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Teachers' Perspectives on a Professional Development Intervention to Improve Science Instruction Among English Language Learners

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Abstract Our 5-year professional development intervention is designed to promote elementary teachers' knowledge, beliefs, and practices in teaching science, along with English language and mathematics for English Language Learning (ELL) students in urban schools. In this study, we used an end-of-year questionnaire as a primary data source to seek teachers' perspectives on our intervention during the first year of implementation. Teachers believed that the intervention, including curriculum materials and teacher workshops, effectively promoted students' science learning, along with English language development and mathematics learning. Teachers highlighted strengths and areas needing improvement in the intervention. Teachers' perspectives have been incorporated into our on-going intervention efforts and offer insights into features of effective professional development initiatives in improving science achievement for all students.

Keywords Teachers' perspectives · Professional development intervention · English language learners · Urban education · Diversity and equity

Introduction

As the school-age population in the nation becomes progressively more diverse, it is vital to develop a knowledge base that successfully promotes academic achievement and equity for all students. This need is particularly critical in science education, where achievement gaps between mainstream and non-mainstream students have

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persisted over several decades (Campbell et al. 2000). In addition, the science achievement scores of US students in general lag behind those of students in other developed nations (Schmidt et al. 1997). Thus, closing the achievement gaps among linguistic and cultural groups, while improving the science achievement of all students, should be seen as dual goals for science education.

Despite this need, most elementary teachers are not sufficiently prepared to teach science effectively in terms of both knowledge of science content and familiarity with inquiry-based science instruction (Kennedy 1998; Loucks-Horsley et al. 1998). Nor are today's teachers adequately equipped to meet the learning needs of linguistically and culturally diverse students in science instruction (Lee et al. 2004; National Center for Education Statistics [NCES] 1999). Many teachers are unaware of linguistic and cultural influences on student learning, do not consider teaching for diversity as their responsibility, purposefully overlook cultural–racial differences, or resist multicultural views of learning (Bryan and Atwater 2002; Buxton 2005).

Our 5-year research project was motivated by on-going concerns about the low science achievement among English language learning (ELL) students. Our research examined science teaching and learning in the context of the looming high-stakes science assessment, which began in 2006 in Florida, the state in which the research is being conducted, and nationally in 2007 under the *No Child Left Behind* [NCLB] Act of 2001. The participants in this 5-year research include all third-, fourth-, and fifth-grade teachers and their students in seven elementary schools in a large urban school district. Four of the schools enroll large numbers of Spanish-speaking students, and the other three enroll large numbers of Haitian Creole speaking students. These seven treatment schools are engaging in the intervention for 3 years and for 1 additional year without intervention to test sustainability. In addition, eight comparison schools are engaging in the intervention during the final 3 years of the project to test replicability. Participating teachers are engaging in a professional development intervention through the provision of the project-developed curriculum materials and teacher workshops. The intervention is designed to help teachers improve their (a) knowledge of science content, (b) skills at fostering students' engagement in science inquiry and understanding of science concepts, and (c) support of English language development of ELL students.

The first-year implementation (2004–2005) of the intervention involved 44 third-grade teachers and their students from the seven treatment schools. As we measured the impact of the intervention on student achievement, we sought to understand such impact through the perspectives of participating teachers. In this study, we examined teachers' perspectives on our professional development intervention during the first year of implementation. In addition to teachers' feedback to our intervention throughout the school year, we sought their feedback on the year-end questionnaire in three areas: (a) effectiveness of major components of the intervention, (b) impact of the intervention on science instruction and student learning, and (c) areas of strengths and areas needing improvement in the intervention. Teachers' perspectives on the intervention were (and are being) incorporated into our on-going intervention efforts, and overall effectiveness will be examined, using a longitudinal research design. Furthermore, teachers' perspectives have offered insights (and continue to offer insights as the project progresses) into features of effective professional development initiatives in achieving the goal of greater science achievement for all students.

Literature Review

Teachers of ELL students are charged with promoting students' English language and literacy development, as well as academic achievement in subject areas. Unfortunately, many elementary school teachers have difficulty teaching ELL students conventionally, let alone teaching new content or adopting reform-oriented practices (Lee and Fradd 1998; NCES 1999). For those teachers who do incorporate reform activities in their instruction, they should still negotiate the potentially competing agendas of reform-oriented practices with accountability demands (Cohen and Hill 2000; Knapp 1997; Lee and Luykx 2005).

To provide effective science instruction, teachers need opportunities to develop their own deep and complex understandings of science concepts and recognize how students' misconceptions cause learning difficulties (Kennedy 1998; Loucks-Horsley et al. 1998). Teachers also need to engage in science inquiry themselves to be able to foster student initiative in inquiry (National Research Council [NRC] 2000). Additionally, teachers need to learn how to enable students to share and negotiate ideas and construct collective meanings about science (Lemke 1990).

In addition to ensuring that ELL students acquire the necessary communicative language functions used for social communication, teachers need to create classroom conditions that promote ELL students' development of general and content-specific academic language (O'Malley and Valdez Pierce 1996; Wong-Fillmore and Snow 2002). Additionally, 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, provide multiple modes for students to display their learning, and ensure student engagement in a manner allowing for maximum language development at their individual levels.

Opportunities for professional growth to address teaching science to ELL students are necessary, but demanding. The literature indicates some difficulties involved in implementing initiatives that integrate subject area instruction, such as science, with English language and literacy. Many teachers, assuming that ELL students must acquire English before learning subject matter, are unaware of linguistic influences on student learning and purposefully overlook linguistic differences and accept inequities as a given condition (August and Hakuta 1997; Bryan and Atwater 2002; García 1999; Rodriguez and Kitchen 2005).

In science education, research on instructional interventions to promote science and literacy achievement for ELL students is limited, but has begun to emerge in recent years (see the review of literature by Lee 2005). Several studies examined the impact of professional development on teachers' beliefs and practices in integrating science with English language development for ELL students. Some of these studies also examined the impact on students' science achievement, literacy (writing) achievement, or both. For example, Stoddart et al. (2002) involved elementary school teachers of predominantly Latino ELL students. Based on a conceptual framework for integrating English language development with inquiry-based science, the researchers examined teachers' understanding of science and ESOL integration. 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 instruction and second language development to a more elaborate reasoning about the different ways that the two could be integrated.

Hart and Lee (2003) provided professional development opportunities to elementary school teachers serving students from linguistically and culturally diverse backgrounds. Through the provision of curricular materials and teacher workshops, the professional development intervention focused on assisting teachers in integrating English language and literacy development as part of science instruction with ELL students. After their participation in the intervention over the school year, teachers expressed more elaborate and integrated conceptualizations for integration of science and literacy and provided linguistic scaffolding strategies more effectively with ELL students. At the end of the school year, ELL students showed statistically significant gains in science and literacy (writing) achievement, enhanced abilities to conduct science inquiry, and narrowing of achievement gaps in comparison to non-ELL counterparts (Lee et al. 2005).

Amaral et al. (2002) examined professional development in promoting science and literacy with predominantly Spanish-speaking elementary students as part of a districtwide local systemic reform initiative. Over 4 years, the inquiry-based science program gradually became available to all teachers at all elementary schools in the school district. Teachers were provided with professional development, in-classroom professional support from resource teachers, and complete materials and supplies for all the science units. Students in the district participated in kit- and inquiry-based science instruction that included the use of science notebooks. Results indicated that both science and literacy (writing) achievement increased in direct relation to the number of years they participated in the program. English proficient students performed significantly better than limited English proficient students in both science and writing.

Several studies examined the impact of curriculum materials on science achievement of ELL students. For example, Hampton and Rodriguez (2001) implemented a hands-on, inquiry science curriculum (i.e., the Full Option Science Series, FOSS; http://www.lawrencehallofscience.org/foss/) with Spanish-speaking elementary children who were developing second language (English) fluency, along with their first language (Spanish) skills. The results indicated that there was a strong positive feeling among university interns and classroom teachers about the value of this inquiry approach for increasing the children's understanding of science concepts in both languages. On written assessment containing three inquiry items and three open-ended response items about foods and nutrition, correct performance ranged from 33 to 51% across the six items. There was relatively little difference between children who chose to respond in Spanish and those who chose to respond in English.

Fradd et al. (2002) developed and tested curriculum materials that integrated science inquiry, home language and culture, and English language and literacy development of ELL students. The units on matter (culminating in the water cycle) and weather were implemented with elementary students from different ethnolinguistic backgrounds (Hispanic, Haitian Creole, and monolingual English-speaking students of White and African American descent). At the beginning and end of each unit, students completed a paper-and-pencil test containing multiple-choice, short-answer, and extended-written-response items. Students from all ethnolinguistic groups showed statistically significant achievement gains in science knowledge and inquiry.

In short, the literature has addressed the impact of professional development and curriculum materials on teachers' beliefs and practices in integrating science with English language development for ELL students, as well as the impact on science and literacy (writing) achievement of ELL students. This literature provides emerging insights for developing effective interventions for teachers of ELL students. Missing in this literature are teachers' perspectives on the impact of interventions on their teaching practices and their students' learning. Teachers' perspectives on the intervention mediate its impact on teaching and learning.

Purpose of the Study

Our larger research implemented a professional development intervention in science instruction with elementary teachers of ELL students in urban schools. Through the provision of curriculum materials and teacher workshops, our intervention was designed to improve teachers' knowledge, beliefs, and practices in teaching science while promoting English language development of ELL students.

To measure the intervention's impact on students' science achievement gains and achievement gaps at the end of the first-year implementation, we involved slightly over 1,000 third-grade students at seven treatment schools and approximately 1,000 third-grade students at eight comparison schools.[1] With the third-grade students in the treatment group, we administered a project-developed science test, along with several public release items from the National Assessment of Educational Progress (NAEP 2000) and the Third International Mathematics and Science Study (TIMSS 1995) in the beginning and at the end of the school year. We also analyzed student performance on a statewide mathematics test, particularly the measurement strand emphasized in our intervention, between the treatment and comparison groups. The results indicated an overall positive impact of our intervention (for details, see Lee, Maerten-Rivera et al. 2007). First, given a maximum score of 24, the treatment students displayed a statistically significant increase in science achievement from a pretest ($M = 7.35$, $SD = 3.36$) to a posttest ($M = 14.17$, $SD = 4.43$). Second, there were no statistically significant differences in science achievement gains between

[1] Literacy (writing) achievement with third-grade students at the end of the first-year implementation will also be analyzed.

students at ESOL levels 1–4 and students who had exited from ESOL or never been in ESOL in the treatment group. In other words, achievement gaps stayed consistent. Third, the treatment students showed higher scores on a statewide mathematics test, particularly on the measurement strand emphasized in the intervention, than the comparison students.[2] Finally, the results based on item-by-item comparisons with national (NAEP 2000) and international (TIMSS 1995) samples of students indicated overall positive science performance of the treatment students at the end of the school year.

In attempting to better understand the impact of the intervention on student achievement, this study examined teachers' perspectives on our professional development intervention. Teachers offered their feedback on those components of the intervention that they considered effective for their teaching and student learning, on the perceived impact on their teaching and student learning, and on areas of strengths and areas needing improvements. Teachers' perspectives would offer insights into our on-going intervention efforts that, in turn, will have cumulative effects on student achievement over the years. Teachers' perspectives would also offer insights into the emerging literature on professional development for science instruction with ELL students.

Professional Development Intervention

The intervention consisted of curriculum materials for both students and teachers and teacher workshops throughout the school year. The curriculum materials and workshops were designed to complement and reinforce each other for the improvement of teachers' knowledge, beliefs, and practices in science instruction, along with English language development for ELL students.

Curriculum Units

Throughout the project period, a series of curriculum units will be developed that constitute the entire science curriculum for grades three through five, as mandated by the state science content standards and also recommended by the National Science Education Standards (NRC 1996). The third-grade students will continue their participation in the intervention through the fifth grade, when the statewide science assessment becomes part of the school accountability imposed by the state. The three units for grade three (Measurement, States of Matter, and Water Cycle and Weather) were developed and rigorously tested in our previous research. Based on the design principles for curriculum development in our previous research, the units for grades four and five for our current research are under development and will reflect key science content mandated by the state. We expect that the units will

[2] At the time of the final workshops in late May 2005 during which the data collection was conducted, teachers had been informed of the student- and school-level scores on the statewide high-stakes assessments in reading and mathematics.

continue to be refined, based on teacher feedback, classroom observations, and student assessment results in our current research.

The teacher guide for each unit begins with an explanation of (a) how to promote students' understanding of key science concepts and "big ideas" (patterns of change, systems, models, and relationships) to explain natural phenomena, (b) how to incorporate English language and literacy development as part of science instruction, (c) how to incorporate mathematics as part of science instruction, and (d) how to progress along the continuum of teacher-explicit to student-initiated science inquiry for students with various levels of experience of school science (for conceptual discussion, see Fradd and Lee 1999; Lee 2002, 2003, 2004). For each lesson, the teacher guides include (a) specific correlations with state content standards in science, language arts, and mathematics; (b) key vocabulary terms in English, Spanish, and Haitian Creole; (c) a 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 teacher guides offer 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 (for details, see Lee et al. 2004). 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 (for details, see Lee et al. 2005). Units gradually progress to higher levels of complexity in terms of both science concepts and the level of inquiry required from students. 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.

The teacher guides provide content-specific teaching strategies for each lesson. They 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. They also provide science background information and explanations for the questions posed in the student booklets, with a particular emphasis on students' misconceptions and learning difficulties. Additionally, they offer suggestions for extension activities, assessment activities, and homework assignments.

English Language and Literacy

Student booklets highlight activities or strategies to foster reading and writing in the context of science instruction (for details, see Hart and Lee 2003). 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. Teacher 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 are asked to write an descriptive paragraph describing the scientific process under investigation. Writing tasks, wherein students write summaries of science experiments conducted in class, are used as homework assignments. Writing prompts are provided as supplementary materials for literacy activities. Trade books or literature related to the science concepts under investigation are incorporated.

In addition to general literacy development in English, the units address the needs of ELL students by providing explicit guidance to promote their English proficiency (for details, see Hart and Lee 2003). For example, language load for students at varying levels of English proficiency is increasingly more demanding from grades three through five. Science terms in Spanish and Haitian Creole are provided to support communication and comprehension. The units introduce key vocabulary in the beginning and encourage students to practice the vocabulary in a variety of contexts 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. Teacher 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 students learn to communicate independently, in small groups, and with the whole class.

Mathematics

While the focus of the curriculum is science and literacy, the units also consider mathematics (National Council of Teachers of Mathematics 2000) as an important supporting area. As part of science instruction, students learn and reinforce mathematics knowledge as they measure properties of objects and events in the real world (e.g., weight, length, volume, temperature, time). They develop estimation strategies, as well as skills for precise measurements. They compare and contrast the metric and traditional system of measurement throughout the lessons, allowing opportunities to construct a deep understanding of the appropriate use of units for each system. In addition to the focus on measurement, students use the tools of data analysis for organizing and interpreting data. They learn how to record and present data in multiple formats, such as charts, tables, and graphs. They also have opportunities to determine measures of central tendency (mean, median, and mode) when conducting multiple trials. Thus, students become precise and accurate in taking measurements, applying mathematical concepts, identifying patterns and anomalies in data, using multiple representational formats for data displays, and reasoning quantitatively.

Teacher Workshops

During the first year of the project, third-grade teachers in the treatment group attended 5 full-day workshops on regular school days. The first workshop was organized around describing the purpose of the project, obtaining teachers' consent, and introducing the first few lessons of the Measurement unit. The second workshop was organized around the Measurement unit; the third workshop around the States of Matter unit; the fourth workshop around the Water Cycle and Weather unit; and the final workshop consisted of data collection activities, including teachers' reflection and feedback. Each workshop was conducted twice, with half of the teachers attending the first session and the other half attending the second; this was done to reduce the number of participants at each workshop and to eliminate concerns from large schools where all of the third-grade teachers would have been out on the same day.

Science

As part of our first-year efforts for professional development in a longitudinal design, 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 administered at the fifth-grade level.

One area of emphasis involved scientific inquiry. The third workshop on the States of Matter unit introduced and highlighted inquiry-based science. Project personnel and teachers held a group discussion on science inquiry (NRC 1996, 2000) and how to promote student initiative in conducting inquiry as teachers gradually reduce their level of guidance. Also, teachers were introduced to the importance of appropriate experimental design when having students conduct experiments. Based on this discussion, teachers worked in small groups on lessons from the States of Matter unit. Then, using inquiry tasks as examples, project personnel demonstrated how to structure science instruction around inquiry activities. Given "practice" inquiry tasks, small groups of 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 science inquiry continued with the Water Cycle and Weather unit at the fourth workshop.

Scientific reasoning was emphasized throughout the workshops. During the second workshop on the Measurement unit, teachers brought students' work samples from the Measurement student booklet and discussed student reasoning of measurement concepts. At the end of the second workshop, teachers completed released practice items from a statewide science test. Teachers' reasoning about their test responses was one focus of the third workshop. At the fourth workshop on the States of 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 (Lee, Luykx et al. 2007). Using segments of students' interview transcripts, teachers analyzed students' difficulties in designing the experiment. At the final workshop, major patterns in students' reasoning about various measurement concepts and skills from our current research were presented. Teachers discussed possible reasons for students' learning difficulties with measurement.

The state science content standards were emphasized as a backbone of the workshops. At the first workshop, project personnel described how the curriculum units from grades three through five would align to the state science content standards. At the second workshop, teachers became familiar with the benchmark clarification of those state science standards that are being assessed at grade five. Teachers were introduced to the state-defined content clusters, including those benchmarks that are annually assessed, as well as those assessed every 3 years. Teachers were also made aware of assessment-item formats and probable impacts of high-stakes science assessment results on school grades according to the state accountability system starting with the 2006–2007 school year. For each curriculum unit at each workshop, project personnel demonstrated how the unit corresponded to specific science benchmarks. Especially, project personnel helped teachers recognize how students' scientific inquiry and reasoning abilities could enhance performance on statewide science assessments.

English Language and Literacy

The workshops focused on incorporating English language and literacy development into specific science lessons. At the second workshop, using the examples in the Measurement unit, project personnel described various strategies for developing students' reading and writing skills within the context of science lessons. We also described how to provide linguistic scaffolding for ELL students. The discussion focused on how teachers (a) adjust the level and mode of their 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 their 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, which involves working in groups to gain expertise about particular domains of knowledge and then sharing that knowledge with the whole group, regarding how to incorporate ESOL strategies in the context of science lessons. 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.

Mathematics

While the intervention's focus is on science and literacy, the workshops also emphasized the role of mathematics in science inquiry. At the first and second workshops on the Measurement unit, teachers discussed various aspects of measurement, such as accuracy in measurement, error in measurement, increments in instruments, and calibration of instruments. At the third and fourth workshops on the States of Matter and Water Cycle and Weather units, we emphasized how mathematics concepts and skills are fundamental to engaging in science inquiry, including measurement, recording and display of data using multiple representational formats (e.g., graphs, charts, tables, drawings), and patterns and anomalies in the data. In the context of conducting experiments, teachers discussed measurement issues, such as accuracy in measurement, controlling variables, multiple trials, and data analyses.

Methods

Research Context

School District

The research was conducted in a large urban school district in the southeastern US with a student population displaying a high level of linguistic and cultural diversity. During the 2004–2005 school year, the ethnic makeup of the student population in the school district was 60% Hispanic, 28% Black (including 7% Haitian, according to the district data on students' home language), 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 (LEP).

Schools

In late May 2004, we selected schools based on three criteria: (a) percentage of ELL students (predominantly Spanish speaking, Haitian Creole speaking students, or both) 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) school grades of primarily grade C or D, based on reading, writing, and mathematics test scores from grades three through five according to the state's accountability plan since its inception in the 1998–1999 school year through the 2002–2003 school year.

Of the 206 elementary schools in the district, 35 schools met these criteria. Two schools were excluded because they had been part of our previous research, resulting in a pool of 33 schools. Before summer vacation started in mid-June 2004, we sent a letter of invitation to these schools for their participation in the research; 17 schools expressed their desire to participate starting from Fall 2004. Of the 17 schools, eight schools were assigned into the treatment group, and nine schools were assigned to the comparison group. Once the research commenced, one school from the treatment group chose not to participate, and one school from the comparison group dropped out as well. Thus, the research during the first year involved 15 elementary schools, including seven in the treatment group and eight in the comparison group.

Teachers

For our schoolwide initiative, we invited every third-grade teacher in each treatment school to participate, for a total of 44 teachers, during the first year of our intervention. Table 1 presents the demographic and professional backgrounds of these teachers. The majority of teachers identified themselves as members of racial or ethnic non-mainstream groups. Close to half of the teachers reported graduate degrees beyond bachelor's degree. Their teaching experience ranged from 1 to 37 years, with an average of 10 years. They had been teaching at their current schools for an average of 7 years.

Data Collection and Analysis

We sought teachers' feedback from multiple data sources throughout the school year. At each workshop, teachers were invited to share "what works" and "what does not work" with the whole group. We informed teachers that their suggestions for improvement of the intervention were welcome and would be incorporated into

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)*	English	32	84
	Spanish	5	13
	Haitian Creole	1	3
	French	1	3
	Dutch	1	3
	Sranang Tango	1	3
Degrees	Bachelor's	22	58
	Master's	15	39
	Specialist	1	3

Note. Multiple native languages could be selected.

our on-going efforts. This promoted an atmosphere of openness and encouraged feedback from teachers. Detailed records of teachers' responses were obtained at each workshop.

In addition to teachers' feedback throughout the school year, all participating third-grade teachers were asked to complete a questionnaire at the year-end workshop (see Appendix). To obtain unbiased responses from the participating teachers, prior to administration of the questionnaire, we asked teachers in small groups to identify ways to refine the third-grade curriculum materials and to share their suggestions with the whole group. This sharing brought individual teacher's perspectives to the public arena. Then, we assured teachers that their individual responses on the questionnaire would be kept confidential and reported only as aggregated data.

The questionnaire asked for their feedback on three sets of questions. The first set of questions examined the effectiveness of each of the components of the intervention for science instruction and student learning. Teachers were asked to rate the effectiveness of student science booklets, teacher guides, science supplies, and teacher workshops. Then, teachers were asked to rate the effectiveness of the intervention in addressing students' science learning, preparation for statewide assessment in science, English language development, home language and culture, mathematics learning, and scientific reasoning. The items were rated, based on a 4-point Likert-type scale, where a *1* indicated *very ineffective* and a *4* indicated *very effective*. The second set of questions examined the impact of the intervention on science instruction and student learning. Teachers were asked to provide written responses on their perceptions of the impact on their knowledge of third-grade science topics, science instruction, support for English language development in science instruction, and integration of mathematics in science instruction. Teachers were also asked to provide written responses on their perceptions of the impact of the project on how their students learned science, English language and literacy in science instruction, and mathematics in science instruction. The third set of questions examined areas of strengths and areas needing improvements in the intervention. Teachers were asked to rank order the three most effective components in the intervention, as well as three components needing improvement.

Teachers' ratings from the first set of questions regarding the effectiveness of the intervention were analyzed in terms of means and standard deviations. Teachers' open-ended responses from the second and third sets of questions were independently analyzed by two coders to develop emergent themes (Bogdan and Biklen 2003). There was a high level of agreement between the two coders, with a small number of disagreements resolved through discussion. For the second set of questions regarding the impact of the intervention on science instruction and student learning, most of the teachers' responses contained one key idea, rather than multiple ideas within each response. Thus, the responses were analyzed in terms of the number of teachers. Teachers' written responses were then analyzed with regard to major themes, and quotes are provided to illustrate each theme in the Results section. For the third set of questions regarding the areas of strengths and areas needing improvement, the numbers of teachers' responses indicating the first, second, and third rankings for the components of the intervention were obtained.

Then, differential weights were assigned to the first (weight 3), second (weight 2), and third rankings (weight 1), and the total weights were obtained.

After the analysis of the teachers' responses on the questionnaire was completed, these results were triangulated with their suggestions for what works and what does not work at each of the workshops. The results from these multiple sources were largely consistent. As a result, this paper reports teachers' responses on the questionnaire as the primary data source.

Results

Effectiveness of Components of the Intervention for Science Instruction and Student Learning

Effectiveness for Science Instruction

Teachers rated main components of the intervention on science instruction as highly effective. On a 4-point Likert-type scale, the mean ratings for the science supplies was 3.84 ($SD = .65$), teacher workshops was 3.79 ($SD = .68$), science booklets for students was 3.68 ($SD = .71$), and teacher guides was 3.61 ($SD = .78$). In addition to the Likert-type scale ratings, teachers were asked to provide comments on the effectiveness of the intervention. Four teachers cited the workshops as being helpful in preparing them for science instruction, as one stated, "Workshops are quite useful because the units are discussed and practiced before administering to students." Four teachers found the supplies helpful, as one commented, "The supplies are time and money savers." Three teachers mentioned the teacher guides and student booklets; one teacher noted that "The teacher guide is user friendly," and another wrote, "The booklets help us not to worry about making copies for students."

Effectiveness for Student Learning

In rating the effectiveness of the intervention in addressing specific areas of student learning, teachers indicated that the intervention was highly effective in addressing science learning ($M = 3.73$, $SD = .70$), scientific reasoning ($M = 3.64$, $SD = .66$), preparation for statewide science assessment ($M = 3.63$, $SD = .66$), and mathematics learning ($M = 3.61$, $SD = .62$). Teachers indicated that the intervention was also effective in promoting English language development ($M = 3.41$, $SD = .70$) and addressing students' home language and culture in science instruction ($M = 3.14$, $SD = .72$).

Of those teachers making additional comments, three teachers stated that the integration of mathematics and science was helpful in preparing their students for the measurement component of high-stakes assessment in mathematics. Three teachers commented that the materials were supportive of English language development of ELL students, as one stated, "The program is clearly effective, especially for my ESOL students, because they have a chance to learn and express their ideas."

Impact of the Intervention on Science Instruction and Student Learning

Impact on Science Instruction

Teachers' perceptions of the impact of the intervention on science instruction are organized with regard to teachers' knowledge of third-grade science topics, science teaching, English language development in science instruction, and mathematics in science instruction (see Table 2).

The majority of the teachers (36) indicated that their knowledge of the relevant science content was enhanced through their participation in the

Table 2 Impact on science instruction ($n = 44$)

Topic area and themes	Number of teachers
Knowledge of third-grade science topics	
Enhanced knowledge of science	36
Positive attitudes	3
No impact	1
No response	4
Science teaching	
Instructional strategies	16
Hands-on activities or experiments	15
Positive attitudes	8
Positive responses without giving reasons	3
No response	2
English language development in science instruction	
Vocabulary in three languages	12
Vocabulary development	11
Instructional strategies	9
Positive responses without giving reasons	5
Not applicable to my classroom	1
"I don't know"	1
No impact	1
No response	4
Mathematics in science instruction	
Science and mathematics integration	21
Specific math topics or skills (measurement and data display)	13
Hands-on science for mathematics learning	3
Positive responses without giving reasons	2
No response	5

intervention. One teacher stated, "I have more in-depth knowledge of each of the topics and how to teach these topics on a third-grade level." Two of these 36 teachers pointed out their enhanced knowledge of hands-on activities or experiments. One stated, "It has increased my knowledge especially with meaningful experiments that could easily be performed to supplement lessons." Another three teachers reported more positive attitudes in terms of their interest, confidence, and enjoyment in teaching science.

When asked to describe the impact on how they teach science, 16 teachers reported more effective strategies for teaching science. While many teachers made references about strategies in generic terms (e.g., small groups, more effective strategies), several teachers made references about students' thinking and reasoning. One teacher stated, "Gave interesting and in-depth ideas for children to explore, which made me go beyond what I would have normally taught." Another 15 teachers reported that their science teaching was enhanced with more hands-on activities or experiments. They felt they were able to provide a more well-rounded science lesson in which students were given opportunities to explore and reason. One teacher stated, "Most of the science lessons are now more of hands-on than before. Students have more of an opportunity to figure things out as they reason with peers." Another stated, "I used to lecture instead of integrating so many more hands-on activities that facilitate learning." An additional eight teachers reported positive attitudes in terms of confidence, excitement, fun, interest, enthusiasm, and enjoyment in teaching science.

When asked to describe the impact on how they promote English language and literacy development in science instruction, 12 teachers attributed the effectiveness to key vocabulary in three languages (English, Spanish, and Haitian Creole) included in the beginning of each lesson. One teacher stated, "Having the vocabulary in the different languages has been helpful to reinforce to the various levels of English proficiency." Another stated, "Increases the vocabulary that non-English speakers might have in another language—put them in groups with proficient students and better help these students." Related to key vocabulary in three languages, 11 teachers reported enhanced vocabulary instruction. The vocabulary was used to help students access prior knowledge. One teacher stated, "Helped me to recognize the importance of cultivating background knowledge, which included vocabulary development." The vocabulary was also used to assist learning, as one teacher stated, "Presenting the new vocabulary and making my students use it in class and apply what they learn." In addition, nine teachers reported instructional strategies, including the use of visuals, oral presentations, small-group work, cooperative learning, and hands-on activities.

Finally, teachers were asked to provide feedback about ways in which they promoted mathematics in science instruction. The 39 teachers who responded to this question all indicated a positive impact on mathematics in science instruction. A majority of teachers (21) recognized the value of integrating the two subjects to enhance students' ability to understand the natural relationship. One teacher stated, "I integrate math instruction with science so that my students learn the value of both and see how they are connected." Another stated, "It [math] was taught throughout the science lessons, as well as correlated with the math book and in other real-life settings." Another 13 teachers reported specific mathematics topics or skills in the context of science. Most of these teachers highlighted measurement and data display (tables, charts, graphs). Three of the teachers indicated the value of hands-on science experience in learning mathematics; as one stated, "Better helps abstract math. It's more concrete when the kids have things to manipulate and have hands-on materials."

Impact on Student Learning

Not only were teachers asked to describe the impact on their science instruction, but they were also asked about the impact on student learning (see Table 3). Common themes emerged between the impact on science instruction and student learning, English language and literacy development, and mathematics learning in science instruction.

Table 3 Impact on student learning ($n = 44$)

Topic area and themes	Number of teachers
Science learning	
Hands-on experiences or experiments	17
Experiments producing positive attitudes	7
Positive attitudes	6
Enhanced science knowledge and reasoning	8
Positive responses without giving reasons	4
No response	2
English language and literacy development	
Vocabulary development	14
Hands-on experiences or experiments	8
Increased literacy skills	2
Positive responses without giving reasons	7
Other	2
Not applicable to my classroom	1
"I don't know"	1
No impact	2
No response	7
Mathematics learning	
Science and mathematics integration	19
Specific math topics or skills (measurement and data display)	7
Hands-on science for mathematics learning	4
Positive responses without giving reasons	5
"I don't know"	1
No response	8

Just as teachers reported an increased use of hands-on activities or experiments in their science teaching, 17 teachers reported that the use of hands-on experiences or experiments had an impact on their students' science learning. One teacher said, "They ask better questions and use observation skills more"; another said, "My students learned how to reason and explore topics using the science inquiry framework." Still another said, "Children are more knowledgeable about the scientific process. Science is now more student oriented." Another eight teachers reported that experiments led to students' positive attitudes in terms of excitement, enjoyment, interest, motivation, and fun in learning science. One teacher said, "They're excited about learning science now that we have experiments or hands-on projects." Six teachers also reported students' positive attitudes. Finally, eight teachers reported enhanced science knowledge and reasoning abilities. One commented, "I believe that the depth of science knowledge was increased due to the high-level thinking skills the units provided."

The majority of teachers reported that the intervention had an impact on English language and literacy development. Many (14) reported that students experienced an increase in use of appropriate vocabulary. Some of these teachers indicated vocabulary development as part of concept development through oral or written communication. One teacher said, "Vocabulary increased and their writing reflects a deeper understanding of concepts of terminology." Another expressed a special need with beginning ESOL students, "Low level ESOL one students still need basic communication and vocabulary before understanding more scientific vocabulary." Three of the 14 teachers mentioned the vocabulary in three languages, including one who stated, "The ESOL students made a connection because they saw the vocabulary words in their native language. It served as a motivator as well." Another eight teachers reported the role of hands-on experiences or experiments for literacy development. One teacher said, "Having hands-on experience made it easier for students to learn versus reading the material"; another said, "Language the students would have never learned in a science book—they now know with hands-on projects." An additional two teachers specifically pointed out enhanced literacy skills, including "the ability to utilize context clues" and "to read the stories in science and develop different skills in literacy."

Finally, the majority of teachers believed that the integration of mathematics and science was more frequent and had a positive impact on their students. Many teachers (19) reported that students were able to recognize the connection between science and mathematics, as one said, "Some of them have realized that math and science go hand in hand, making it easier to understand concepts or skills." Another seven teachers pointed out specific topics or skills in mathematics in the context of science learning. One said, "It was easier for students to understand why people use measurements and collect data (graph) for some of the [States of] Matter experiments." Finally, four teachers reported that hands-on science provided opportunities for mathematics learning. One teacher stated that "[The intervention] offers the hands-on practice and the everyday activities that the math book does not offer."

Table 4 Areas of strength and areas needing improvement ($n = 44$)

	Rank 1 (X3)	Rank 2 (X2)	Rank 3 (X1)	Total number of teachers	Weighted score
Areas of strength					
Supplies	22	12	6	40	96
Teachers' guides	10	15	8	33	68
Student booklets	2	15	15	32	51
Workshops	7	1	8	16	31
Other	4	3	2	9	20
Areas needing improvement					
Student booklets	17	4	6	27	65
Workshops	3	4	–	7	17
Teachers' guides	2	3	1	6	13
More supplies	3	–	2	5	11
"Nothing"	1	1	1	3	6
Other	2	3	–	5	12

Areas of Strength and Areas Needing Improvement in the Intervention

Teachers' responses are reported in terms of rankings and weighted scores (see Table 4).

Areas of Strength

The written responses were consistent with effectiveness ratings from the first set of questions. Teachers emphasized the provision of supplies as the primary strength of the intervention. They mentioned "not having to worry about searching for [supplies] themselves" and making it "worry free and less stressful." They also mentioned that students had the opportunity to work with various tools. The second most commonly reported strength was the teacher guides. Teachers made reference to the visual materials, including pictures, graphs, charts, and tables. Teachers named student booklets as the third strength. The teachers indicated that the lessons were well designed and incorporated visual materials. In addition, they commented on the convenience of consumable student booklets and the effective use of the science inquiry framework. Finally, teachers mentioned workshops as effective in providing opportunities to "complete the experiments and gain the background knowledge of concepts," "do the experiments first ourselves before doing them with the students," and "engage in peer collaboration."

Areas Needing Improvement

Compared to the number of teachers who reported areas of strength, the number of teachers who reported areas needing improvement was substantially smaller. The most frequently cited comment focused on the need to improve student booklets. These comments fell into four categories with roughly equal numbers. Several teachers expressed dissatisfaction with stapled pages of student booklets and suggested alternative binding. Others suggested eliminating some lessons or activities and shortening the units, (especially the Measurement unit). Still others asked for more curricular support for assessment and grading, such as the inclusion of various types of assessment (e.g., multiple-choice items) in addition to the written response items, and more frequent assessment items for grading purposes. The remaining comments about student booklets involved the contents, such as providing more science experiments, including a glossary of science vocabulary for each unit, reducing the length and difficulty of reading passages for students with reading difficulty or ESOL students, and avoiding repetitiveness in some lessons.

Teachers commented on the need to improve workshops by including more science experiments and encouraging more interactions among teachers within and across participating schools. Teachers also expressed the need to improve teacher guides by making them less wordy, reducing the amount of information provided, matching the pages of teacher guides with the pages of student booklets, and "providing additional experiments to do in case of further clarification for students." Finally, teachers asked for additional supplies for small-group activities.

Conclusions and Implications

The literature is replete with examples indicating that elementary teachers are often not adequately prepared in science and not comfortable teaching science (Kennedy 1998; Loucks-Horsley et al. 1998). Such difficulties are confounded for teachers working with ELL students, who must learn science while simultaneously acquiring English proficiency (Lee and Fradd 1998; Stoddart et al. 2002). The demands of teaching science to ELL students will become greater when science factors into school accountability starting in 2006 in the state in which the research is being conducted and in 2007 for the nation under the *NCLB* Act.

Our professional development intervention is designed to promote elementary teachers' knowledge, beliefs, and practices in teaching science, along with English language and mathematics for ELL students in urban schools. The results of the first-year implementation of our intervention indicate positive achievement gains among the students in the treatment group (Lee, Maerten-Rivera et al. 2007). To better understand student achievement results, we seek teachers' perspectives through multiple data sources. Additionally, we seek teachers' perspectives to improve our on-going intervention efforts that, in turn, are likely to further enhance student achievement over the years. Furthermore, such perspectives will contribute to the emerging literature on professional development in science education with diverse student groups, including ELL students.

Conclusions

Teachers believed that the intervention through the provision of curriculum materials and teacher workshops was effective overall. They also believed that the intervention effectively addressed various areas to promote student learning in science along with English language development and mathematics learning. Teachers highlighted many strengths in the intervention, and the number of teachers reporting strengths far outweighed the number of teachers reporting areas needing improvement (see Table 4). Supplies were rated as the primary strength, suggesting that elementary classrooms often lack appropriate science instructional materials and supplies, a state of affairs often exacerbated by a more generalized lack of resources and funding in urban schools serving large numbers of ELL students (Hewson et al. 2001; Kahle et al. 2000; Knapp and Plecki 2001; Spillane et al. 2001). Although teachers most frequently commented on the need to improve student booklets, almost half of the comments involved concerns that were not related to the contents, including binding the student booklets, reducing the number of lessons, or shortening the activities. The remaining half of the comments about student booklets involved the need for more frequent assessment items for grading purposes and the need to improve the contents of the lessons.

Teachers' perspectives regarding the impact of the intervention on their instruction were generally consistent with their perceptions on the impact on student learning (see Tables 2, 3). Almost all the teachers expressed enhanced knowledge of third-grade science topics. A predominant theme involved the importance of hands-on experience or experiments (with the provision of supplies and equipment) in science learning. The results are consistent with the professional development literature indicating that, as teachers increase their knowledge of science content and effective instructional strategies, they also need support in the form of science curricular resources and materials to implement these new practices.

Teachers also highlighted the impact of the intervention on English language and literacy development and mathematics learning in science instruction. They emphasized students' enhanced vocabulary development, which was assisted by the vocabulary terms in three languages provided in each lesson. They emphasized science and mathematics integration and the role of specific mathematics topics or skills, such as measurement and data displays, in the context of science. The results are consistent with the literature, indicating that integration of science with core subject areas is essential in low-performing urban elementary schools since instructional time for science is often limited and tightly regulated due to the urgency of developing basic literacy and numeracy in students with limited literacy and numeracy skills and those learning English as a new language. Furthermore, teachers face added challenges in the context of high-stakes assessment and accountability, as sanctions against poor academic performance are disproportionately leveled against urban schools (Settlage and Meadows 2002; Wideen et al. 1997).

Teachers' perspectives suggest that an "integrated" professional development intervention addressing science, English language development, and mathematics for ELL students can be perceived positively by teachers, can be implemented effectively, and can result in improved student achievement outcomes. The results contribute to the emerging literature on professional development interventions simultaneously addressing science and English language and literacy for ELL students (Amaral et al. 2002; Fradd et al. 2002; Hampton and Rodriguez 2001; Hart and Lee 2003; Lee et al. 2004; Stoddart et al. 2002). Furthermore, this study contributes to the literature in three additional ways. First, it offers teachers' perspectives, which are absent in the existing literature. Second, it provides support that teachers can effectively integrate mathematics learning with science and English language and literacy for ELL students. Finally, it addresses an intervention in the context of looming high-stakes assessment in science in the state and the nation.

Implications

Teachers are key to educational innovations, and success of a professional development intervention relies on considering teachers' perspectives while enabling teachers to adopt reform-oriented practices. Our intervention faces additional challenges as it integrates science, English language and literacy, and mathematics for ELL students in anticipation of high-stakes science assessment. The third-grade students during the 2004–2005 school year will be the first student cohort to participate in the statewide high-stakes science assessment at the fifth-grade level that will become part of school accountability in the 2006–2007 school year.

During the summer of 2005, we revised and refined the third-grade science curriculum materials based on teachers' suggestions. The revisions fell into two categories:

1. Physical additions:
   - Spiral bound student booklets, instead of stapled pages;
   - Transparencies showing vocabulary terms in three languages in teacher guides; and
   - New supplies to enrich some of the lessons and additional supplies for small-group activities.

2. Content additions:
   - Questions to activate students' prior knowledge in student booklets and teaching suggestions in teacher guides;
   - More visual materials in student booklets (e.g., illustrations, graphics, pictures) and teacher guides (e.g., transparencies);
   - Glossary of science terms in teacher guides; and
   - Various types of assessment items in student booklets and suggestions for classroom assessment and grading in teacher guides.

However, we did not incorporate all of the suggestions in the revision. For example, although some teachers asked for reducing or shortening some of the lessons in the Measurement unit, we kept the unit in the current form. This was done because of students' high performance on the statewide high-stakes mathematics assessment (especially in the measurement strand) and the necessity of well-developed measurement skills to engage in science inquiry. Although several teachers asked for reducing the language load in student booklets for ESOL levels 1 and 2 students, we kept the current reading level since we have the same expectations for all students and producing student booklets at different levels of English proficiency would be beyond the resources available in the intervention. Instead, we provided other supports, such as more visual materials and more supplies for student engagement. Although some teachers commented that there is too much information in teacher guides and that these guides tend to be wordy, we did not make substantial changes since elementary school teachers would generally need background science information and teaching suggestions.

In addition to curricular revisions in response to teachers' suggestions, we also recognized that certain aspects of the curriculum materials needed clarification or elaboration to help teachers improve their instructional practices. In the revision, we highlighted the importance of accuracy in taking measurement, increments on instruments, and error in measurement. Also, throughout the teacher guides for the States of Matter and the Water Cycle and Weather units, we highlighted the importance of control of variables, multiple trials, and accuracy of measurement in conducting science inquiry.

In our second-year teacher workshops in the summer of 2005, with many of the teachers continuing their participation in the second year, we incorporated teachers' suggestions and our own assessments of areas where teachers require support for continued professional growth. The workshops started with our rationale about the teacher suggestions we chose to incorporate into curriculum revision. We also emphasized the importance of a clear understanding of measurement and science inquiry, as noted previously. Additionally, we discussed various graphic organizers and then engaged teachers in developing concept maps for the measurement topic. In our on-going workshops, we will further assist teachers to engage in reform-oriented practices in teaching science, while also promoting English language development and mathematics learning. For example, as teachers overwhelmingly emphasized the importance of hands-on experience or experiments, we will use this as an anchor to promote scientific understanding and inquiry and also to enrich English language and literacy development and mathematics learning. Additionally, although incorporating students' home language and culture was not the focus of teacher workshops during the first year (as indicated by the teachers' relatively low rating of effectiveness in this area), we will address this topic in future workshops.

The results of this study offer insights into both our intervention efforts and research activities using a longitudinal research design over the years. Our on-going intervention efforts will be assessed continuously, based on multiple data sources, including teachers' perspectives, as well as classroom observations, interviews and questionnaires with teachers and administrators, and student-achievement outcomes. The longitudinal design in our research enables us to examine the impact of the intervention on change in teachers' knowledge, beliefs, and practices in teaching science along with English language and mathematics for ELL students. Teacher change, in turn, will be reflected in the students' achievement outcomes over the years.

Our professional development intervention targets traditionally underserved students—ELL students in urban schools. The intervention has implications for scaling up with non-volunteer teachers as a schoolwide initiative. The intervention is designed to impact instructional practices to improve student learning that is measured in terms of scientific understanding, reasoning, and inquiry. Student learning through the intervention will also be reflected in the statewide high-stakes assessment in science. In achieving the goal of greater science achievement for all students, teachers' perspectives play a key role in refining our own intervention efforts and in building a knowledgebase for effective professional development initiatives more generally.

Appendix

Teacher Feedback Questionnaire

Part I

1. Please indicate how effective each of the components of the project has been for your science instruction:

	Very ineffective	Somewhat ineffective	Somewhat effective	Very effective
a. Student science booklets	1	2	3	4
b. Teacher guides	1	2	3	4
c. Science supplies	1	2	3	4
d. Teacher workshops	1	2	3	4

Comments:

2. Please indicate how effectively the project has addressed each of the following areas:

	Very ineffective	Somewhat ineffective	Somewhat effective	Very effective
a. Science learning	1	2	3	4
b. Preparation for statewide science assessment	1	2	3	4
c. English language development	1	2	3	4
d. Students' home language and culture	1	2	3	4
e. Mathematics learning	1	2	3	4
f. Scientific reasoning	1	2	3	4

Comments:

Part II

3. What impact has your participation in the project had on

a. Your knowledge of third-grade science topics?
b. How you teach science?
c. How you promote English language development in science instruction?
d. How you promote mathematics in science instruction?

4. What impact has the project made over the school year with regard to

a. How your students learn science?
b. How your students learn English language and literacy in science instruction?
c. How your students learn mathematics in science instruction?

Part III

5. What aspects or activities of the project (e.g., science supplies, student booklets, teacher guides, workshops, etc.) have been most effective? (What have we done well?) Please rate three in order of effectiveness.

    1.
    2.
    3.

6. What aspects or activities of the project (e.g., science supplies, student books, teacher guides, workshops, reasoning interview, etc.) need improvement? (What can we do better?) Please rate three in order of improvement needed.

    1.
    2.
    3.

Thank you very much!

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