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Promoting Science Among English Language Learners: Professional Development for Today's Culturally and Linguistically Diverse Classrooms

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Abstract

We describe a model professional development intervention for supporting third through fifth grade teachers' science instruction in urban elementary schools with high numbers of English language learners (or ELL students). The intervention consists of curriculum materials for both students and teachers, as well as teacher workshops throughout the school year. The curriculum materials and workshops are designed to complement and reinforce each other in improving teachers' knowledge, beliefs, and practices in science instruction and English language development for ELL students. In addition to these primary goals, secondary goals of the intervention include supporting teachers' and students' mathematical understanding, improving teachers' and students' scientific reasoning, capitalizing on students' home language and culture, and preparing students for high-stakes science testing and accountability through hands-on, inquiry-based learning experiences. We hope our model might serve as a point of departure for other professional development efforts situated in similar settings.

Promoting Science Among English Language Learners: Professional Development for Today's Culturally and Linguistically Diverse Classrooms

The importance of teacher professional development has long been recognized as an essential component of improving our nation's schools. The increased expectations for high academic achievement by all students, as embodied in the *No Child Left Behind Act (NCLB)* of 2001 (PL 107-110), cannot possibly be fulfilled without a well prepared teaching force. The plethora of state accountability systems that have arisen as offspring of NCLB place a great deal of pressure on teachers to implement well articulated curriculum, instruction, and assessment systems that foster the academic growth and development of an increasingly diverse student population. This student diversity is multifaceted, as a typical teacher is likely to preside over a class of students reflecting cultural and linguistic diversity, students with varying exceptionalities, and students from different socioeconomic status (SES) backgrounds.

Despite these challenges, and the clear role that teacher professional development must play in attaining the goal of high academic achievement of all students, insufficient attention has been devoted to the characteristics of professional development that might best support teachers in accomplishing this goal. While NCLB requires states to provide teachers with high quality professional development, it fails to expound upon the nature of this professional development or its delivery. As science becomes the latest subject to be included in measures of annual yearly progress (AYP) under *NCLB*, it is perhaps timely to consider some of the issues around providing high quality teacher professional development in today's classrooms. In this paper we present our framework for facilitating the professional development of teachers of science in culturally and linguistically diverse urban elementary classrooms. We hope our model might serve as a point of departure for other professional development efforts situated in similar settings.

Professional Development in Teaching Science for Student Diversity

It has been well documented that most elementary teachers are not adequately prepared to teach science effectively, as they frequently lack both the science content knowledge and the familiarity with inquiry-based science instruction needed to teach reform-based science (Kennedy, 1998; Loucks-Horsley, Hewson, Love, & Stiles, 1998). To complicate matters, most teachers are also insufficiently prepared to meet the learning needs of linguistically and culturally diverse students (National Center for Education Statistics, 1999). Thus, it should not be surprising that many teachers struggle to simultaneously address both science content and students' linguistic and cultural backgrounds, nor that they may fail to recognize the importance of doing so (Bryan & Atwater, 2002; Rodriguez & Kitchen, 2005).

In recent years, a limited number of professional development efforts have considered issues of linguistic and cultural diversity in science education (see Lee & Luykx, 2006, for a comprehensive literature review). These studies have examined topics, such as the impact of professional development on science teachers' beliefs and practices when working with diverse student groups (Ballenger & Rosebery, 2003; Lee, 2004), and how teachers of ELL students can simultaneously promote science learning and English language development (Amaral, Garrison, & Klentschy, 2002; Hampton & Rodriguez, 2001; Hart & Lee, 2003). These efforts have met with varying degrees of success in fostering positive changes in teachers' beliefs and practices around teaching science with diverse student groups. Despite some successes, this body of work points to a multitude of challenges in facilitating teachers' professional development in support of culturally and linguistically diverse students' academic success in science.

Elsewhere (Author, 2007a), we have described in some detail a six-category taxonomy of these challenges, summarized as follows: (1) difficulties residing with teachers' beliefs about student diversity (August & Hakuta, 1997; Bryan & Atwater, 2002); (2) difficulties residing in the time-intensive engagement needed to address both science instruction and students' linguistic and cultural diversity within a professional development setting (Kennedy, 1998); (3) difficulties promoting culturally relevant curriculum materials that recognize diverse cultural perspectives and contributions within the current framework of standards-based instruction (Aikenhead, 1997; Buxton, 2006); (4) difficulties in scaling up, as successful interventions have tended to focus on small numbers of volunteer teachers (Elmore, 1996); (5) difficulties overcoming the perception, fostered by standards-based testing, that linguistic and cultural minorities must simply assimilate to the dominant language and culture (Lee & Luykx, 2005); and (6) difficulties with English-only policies that disregard the importance of students' home language development as a relevant aspect of academic achievement (Garcia & Rodriguez, 2000; Wiley & Wright, 2004).

Many of these challenges arose in the professional development components of our prior research projects (Author, 2006, 2007a). Thus, as we conceptualized the professional development for our current project, we viewed our efforts as responses to a series of competing tensions—tensions that our participating teachers were likely to feel as they attempted to implement our intervention in their classrooms, and tensions that we ourselves felt as we considered the most important content, ideas, and strategies that we wished to impart to our participating teachers. These tensions fall into three categories: (a) balancing science content and inquiry; (b) supporting content areas of English language and literacy and mathematics; and (c) recognizing contextual features of multicultural and multilingual classrooms, urban settings, and high-stakes testing and accountability.

Science Content and Inquiry

The first critical tension involved our need to simultaneously address two overarching foci of science teaching in our professional development. We were committed to helping teachers improve their science content knowledge. It is self-evident that teachers who lack the basic content knowledge they are responsible for teaching are greatly limited in their ability to support students' mastery of this material. Despite participants' survey responses indicating their perceived competence in their knowledge of science content at their grade level (Author, in press), our initial interactions with participants pointed to many gaps in their science content knowledge. While keen to address these content knowledge gaps, we also felt it essential to do so while highlighting pedagogy and inquiry practices. Although widely accepted as important for all students, the role of hands-on and inquiry-based pedagogy has been shown to be especially important when working with ELL students (Amaral et al., 2002; Hart & Lee, 2003). Most of our practicing teachers, however, had not themselves learned science through hands-on inquiry and had some reservations about teaching in this manner. We developed an explicit focus on promoting student reasoning as a way to help teachers differentiate between basic observation (lower level reasoning) and evidence-based explanation (higher level reasoning) (Author, 2007b).

To address science content and inquiry simultaneously, we developed a comprehensive science curriculum for grades three through five (described below). While not initially intended as a curriculum development project, in order to address all six challenges outlined above, we concluded that our project would be best served by developing our own curriculum. Although it is important that teachers learn to follow a reform-oriented curriculum, this is not enough. To fully realize the intentions of the curriculum, they should also understand *why* they are doing what the curriculum asks. If teachers view the curriculum as a script to be followed, they will be unlikely to modify or enrich their ideas about content or pedagogy. Teachers become simple technicians following a rote plan, rather than reflective practitioners who build on the curriculum in response to their unique student needs and learning contexts.

Supporting Content Areas — English Language and Literacy and Mathematics

A second set of professional development tensions we grappled with involved our commitment to infuse learning opportunities for English language and literacy development and mathematics learning. We viewed these as supporting areas, and understood that teachers would be more willing to devote class time to science if they believed that language and mathematics learning was also taking place.

When developing the curriculum we included literacy and ESOL experts to ensure that we were building appropriate English language and literacy development strategies throughout. We provided explicit suggestions to support general literacy development for all students, specific strategies aimed at the unique language learning needs of ELL students, connections between academic language development and ELL students' home language use, and ways to leverage students' experiences at home and in the community. However, it remains an empirical question as to whether teachers, through their participation in the professional development intervention, will build on these strategies to engage students of all levels of English proficiency in academic language development, to offer multiple points of entry for students of differing levels of English proficiency, and to provide multiple modes for students to display their learning.

In support of mathematics, we took a similar approach, infusing a range of mathematics concepts and skills relevant to science inquiry practices. We view measurement as an essential starting point required for much of the data collection that students are asked to perform during science activities. The display, analysis, and interpretation of data provide fertile ground for mathematical problem solving, involving both calculations and conceptual ideas such as central tendency and anomalies. Again, however, we had to question whether teachers would fully realize the intentions of the curriculum and individualize these strategies based on their own personal strengths, interests, and needs.

Contextual Issues

Our third and final professional development tension involved the influence of other contextual issues, especially challenges related to “at-risk” urban schools and high-stakes testing and accountability. On the survey administered in our project, teachers pointed to barriers stemming from student retention, lack of parental support, and limitations of students’ academic skills. Other issues involved high mobility rates among both teachers and students and limited resources restricting science instruction. In addition to these bottom-up contextual factors, the most widely discussed contextual factor was the top-down issue of state assessment and accountability, which shifted from not testing science at the inception of our project to beginning to test science during the third year of our project. On the survey and during focus group interviews, teachers expressed pressures from this accountability system in a number of ways, including the way principals scheduled instructional time for science; pressure to focus on test preparation rather than inquiry-based, hands-on science; and pressure to stop teaching science for several weeks prior to testing so as to focus on the more heavily tested subjects of reading and mathematics. Notably, these barriers all have an external locus of control, that is, teachers have only limited ability to influence these barriers. Rarely did they point to their own limitations, such as limited content knowledge or monolingualism, as barriers to student science learning.

Thus, one of the evolving goals of our professional development was that teachers would perceive fewer barriers to their students' science learning over the course of their participation in the intervention. This could be accomplished either through strategies that actually served to lessen these barriers, or through changing teachers' perceptions to view existing conditions as less of a set of barriers. The latter would include a decrease in perceived pressure from the accountability policies over the course of their participation in the intervention, as teachers came to believe that our instructional approach would prepare their students for the test at least as well as an explicit test preparation approach.

Given the range of issues our teachers were facing, including the need for enhanced science content and pedagogical knowledge, the need to support secondary areas of language and mathematics, and the need to address a range of bottom-up and top-down contextual factors, how could our intervention create the conditions whereby teachers would sustain content-rich and reform-oriented science teaching practices? We were especially interested in how this might be accomplished once teachers exited the intervention. The components of both our curriculum and professional development efforts designed to sustain these teaching practices are described in more detail next.

Professional Development Intervention

The intervention consists of curriculum materials for students and teachers, as well as teacher workshops throughout the school year. The curriculum materials and workshops are designed to complement and reinforce each other in improving teachers' knowledge, beliefs, and practices in science instruction and English language development for ELL students. In addition to these primary goals, secondary goals of the intervention include supporting teachers' and students' mathematical understanding, improving teachers' and students' scientific reasoning, capitalizing on students' home language and culture, and preparing students for high-stakes science testing and accountability through hands-on, inquiry-based learning experiences.

Curriculum Units

Our curricular units constitute the entire science curriculum for grades 3 through 5 as mandated by the State of Florida science content standards and also recommended by the *National Science Education Standards* (National Research Council, 1996). Special consideration was given to the State content standards (Florida Department of Education, 1996) and science test item specifications (Florida Department of Education, 2002) to ensure thorough alignment between the curriculum units and benchmarks that are tested by the state assessment in science. The three third grade units (Measurement, States of Matter, Water Cycle and Weather) were developed and rigorously tested in our previous research, and further refined based on teacher feedback, classroom observations, and student assessment results during the current research. The three fourth grade units (Energy, Force and Motion, Processes of Life) were developed during the second year of the project and the three fifth grade units (Nature of Matter, Earth Systems, Synthesis) were developed during the third year of the project.

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

Science. Through teachers' guides and student booklets, the curriculum provides scaffolding for teachers' development of content knowledge and inquiry-based pedagogy, which in turn promotes students' scientific understanding, inquiry, and reasoning.

Student booklets are designed to promote standards-based, inquiry-driven science learning. Science inquiry involves such conventions as control of variables, multiple trials, and accuracy of measurement. Students also learn about independent and dependent variables and constants. To promote science inquiry with students who may be less familiar with scientific practices, the units are designed to move progressively along a continuum from teacher-explicit to student-initiated inquiry. Units gradually progress to higher levels of complexity in terms of both science concepts and the level of inquiry required from students. Teachers' guides offer suggestions on how teachers may provide scaffolding to promote science inquiry, depending on students' prior experience with school science and the demands of specific science tasks. The teachers' guides also offer suggestions about how to set up and implement hands-on activities, along with cautions about what may go wrong and how to respond to such situations.

Within the context of science inquiry, student booklets emphasize key science concepts and big ideas. Following inquiry activities, each lesson provides science background information that explains the question under investigation and related natural phenomena. The units also highlight common misconceptions and potential learning difficulties. To enrich the science content in the student booklets, teachers' guides provide science background information and explanations for the questions posed in the student booklets, with particular emphasis on students' common misconceptions and learning difficulties. Furthermore, they offer suggestions for extension activities, assessment activities, and homework assignments.

English language and literacy. The curriculum focuses on two primary aspects of English language development in science instruction: (a) general literacy in English for all students, and (b) language learning needs of ESOL students.

Student booklets highlight activities and strategies to foster general literacy (i.e., reading and writing) in English for all students. For example, the booklets use specific comprehension questions about inquiry activities, strategies to enhance comprehension of science information in expository text at the end of each lesson, and various language functions (e.g., describing, explaining, reporting, drawing conclusions) in the context of science inquiry. Teachers' guides also provide suggestions to promote literacy development. For example, students engage in authentic communication through the use of hands-on tasks, narrative vignettes, and expository texts related to everyday experiences. Students write expository paragraphs describing the scientific process under investigation, explanations and conclusions of science experiments conducted in class, and responses to writing prompts provided as supplementary materials. Trade books and other literature related to the science concepts under investigation are also incorporated.

In addition to more generic literacy development, the units specifically address the needs of ELL students by providing explicit guidance to promote their English proficiency. For example, science terms in Spanish and Haitian Creole are provided to support communication and comprehension. Language load for students at varying levels of English proficiency is increasingly more demanding as the units progress. The units introduce key vocabulary in the beginning and encourage students to practice the vocabulary in a variety of settings to enhance their understanding throughout the lesson and over the course of the unit. Additionally, the units use multiple modes of communication and representation (verbal, gestural, written, graphic) to enhance students' understanding of science. Teachers' guides emphasize the importance of linguistic scaffolding to promote ELL students' comprehension and understanding of science. For example, extensive graphic materials are included in transparencies (e.g., graphic organizers, Venn Diagrams, pictures of measurement instruments, drawings of experimental set-ups, data tables, graphs, charts). Teachers are encouraged to engage students in a variety of group formations, so that students learn to communicate independently, in small groups, and with the whole class.

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 for science learning. The curriculum highlights three aspects of mathematics: (a) conventions of measurement, (b) conventions of recording and displaying data, and (c) various mathematics concepts and skills in the context of science inquiry.

The intervention begins with a comprehensive third grade unit on measurement that is aligned with the state-mandated mathematics benchmarks. The third grade students learn basic measurement tasks, including the determination of length, weight, volume, temperature, and time, using both metric and traditional systems of measurement. They also practice conventions for measurement instruments. They learn various aspects of measurement, such as standard and non-standard measurement, units of measurement, accuracy in measurement, error in measurement, increments of instruments, calibration of instruments, and estimation versus precise measurement in different settings.

The units across grades 3 through 5 highlight conventions for recording and displaying data using graphs, charts, and tables. Students discuss when and how to use bar or line graphs. They discuss how to place the independent variable on the x-axis and the dependent variable on the y-axis. They also discuss how to label graphs.

The units across grades 3 through 5 employ mathematical concepts and skills in the context of science inquiry. Students discuss accuracy in measurement and sources of measurement error. When conducting multiple trials in experiments, they discuss analysis and interpretation of data, such as central tendency (mean, median, and mode) and anomalies. They also discuss recording and display of data using multiple representational formats (e.g., graphs, charts, tables, drawings). Thus, students become precise and accurate in taking measurements, identifying patterns and anomalies in data, using multiple representational formats for data displays, and reasoning quantitatively.

Context of urban schooling. As teachers increase their knowledge of science content and instructional strategies, they also need support in the form of resources to implement these new practices. Teachers in urban schools face challenges, including a generalized lack of resources and funding, lack of appropriate science instructional materials, and classroom management issues. We provide teachers with complete class sets of materials, including teachers' guides, copies of student booklets, science supplies, and trade books related to the science topics. Furthermore, we replenish copies of student booklets and science supplies every year. In urban schools high rates of both teacher and student mobility present challenges to innovative science curriculum. Mobility is a limiting factor because even the best curriculum can only be as effective as its implementation. Innovative curriculum materials require extensive professional development. If teachers move from grade to grade or school to school, they are less likely to be able to take advantage of professional development. We provide teachers new to our project with extensive professional development focused on content and pedagogy, while we provide enrichment activities focused on student reasoning and students' linguistic and cultural funds of knowledge with teachers continuing their participation into the second and third years. Thus, teacher mobility limits teachers' exposure to the enrichment activities.

Student mobility can also negatively influence innovative curriculum. Our curriculum units are designed to move students through articulated topics from grades 3 through 5. Unlike the spiral curriculum approach used by the local school district, in which each of the eight state science content strands are revisited each year, our curriculum treats key concepts in depth for extended periods until student mastery is achieved and then moves on to a subsequent topic. Thus, students who transfer in to a school using our curriculum will have missed certain topics that will be addressed in the state assessment. To mitigate against this effect, we developed a final fifth grade unit that synthesizes key concepts covered in the earlier grades.

Context of high-stakes testing. For testing and reporting purposes, the state standards are grouped into four equally weighted clusters: physical and chemical sciences, earth and space sciences, life and environmental sciences, and scientific thinking. Due to the large number of science benchmarks in the state standards, a subset of those benchmarks are highlighted and called annually assessed benchmarks. The remaining benchmarks are assessed every three years and are referred to as content sampled benchmarks. Our curriculum units from grades 3 through 5 are designed to address all of the annually assessed benchmarks by the time students take high-stakes science assessment at grade 5. While the curriculum is designed first and foremost to be a tool for teaching inquiry-based science, it is also essential, in the current policy context, to ensure that the curriculum prepares students to succeed on high-stakes science assessment.

Teacher Workshops

As with the curriculum units, the professional development workshops are designed to focus on the three domains of our intervention: (a) science content and pedagogy, (b) supporting areas of English language and literacy and mathematics, and (c) contextual features of urban schooling and high-stakes testing. While pursuing common goals with all participating teachers, we make modifications to meet the needs of teachers depending on (a) teacher grade level (i.e., third, fourth, and fifth grades), (b) years of participation in the intervention (i.e., from one through four years of participation), and (c) cross-grade collaboration.

First, the workshops are designed around the science topics addressed in the three curriculum units unique to each grade. These workshops provide opportunities for teachers from the same grade level to share ideas. Some workshops are grade and school specific while other workshops include same grade teachers from multiple schools.

Second, the specific emphases differ over the years of participation in the intervention. During a teacher's first-year of participation, the focus of professional development is on familiarizing the teachers with the science content, hands-on activities, common student misconceptions, and potential learning difficulties in each lesson. As the teachers continue their participation in subsequent years, they receive differentiated professional development to promote further professional growth in science instruction, integration of science with English language development, and use of mathematics as a support area for science instruction. At selected times during workshops, however, both new and returning teachers from a given grade level engage in common activities, with the returning teachers mentoring the new teachers, sharing the successes and failures they encountered while implementing the project in previous years and providing advice on specific topics and activities.

Third, we make special efforts to promote cross-grade collaboration within project schools. Teachers tell us repeatedly that cross-grade collaboration is critically important, both to learn from lower grade teachers regarding the prior knowledge and skills that students should bring to their classrooms and to hear from higher grade teachers about what weaknesses they see that need to be better addressed in their grades. Teachers also tell us, however, that there are no structures in place at their school sites to support such cross-grade collaboration. Thus, we try to provide periodic opportunities for such collaboration in the context of the workshops. For example, all of the teachers come together for the final day of the 3-day summer workshops (returning teachers come only for this one day). School and district administrators are invited to attend cross-grade collaboration sessions. A summary of teacher participation over the course of their four-year involvement in the intervention is presented in Table 1.

Table 1

Teacher Workshop Plans

	Year 1 Participation	Years 2 and 3 Participation	Year 4 Participation
Grade 3	Five full-day workshops including three-day summer workshops	Three full-day workshops including one-day summer workshop	No workshops (to test sustainability)
Grade 4	Six full-day workshops including three-day summer workshops	Four full-day workshops including one-day summer workshop	No workshops (to test sustainability)
Grade 5	Seven full-day workshops including three-day summer workshops	Five full-day workshops including one-day summer workshop	No workshops (to test sustainability)

Note: Teachers attend one more full-day workshop around the end of the school year, and this workshop is designated primarily for various data collection activities.

Science. As with the curriculum, workshops highlight three aspects of science instruction: (a) inquiry-based science, (b) conceptual understanding, and (c) student reasoning. Inquiry-based science is the primary goal of science teaching and learning in our intervention. While engaging in inquiry tasks in the curriculum units at each grade level, teachers discuss conventions of science inquiry, including control of variables, multiple trials, and accuracy of measurement. Project personnel present inquiry tasks outside the curriculum, and engage teachers in discussion of experimental designs, procedures for gathering data, multiple ways of displaying the data, and conclusions based on data and evidence. Additionally, teachers discuss how to promote student initiative in conducting inquiry, as they gradually reduce their level of guidance. They discuss the notion of the teacher-explicit to student-initiated continuum in providing instructional scaffolding to promote science inquiry. Effective inquiry instruction requires a balance of teacher guidance and student initiative, as teachers make the decisions about when and how to foster student responsibility. Teachers discuss how to move away from teacher-explicit instruction and encourage students to take the initiative and assume responsibility for their own learning.

As teachers engage in science inquiry, they discuss science concepts and big ideas from the major science topics presented in the curriculum, connect science concepts to one another, and apply science concepts to explain natural phenomena or real world situations. Particularly, the workshops highlight students' common misconceptions and learning difficulties.

Scientific reasoning is emphasized throughout the workshops. Teachers bring students' work samples and discuss student reasoning of science concepts or skills. Project personnel present samples of students' reasoning about designing an experiment, and engage teachers in analyzing students' capabilities and difficulties. Project personnel regularly present the results from our current research on students' reasoning about measurement tasks, energy transformations, and the changing seasons, in both school and home environments. These presentations highlight students' cultural and linguistic experiences from their home environments that could serve as intellectual resources for learning school science, as well as their difficulties with concepts and skills.

English language and literacy. To complement and reinforce the curriculum, professional development workshops focus on two primary aspects of English language development in science instruction: (a) literacy (reading and writing) strategies for all students, and (b) language learning strategies specific to the needs of ESOL students.

Project personnel present and make use of various strategies for developing literacy (reading and writing) skills for all students. We believe that science learning and literacy development reinforce each other in a reciprocal process. Therefore, we discuss various literacy strategies embedded in the curriculum and how teachers can reinforce these strategies in their instruction. For example, we consider the importance of activating prior knowledge through advance organizers, and using reading comprehension strategies for engaging students in expository science texts. We highlight multiple language functions (e.g., explain, compare, contrast, report) in relation to science process skills, multiple genres of writing (narrative, expository), and multiple forms of representation (oral, written, graphic). Teachers discuss and practice the use of science trade books, writing prompts, and graphic organizers (e.g., Venn diagrams, concept maps) as aides to developing scientific language.

Moving beyond language development for all students, the workshops also focus on how to provide linguistic scaffolding that specifically addresses the language comprehension needs of

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

The workshops also discuss the use of language support strategies to enhance understanding of academic content and to develop English language proficiency for ELL students. These include the use realia (demonstration of real objects or events), frequent use of hands-on inquiry, and the use of multiple modes of communication and representation through non-verbal (gestural), oral, graphic, and written formats. We discuss the value of introducing key vocabulary in the beginning of lessons, encouraging students to practice the vocabulary in a variety of contexts (e.g., introduce, write, repeat, highlight), and promoting precision in describing and explaining objects and events. For example, we give explicit attention to positional words (e.g., above, below, inside, outside), comparative terms (e.g., cold, colder, coldest), and affixes (e.g., /in-/ in "increase" or "inflate" as opposed to /de-/ in "decrease" or "deflate").

Mathematics. Consistent with the focus in our curriculum, the workshops highlight three aspects of mathematics in supporting science instruction: (a) conventions of measurement, (b) conventions of recording and displaying data, and (c) various mathematics concepts and skills in the context of science inquiry.

All teachers engage in basic measurement tasks, including the determination of length, weight, volume, temperature, and time, using both metric and traditional systems of measurement. They also practice conventions for measurement instruments. Teachers discuss various aspects of measurement, as described earlier.

Teachers learn conventions for recording and displaying data using graphs, charts, and tables. They discuss when and how to use bar or line graphs. They discuss how to place the independent variable on the x-axis and the dependent variable on the y-axis, as well as how to display categorical variables (e.g., colors) and continuous variables (e.g., time). They also discuss how to label graphs.

The workshops highlight how mathematics concepts and skills are fundamental to engaging in science inquiry. Teachers discuss accuracy in measurement and sources of measurement error. They also discuss recording and display of data using multiple representational formats (e.g., graphs, charts, tables, drawings). Using the data from multiple trials or small groups in class, the teachers discuss analysis and interpretation of data, such as central tendency (e.g., means) and patterns and anomalies (e.g., outliers).

Contextual issues of urban schooling. Two of the primary ways that we use the professional development workshops to help teachers consider the issues of urban schooling involve the consideration of students' home language and home culture. We find that many of our participating teachers, despite being from culturally and linguistically diverse backgrounds themselves, tend to hold primarily deficit views of their students' knowledge and abilities. Thus, our focus on students' home language and culture is meant to draw attention to the funds of knowledge that the students bring to the classroom as well as the challenges and academic gaps that the teachers tend to focus on.

With ELL students, teachers need to understand how to use students' home language in science instruction as well as the importance of doing so. The workshops emphasize ways that teachers can use science vocabulary in students' home language (provided in the curriculum in three languages—English, Spanish, and Haitian Creole), and the importance of allowing ELL students to collaborate on lessons in whatever language(s) they are most comfortable. We discuss the benefits as well as the challenges of encouraging bilingual students to assist less English proficient peers and allowing ELL students to write about science ideas or experiments in their home language.

In addition to the consideration of home language, we work with teachers to better understand students' cultural experiences in relation to science. One of our approaches is to present the results from our current research on third grade students' reasoning about various measurement tasks and fourth grade students' reasoning about forms of energy in both school and home environments (and we will do the same with fifth grade students' reasoning about the changing seasons). We use these examples to highlight the funds of knowledge about measurement and energy in students' home environments that can serve as building blocks for learning school science. Based on these presentations, teachers discuss how their students make sense of home experiences and how they can use these home connections to promote student learning. The workshops highlight how teachers incorporate the ways students' cultural experiences may influence science learning as well as culturally-based ways students communicate and interact in their home and community. For example, teachers should use a variety of group formations, so that students learn to work independently as well as collaboratively. We also encourage teachers to learn more about students' lives at home and in the community through allowing students to share cultural artifacts, culturally relevant examples, and community resources.

Contextual issues of high-stakes testing. Finally, we work with teachers to understand both the requirements of the state's new high-stakes test in science, and how best to prepare their students for this test. The messages the teachers are receiving in their schools are largely that the best way to prepare for the test is to repeatedly drill students with test items. One of the primary goals of our professional development is to convince the teachers that by teaching a rigorous, inquiry-based science curriculum, their students will be better prepared to succeed on the test than if they spend their instructional time practicing test items.

The state science content standards are emphasized as a backbone of the workshops. Project personnel describe how the curriculum units from grades 3 through 5 align to the state science content standards. For each curriculum unit at each workshop, project personnel demonstrate how the unit corresponds to specific science benchmarks. Teachers are introduced to the state-defined content clusters, including those benchmarks that are assessed annually as well as those assessed every three years. Teachers become familiar with the benchmark clarifications for those standards that are assessed at grade 5. We also ensure that teachers become aware of assessment item formats and the probable impacts of high-stakes science test results on school grades according to the state's accountability system. Especially, project personnel help teachers recognize how students' science inquiry and reasoning abilities can enhance performance on statewide science assessment. For example, teachers complete a science test comprised of state-released FCAT practice items and discuss their reasoning about their test responses and ways to best prepare their students for the sorts of problem solving needed to succeed on the test. Most teachers come to the conclusion that hands-on, inquiry science is essential for their students to grasp the ideas that are tested in a deep enough way to be able to apply that knowledge to the test.

Conclusions

As our nation's schools become increasingly culturally and linguistically diverse, there is a growing awareness that today's teachers need a broader array of knowledge, skills, and dispositions to provide equitable learning opportunities for all students. However, limited progress has been made in addressing the professional development needs of teachers to better prepare them to succeed in today's culturally and linguistically diverse classrooms. There are several reasons for these shortcomings in professional development, which are magnified in large urban school districts where the greatest degree of cultural and linguistic diversity is concentrated. First, professional development tends to be "strategy-focused" and rarely attempts to conceptualize or implement in a systemic way the multiple challenges of promoting classroom practices that are both equitable and rigorous.

Second, even when professional development efforts address multiple classroom challenges simultaneously, an awareness of the complexity of issues of diversity does not necessarily translate into a workable model of professional development. Such a model must consider a range of factors, including (1) the need for elementary teachers to address both academic content and literacy objectives, often with significant numbers of ELL students (Bryan & Atwater, 2002; Rodriguez & Kitchen, 2005), (2) the context of urban schools with limited resources and high student and teacher mobility (Spillane et al., 2001), and (3) the role of high-stakes testing and accountability with its attendant constraints on how teachers are asked to spend their instructional time (Abedi, 2004; McNeil, 2000). For professional development to be both comprehensive and self-sustaining, it must be convincing to both teachers and administrators in terms of how it addresses each of these challenges. This is especially true for professional development efforts in urban schools, where racial/ethnic minorities, ELL students, and students from low SES backgrounds can highlight the woes of educational inequity.

In our own work, we have tried to integrate and infuse an awareness of these challenges into both our curriculum materials and our teacher professional development. In considering the issue of how elementary teachers can address both content and literacy objectives with ELL students, we embedded a range of language and literacy development strategies, some targeting the English language development needs of all students and others focusing specifically on the needs of ELL students. These strategies were integrated in the curriculum and were then made explicit as topics of our professional development. On the issue of urban schools with limited resources and high student and teacher mobility, we addressed the resource issue by providing the necessary materials and supplies (student workbooks, teachers' guides, and all necessary hands-on supplies). To address teacher mobility, we created a differentiated professional development model for new and returning teachers. To address student mobility, we created a final fifth grade curriculum unit synthesizing the main ideas from the third and fourth grade curriculum. Finally, in terms of the role of high-stakes testing and accountability, we developed our curriculum to be closely aligned with the state benchmarks that serve as the basis for the state science assessment. We then went about the business of persuading both teachers and administrators that engaging in a hands-on, inquiry-based curriculum aligned with the state benchmarks was a better way to prepare students to succeed on the assessment than either textbook or test-preparation driven instruction.

Despite early indications that our efforts are meeting with some success in terms of student achievement (Author, in press), we continue to contend with questions about our project's potential for long-term success and sustainability. Do teachers learn to fully realize the intensions of our intervention, moving beyond viewing our curriculum as a script to be followed and applying reform-oriented practices? Given the multiple challenges we have outlined, how can we create the conditions whereby teachers sustain a content-rich and reform-oriented approach to science teaching with ELL students once they exit the intervention?

Acknowledging that these lingering questions remain open, we believe that the lessons we have learned so far have something to offer to other professional development efforts in similar contexts. First, our work contributes to an understanding of how to work at the intersection of science education, the education of ELL students, teacher professional development, and educational policy. Better understanding the relative influences of each of these features may provide insights about how to assist elementary teachers in enabling ELL students to learn science, while meeting the demands of high-stakes testing and accountability. Beyond increased student achievement in science, our work may also have implications for scaling up professional development with non-volunteer teachers at inner-city schools. Finally, our results may help others consider how curriculum materials and professional development must be harnessed to work together in the service of promoting more equitable learning opportunities for all students in the current high-stakes testing environment.

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