement of all students, including ELL students and students from low-SES backgrounds in urban schools.

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REFERENCES

American Association for the Advancement of Science. (1989). Science for all Americans. New York: Oxford University Press.

Amaral, O. M., Garrison, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. Bilingual Research Journal, 26(2), 213–239.

Bogdan, R. C., & Biklen, S. K. (2003). Qualitative research for education: An introduction to theories and methods. Boston, MA: Allyn & Bacon.

Bryan, L. A., & Atwater, M. M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. Science Education, 86(6), 821–839.

Buxton, C. (1998). Improving science education of English language learners: Capitalizing on educational reform. Journal of Women and Minorities in Science and Engineering, 4(4), 341–369.

Carlsen, W. S. (1991). Subject-matter knowledge and science teaching: A pragmatic perspective. In J. Brophy (Ed.), Advances in research on teaching: Teachers' knowledge of subject matter as it relates to their teaching practice (Vol. 2, pp. 115–143). Greenwich, CT: JAI Press.

Cochran-Smith, M. (1995). Color blindness and basket making are not the answers: Confronting the dilemmas of race, culture, and language diversity in teacher education. American Educational Research Journal, 32, 493–522.

Cohen, D. K., & Hill, H. C. (2000). Instructional policy and classroom performance: The mathematics reform in California. Teachers College Record, 102(2), 294–343.

Davis, E., & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. Educational Researcher, 34(3), 3–14.

García, E. E. (1999). Student cultural diversity: Understanding and meeting the challenge (2nd ed.). Boston, MA: Houghton Mifflin Company.
Fathman, A. K., & Crowther, D. T. (Eds.). (2006). Science for English language learners: K-12 classroom strategies. Arlington, VA: National Science Teachers Association.
Fishman, B., Marx, R., Best, S., & Tal, R. (2004). Linking teacher and student learning to improve professional development in systemic reform. Teaching and Teacher Education, 13(1), 43–76.
Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. American Educational Research Journal, 38(4), 915–945.
Hart, J., & Lee, O. (2003). Teacher professional development to improve science and literacy achievement of English language learners. Bilingual Research Journal, 27(3), 475–501.
Kelly, G. J., & Breton, T. (2001). Framing science as disciplinary inquiry in bilingual classrooms. Electronic Journal of Science and Literacy, 1(1), http://www2.sjsu.edu/elementaryed/ejlts.
Kennedy, M. M. (1998). Education reform and subject matter knowledge. Journal of Research and Science Teaching, 35(3), 249–263.
Knapp, M. S. (1997). Between systemic reforms and the mathematics and science classroom: The dynamics of innovation, implementation, and professional learning. Review of Educational Research, 67, 227–266.
Lee, O. (2002). Science inquiry for elementary students from diverse backgrounds. In W. G. Secada (Ed.), Review of research in education (Vol. 26, pp. 23–69). Washington, DC: American Educational Research Association.
Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. Journal of Research in Science Teaching, 41(1), 65–93.
Lee, O., Deaktor, R. A., Hart, J. E., Cuevas, P., & Enders, C. (2005). An instructional intervention's impact on the science and literacy achievement of culturally and linguistically diverse elementary students. Journal of Research in Science Teaching, 42(8), 857–887.
Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English language backgrounds. Educational Researcher, 27(3), 12–21.
Lee, O., Hart, J., Cuevas, P., & Enders, C. (2004). Professional development in inquiry-based science for elementary teachers of diverse students. Journal of Research in Science Teaching, 41(10), 1021–1043.
Lee, O., Luykx, A., Buxton, C. A., & Shaver, A. (2007). The challenge of altering elementary school teachers' beliefs and practices regarding linguistic and cultural diversity in science instruction. Journal of Research in Science Teaching, 44(9), 1269–1291.
Merino, B., & Hammond, L. (2001). How do teachers facilitate writing for bilingual learners in "sheltered constructivist" science? Electronic Journal in Science and Literacy, 1(1), http://www2.sjsu.edu/elementaryed/ejlts.
National Center for Education Statistics. (1999). Teacher quality: A report on the preparation and qualifications of public school teachers. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.
National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.
National Research Council. (2000). Inquiry and the National Science Education Standards: A guide for teaching and learning. Washington, DC: National Academy Press.
Newmann, F. M., Secada, W. G., & Wehlage, G. G. (1995). A guide to authentic instruction and assessment: Vision, standards and scoring. Madison: University of Wisconsin–Madison, Center on Organization and Restructuring of Schools, Wisconsin Center for Education Research.
Rodriguez, A., & Kitchen, R. S. (Eds.). (2005). Preparing prospective mathematics and science teachers to teach for diversity: Promising strategies for transformative action. Mahwah, NJ: Erlbaum.
Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. Journal of the Learning Sciences, 21, 61–94.
Schneider, B., & McDonald, S. (2007). Scale up in education. Lanham, MD: Rowman & Littlefield.
Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. Journal of Research in Science Teaching, 39(8), 664–687.
Supovitz, J. A. (2001). Translating teaching practice into improved student performance. In S. H. Fuhrman (Ed.), From the capitol to the classroom: Standards-based reform in the states. 100th Yearbook of the National Society for the Study of Education (Part II) (pp. 81–98). Chicago, IL: University of Chicago Press.
Teachers of English to Speakers of Other Languages. (1997). ESL standards for pre-K-12 students. Alexandria, VA: Author.
Tobin, K., & Fraser, B. (1990). What does it mean to be an exemplary science teacher? Journal of Research in Science Teaching, 27(1), 3–25.
Wong-Fillmore, L., & Snow, C. (2002). What teachers need to know about language. Washington, DC: Center for Applied Linguistics.