Teacher Professional Development to Improve the Science and Literacy Achievement of English Language Learners

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Abstract

This paper describes the results of a teacher professional development intervention aimed at enabling teachers to promote science and literacy achievement for culturally and linguistically diverse elementary students. This paper has two objectives: (a) to examine teachers' initial beliefs and practices about teaching English language and literacy in science and (b) to examine the impact of the intervention on teachers' beliefs and practices. The research involved 53 third- and fourth-grade teachers at six elementary schools in a large school district with a highly diverse student population. The results of these first-year professional development efforts, which form part of a 3-year longitudinal design, indicate that at the end of the year, teachers expressed more elaborate and coherent conceptions of literacy in science instruction. In addition, they provided more effective linguistic scaffolding in an effort to enhance students' understanding of science concepts. The results also suggest that teachers require continuing support in the form of professional development activities in order to implement and maintain reform-oriented practices that promote the science and literacy achievement of culturally and linguistically diverse students.

Introduction

The role of teachers in ensuring that all students achieve high academic standards is becoming increasingly complex as a result of the growing diversity of the U.S. student population (National Center for Education Statistics [NCES], 1999a). Teachers of English language learners (ELLs) face several challenges, not the least of which is facilitating students' simultaneous acquisition of academic content and English language and literacy (August & Hakuta, 1997; Chamot & O'Malley, 1994; García, 1999). General English for Speakers of Other Languages (ESOL) training for teachers may not include the content-specific instructional strategies required to effectively deliver challenging academic work alongside the goal of learning English (García, 1999). It takes time and extensive support for teachers to develop a complex set of beliefs and practices that will enable them to assist ELLs in attaining challenging academic standards while developing English language and literacy (García, 1999; McLaughlin, Shepard, & O'Day, 1995).

This study is part of a larger research project examining the process and impact of an instructional intervention centered on promoting achievement and equity in science and literacy for culturally and linguistically diverse elementary students. This study focuses specifically on the English language and literacy domain with an emphasis on the integration of three domains: (a) scientific understanding, inquiry, and discourse; (b) English language and literacy; and (c) students' home language and culture. The purpose of the study is to (a) examine teachers' initial beliefs and practices about incorporating English language and literacy into science instruction and (b) evaluate the impact of teacher professional development workshops on teachers' beliefs and practices over the school year.

As part of a 3-year, longitudinal professional development intervention, this paper reports the results of the first year of implementation. The results will describe teachers' initial beliefs and practices, the extent of change in teachers' beliefs and practices following their first year of participation in the research, and the strengths and weaknesses of the intervention with respect to our professional development goals, primary of which was to assist teachers in promoting the science achievement and literacy development of ELLs. Given that this study involved all third- and fourth-grade teachers within the six participating schools, rather than a self-selected group of volunteer participants, the results have implications for large-scale implementation (i.e., scaling up) of the intervention with non-volunteer teachers through schoolwide initiatives.

Literature Review

English language and literacy development is integral to content-area instruction with ELLs (Lee & Fradd, 1998). English-language proficiency involves learning to read and write in English. It also involves learning conventions of literacy, such as vocabulary, syntax, spelling, and punctuation in social and academic contexts (Stoddart, Pinal, Latzke, & Canaday, 2002). With respect to specific content areas, proficiency in academic English includes knowledge of various genres and registers representing a number of disciplines (García, 1999; Schleppegrell & Achugar, 2003). In science, academic language features and functions include formulating hypotheses, designing investigations, collecting and interpreting data, drawing conclusions, and communicating results (Chamot & O'Malley, 1994; National Research Council [NRC], 2000). Additionally, science employs non-technical terms that have meanings unique to scientific contexts (e.g., matter, force, energy, space).

ELLs frequently confront the demands of science learning through the vehicle of a yet-unmastered language. In academic genres and registers, such as those related to science, language is interpreted and expressed in fundamentally different ways from the commonsense understandings embedded in informal everyday language. Coding knowledge according to particular academic genres and registers presents difficulties for many students because it includes much more than just knowledge of grammatical structures and lexicons and requires ways of knowing, reasoning, and communicating specific to academic disciplines (Lemke, 1990). Without the support of bilingual education programs, ELLs who lack requisite literacy development in English often encounter academic learning difficulties that preclude them from effectively participating in science learning (Cullison, 1995; Lee & Fradd, 1996). This results in academic progress that is considerably behind that of their native English-speaking counterparts (NCES, 2000).

Content-area instruction provides a meaningful context for English language and literacy development, while language processes provide the medium for understanding academic content (Casteel & Isom, 1994; Lee & Fradd, 1996; Stoddart et al., 2002). In science instruction, hands-on and inquiry-based science instruction provides opportunities for students to develop scientific understanding and engage in inquiry practices more actively than traditional textbook-based instruction. However, science supplies are not always available in elementary schools, particularly in inner-city schools with limited funding and resources (Hewson, Kahle, Scantlebury, & Davis, 2001; Spillane, Diamond, Walker, Halverson, & Jita, 2001). Yet, research studies suggest that students attending these schools (most of whom come from non-mainstream backgrounds, including ELLs) can benefit greatly from hands-on and inquiry-based science instruction for a number of reasons: (a) Hands-on activities are less dependent on formal mastery of the language of instruction and, thus, reduce the linguistic burden on ELLs; (b) collaborative, small-group work provides structured opportunities for developing English proficiency in the context of authentic communication about science knowledge; and (c) hands-on activities based on natural phenomena are more accessible to students with limited science experience than is decontextualized textbook knowledge (Lee, 2002; Lee & Fradd, 1998; Rosebery, Warren, & Conant, 1992).

By engaging in science inquiry with other students, ELLs may develop not only their English grammar and vocabulary, but also their familiarity with the genres and registers appropriate for different academic activities, tasks, and contexts. Furthermore, science inquiry instruction bridges authentic, communicative language activities and hands-on, contextualized exploration of natural phenomena (Baker & Saul, 1994; Casteel & Isom, 1994). Science instruction in the context of hands-on inquiry can serve as a catalyst to promote students' communication of their understanding in a variety of formats, including written, oral, gestural, and graphic (Lee & Fradd, 1998).

However, the majority of teachers instructing ELLs are unprepared to integrate English language and literacy with content-area instruction or have only a rudimentary understanding of this integration (Baker & Saul, 1994; Stoddart et al., 2002). Some teachers assume that English language learning must precede content-area instruction (Collier, 1989; Cummins, 1981), although this approach almost inevitably leads to ELLs falling behind their English-speaking peers (August & Hakuta, 1997; García, 1999). Others who attempt to integrate these two areas encounter obstacles (Rollnick, 2000), such as contending with the tension between access to English and access to meaning (Adler, 1995, 1998), the uncertainty related to the use of code switching as a learning and teaching resource (Setati, 1998; Setati & Adler, 2000), and the complexities of academic language that result in difficulties in transitioning from informal, exploratory discourse to discipline-specific discourse (Setati, Adler, Reed, & Bapoo, 2002).

Professional development seeks to improve teachers' skills, thereby enhancing teacher quality. Although current research outlines principles of effective professional development, the majority of these endeavors focus on subject-matter content, such as science, and how children learn this content (Garet, Porter, Desimone, Birman, & Yoon, 2001; Kennedy, 1998; Loucks-Horsley, Hewson, Love, & Stiles, 1998). At the elementary school level, research efforts that simultaneously link literacy and science instruction are limited. Recent science education research with mainstream students has focused on the intersection of students' science knowledge and literacy development. Craven, Hogan, and Henry (2001) described a workshop for teachers aimed at encouraging them to consider how reading, writing, and science are linked and promoting students' writing in science. Some researchers have stressed the importance of reading during science lessons and have suggested guidelines on teaching approaches that promote scientific literacy (Staples & Heselden, 2001). Still others have highlighted the importance of examining the language used in science texts and have developed instructional units (e.g., water cycle) that integrate literacy and science (Varelas, Pappas, Barry, & O'Neill, 2001).

Research that provides an understanding of literacy and science with ELLs has begun to emerge in recent years (Lee & Fradd, 1998; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Intervention studies that seek to integrate inquiry-based science, language, and literacy instruction with ELLs have shown promise for enhancing teachers' understanding of science and literacy integration (Stoddart et al., 2002), for developing appropriate instructional materials that integrate science and literacy while accounting for students' diverse languages and cultures (Fradd, Lee, Sutman, & Saxton, 2002), and for improving student achievement in science and literacy (Amaral, Garrison, & Klentschy, 2002; Fradd et al., 2002).

The literature suggests a need for professional development approaches that integrate students' linguistic and cultural diversity with subject-area instruction (Fradd & Lee, 1999; Gee, 1997; NCES, 1999b). This study seeks to contribute to the emerging literature on instructional interventions, specifically targeted toward ELLs, that promote English language and literacy in the context of content-area instruction, such as science. As part of a larger research project, this present study is an exploratory attempt to test such an approach based on conceptual grounding of key constructs and elaboration of instruments to measure teachers' beliefs and practices with regard to promoting the science achievement and literacy development of ELLs. Specifically, the research questions for this study are:

1. What are teachers' initial beliefs and practices related to teaching English language and literacy as a part of science to ELLs?
2. What is the impact of the instructional intervention on teachers' beliefs and practices related to teaching English language and literacy as a part of science to ELLs over the course of the school year?

Methodology

Background of the Study

The research was conducted at six elementary schools in a large urban school district in the Southeast. During the 2001–2002 school year, the ethnic makeup of students in the district included 57% Hispanic, 30% Black non-Hispanic (including 7.4% Haitian), 11% White non-Hispanic, and 2% Asian American and Native American students. Districtwide, 70% of elementary students participated in free or reduced lunch programs, and 25% were designated limited English proficient. The state implements programs in ESOL, which focus on the acquisition of English language without bilingual education. The availability of content-area instruction (e.g., math and science) to teach ELLs in their home languages is limited. Additionally, classroom instruction in Grades 3 through 5 is primarily comprised of activities to prepare students for high-stakes, statewide assessments in reading, writing, and mathematics, particularly during the months immediately preceding the testing. Beginning in the 2002–2003 school year, statewide assessment in science was also administered at the fifth-grade level, although it will not count toward school accountability until the 2004–2005 school year.

Participants

The six participating elementary schools mirrored the diversity of the school district in terms of demographic makeup. Each school varied with regard to students' ethnic and linguistic backgrounds, socioeconomic status, English proficiency, and mobility rates. A summary of key features of the schools is presented in Table 1.

The present study involved fifty-three third- and fourth-grade teachers at six elementary schools (fifth grade was added during the 2002–2003 school year). A total of about 1,500 students (750 per grade) participated, with the class size ranging from 25 to 35 students. All but two of the fifty-three teachers were female. Twenty-two reported English as their native language, eighteen reported Spanish, six reported both English and Spanish, one teacher reported Haitian Creole, and seven teachers did not respond to this item. Twenty-five identified themselves as Hispanic, eleven as White non-Hispanic, eleven as Black non-Hispanic (including one teacher of Haitian descent and one from the Bahamas), one as Asian/multiracial, and five chose not to report ethnicity. The majority (thirty-seven) were ESOL certified (either through college coursework or district professional development), and half had master's degrees. Their teaching experience ranged from 1 to 34 years (mean years of teaching was 12.3 years). Notably, participating teachers were not selected for their interest in "teaching science for diversity." This suggests that their preparation, beliefs, and practices may be more representative of teachers in general than might be the case with a self-selected group of volunteer teachers with a unique interest in science and/or diversity issues.

The type and amount of science instruction in which teachers engaged prior to the intervention varied considerably from teacher to teacher. While many teachers reported utilizing school-adopted science texts to guide their instruction, others reported teaching science very little, if at all. Among those teachers who reported teaching science minimally prior to the intervention, a fear of teaching science due to lack of knowledge or dislike for the subject area and the pressure to emphasize reading, writing, and mathematics in preparation for statewide assessments were cited as the principal reasons for their reluctance to teach science.

As part of the intervention, teachers taught two instructional units at each grade level (described below). On average, instruction took place 2 hours a week. Some teachers integrated science as part of their language arts or mathematics instruction. All teachers were provided with complete sets of curricular materials, including teachers' guides, student booklets, and science supplies (including trade books related to the science topics in the units). Despite a hiatus in science instruction from January through mid-March in preparation for the statewide assessments in reading, writing, and mathematics, the majority of teachers completed instruction of their respective units by the end of the school year.

Table 1

Key Features of Schools

	School 1	**School 2**	**School 3**	**School 4**	**School 5**	**School 6**
Percentage Hispanic	92	87	11	25	25	33
Percentage Black non-Hispanic	2	1	87	69	16	34
Percentage White non-Hispanic	5	10	<1	3	55	32
Percentage Asian/Indian/ multiracial	<1	2	1	2	4	1
Percentage free/reduced lunch	85	44	99	95	19	16
Percentage limited English proficient	47	19	26	46	10	1
Percentage student mobility	28	17	43	38	18	4
Total students	1,478	1,239	740	678	727	380

Note. The ethnicity category system is one used by the school district. While they are problematic in several ways—for example, the lumping together of Haitian immigrant and African American students as "Black"—these ethnicity categories are included here simply to characterize the participating schools in broad terms. More detailed demographic data was collected on the third- and fourth-grade students participating in the study.

Intervention for Professional Development

The professional development intervention occurred through the provision of science curricular materials (Fradd et al., 2002) and teacher workshops. Curricular materials and workshops were designed to complement one another.

Development of curricular materials

For the purposes of this study, two instructional units each were developed for Grade 3 (measurement and matter) and Grade 4 (water cycle and weather). These topics follow the scope and sequence of instruction from basic skills and concepts (measurement, matter) to variable global systems (water cycle, weather). Except for the water cycle unit (which is shorter than the others), each unit is designed to be implemented over 2 to 3 months, assuming 2 hours of instruction per week.

As part of our ongoing research since 1995, the four units have undergone an iterative process of revision and refinement (Fradd et al., 2002) and have continued to be used in this research. The curriculum development team was made up of scientists, science educators, bilingual and ESOL educators, and district administrators in science and mathematics. Moreover, a key feature was the involvement of experienced elementary teachers from our previous research who contributed to the development and ongoing revision of the units. Based on their experience and understanding of the overall research goals, these teachers provided insights about the linguistic and cultural experiences of ELLs, the instructional appropriateness and adequacy of the science content for elementary students, and the feasibility of implementation in elementary classrooms.

The units promote standards-based, inquiry-based science learning following the national standards in science (American Association for the Advancement of Science, 1989, 1993; NRC, 1996). In addition, consistent with the project goal of promoting ELLs' science learning, students' linguistic and cultural experiences in relation to science were taken into consideration when the team developed the units (see Fradd et al., 2002).

Also included in the units are instructional strategies and activities to foster students' literacy skills, including those that encourage reading and writing and provide linguistic scaffolding to enhance students' understanding of science topics (International Reading Association and the National Council of Teachers of English, 1994). For example, each lesson opens with a narrative vignette to activate students' prior knowledge on the science topic; specific comprehension questions about inquiry activities are central to each lesson; recording data and reporting results in multiple formats, including oral, written, and graphic (such as in data tables, graphs, drawings, and prose), is encouraged; strategies to enhance comprehension of expository text about science information at the end of each lesson are provided; a variety of language functions (e.g., describe, explain, report, draw a conclusion) are used in the context of science inquiry (Casteel & Isom, 1994); and trade books and suggested literacy activities related to the science concepts under investigation are included.

In addition to general literacy development in English, the units emphasize strategies to address the needs of ELLs by providing explicit guidance on promoting English proficiency (Teachers of English to Speakers of Other Languages, 1997). For example, each lesson begins with an introduction on key vocabulary, and students practice the vocabulary in a variety of contexts to enhance their understanding throughout the lesson and over the course of the unit. Explicit attention is given to particular words to support precision in describing and explaining objects and events, such as positional words (e.g., above, below, inside, outside), comparative terms (e.g., cold, colder, coldest), and affixes (e.g., *in* for increase or inflate as opposed to *de* in decrease or deflate). The units also utilize activities and tasks that promote meaningful engagement and authentic communication through the use of hands-on materials, cooperative groups, narrative vignettes, and expository texts related to everyday experiences.

Teacher workshops

There were four full-day workshops on regular school days over the course of the year. Workshops focused on how to guide students to engage in science inquiry and how to integrate English language and literacy in science instruction. Teachers attended separate workshops in order to address specific issues pertaining to the instructional units for their respective grade levels. To promote cross-grade collaboration, third- and fourth-grade teachers met together at the last workshop.

As part of an initial professional development effort within a longitudinal design, workshops were designed to familiarize teachers with the purpose and objectives of the research and help them gain experience in implementing instructional activities and strategies with their students. Project personnel with expertise in science, literacy, ESOL and bilingual, and linguistic and cultural issues in education coordinated the workshops. Several teachers who had participated in our previous research (and continued their participation in the current research) took an active role in demonstrating how the instructional units could be implemented in diverse classroom settings. Workshop activities were structured to encourage active teacher involvement, sharing of questions and suggestions, and teacher reflection on their beliefs and practices. It should be noted that more detail is given below for the second workshop than the other workshops because the focus of this paper is literacy, which was addressed specifically during the second workshop.

The first workshop focused particularly on how to promote inquiry-based science (NRC, 1996, 2000). Building on the first workshop, the second focused on incorporating English language and literacy into specific science lessons. Although broader views of literacy include many linguistic features that go beyond those typically associated with reading and writing, this research adopted a narrower view focusing on comprehension and production of written (English) texts and graphic representations of scientific information. After project personnel gave an overview of the project's goals for making literacy a part of science instruction, the discussion focused on how science inquiry and literacy development reinforce each other in a reciprocal process (Casteel & Isom, 1994). Project personnel and teachers discussed various strategies for developing reading and writing skills. Examples suggested during the discussion included having students write a paragraph describing a scientific process, having them write a narrative story based on a science-related concept, and having them engage in whole-group, small-group, or individual reading related to science instruction. Project personnel also shared trade books relevant to the science topics for enhancing reading and writing skills.

Project personnel and teachers discussed how they might provide effective linguistic scaffolding, with teachers adjusting the level and mode of their communication (verbal, gestural, written, graphic) to enhance students' understanding of science. Linguistic scaffolding is particularly important with ELLs who may be functioning at varying levels of English proficiency. Project personnel and teachers discussed features of the instructional units that promote English proficiency of ELLs in the context of science learning (see the description of instructional units above). Several continuing teachers from our previous research shared literacy activities that they had developed or used in the context of science instruction with their students.

Then, small groups of teachers worked on lessons from the second unit for their grade level, focusing on ways to incorporate literacy activities and ESOL strategies into science instruction, while also making lesson activities more inquiry based, open ended, and student centered. During small-group presentations, teachers demonstrated literacy activities, showed how to incorporate ESOL strategies in the context of teaching the lesson, and engaged in whole-group discussion.

The third workshop focused on the role of students' home languages and cultures in science instruction. At the final, end-of-year workshop with both third- and fourth-grade teachers together, they shared feedback on the content and design of the instructional units, their experiences with classroom implementation of the units, their perceptions of student progress, and their changing thoughts about how to incorporate English language and literacy in science instruction, while accounting for students' home languages and cultures.

Data Collection

Multiple sources of teacher data were collected in this study, including focus group interviews, self-report pre- and post-questionnaires, and classroom observations of science instruction.

Focus Group Interviews

The interview protocol was developed based on our previous research (see Lee & Fradd, in press), existing instruments, and relevant literature. Literacy-related interview items examined teachers' conceptions of the goal of literacy instruction and ways to promote literacy in the context of science instruction:

1. What is your goal for literacy instruction?
    a. What does "literacy" mean to you?
    b. What are the most important literacy skills that you are trying to teach?
    c. What do you do to promote students' writing? Reading?
2. How do you promote literacy in science instruction?
    a. What is the role of literacy in science instruction?
    b. Give an example of how you promote literacy as part of science instruction.

Focus group interviews were conducted by project personnel during the workshops in the beginning and again at the end of the school year (a total of 20 interviews). Interviews lasted from 45 minutes to an hour, and were audiotaped and then transcribed.

Questionnaire

In addition to items to obtain demographic data about teachers' biographical and professional backgrounds, the questionnaire included three items about literacy activities in science instruction: (a) integrating reading in science instruction, (b) integrating writing in science instruction, and (c) integrating appropriate (English) grammar in science instruction. The questionnaire measured teachers' perceptions (i.e., what teachers thought they knew), and not their actual knowledge or practices. Using a 5-point Likert rating, teachers were asked to rate their own knowledge about, and the importance of, each item (1 = very low, 2 = low, 3 = average, 4 = high, 5 = very high). The questionnaire was administered during the initial workshops and again at the end-of-the-year workshop.

Classroom Observations

The observation scales were designed to assess teachers' instructional practice, as opposed to teachers' beliefs or perceptions measured through the focus group interviews and the questionnaire. They served as a guide for constructing narrative field notes as well as for rating the teaching practices observed. For the domain Literacy in Science Instruction, the classroom observation guideline included three scales, with each scale producing a 5-point Likert rating score: (a) Reading and Writing in the Context of Science, (b) Linguistic Scaffolding to Enhance Science Meaning (this was not included in the questionnaire), and (c) Conventions of Language and Literacy (which was used as a guide for classroom descriptions but was not numerically rated):

1. Reading and Writing in the Context of Science—To what extent does the teacher promote literacy (reading and writing) activities in the science lesson?
2. Linguistic Scaffolding to Enhance Science Meaning—To what extent does the teacher tailor his or her communication (verbal, gestural, written, graphic) to enhance students' understanding of science?
3. Conventions of Language and Literacy—To what extent does the teacher monitor students' use of grammatical and graphic conventions to enhance students' use of standard English (oral and written)?

These observation scales produce numeric indicators of the instructional environments that students' experience, based on observers' judgments about both teachers' instructional practice and students' learning behaviors. Each observation scale uses a 5-point Likert rating system based on two criteria: (a) the intensity with which something (e.g., linguistic scaffolding) is taking place and (b) the number of students who are engaged in doing that thing. As a general rule, the five ratings indicate the following: no activity pertinent to the observation scale in question (Rating 1); minimal intensity, limited to the teacher or to a few students (Rating 2); greater and/or uneven intensity, comprising some students (Rating 3); substantial and intense, comprising many to most students (Rating 4); and very intense, comprising most to all students (Rating 5).

Prior to conducting the fall 2001 observations, seven project team members participated in training to establish reliability across observers. After watching a videotape of an elementary science lesson using one of the instructional units from our previous research, the observers submitted their ratings to obtain reliability estimates, followed by discussion of the individual ratings and justifications. This process was then repeated with two other videotaped lessons. Inter-rater reliability estimates for single raters were $r = 0.74$, $r = 0.84$, and $r = 0.60$ for each of the three videotaped lessons. The same training procedure was conducted again using one videotaped lesson among the seven observers prior to spring 2002 observations, and the inter-rater reliability estimate for single raters was $r = 0.81$.

Over the course of the school year, a single observer visited each teacher twice (one visit for each unit taught). In general, individual observers visited the same teachers in spring 2002 as they had in fall 2001. The observation rating process was not standardized or controlled, inasmuch as different teachers were observed teaching different lessons. Each observation produced narrative field notes and numeric ratings along with justifications. Observations took about 45 minutes to 1 hour.

Data Analysis

Data were analyzed using a mixed-method approach. Quantitative analyses were applied to pre- and post-questionnaire and observation data to assess changes in teachers' reported beliefs and their actual practices. Qualitative analysis of pre- and post–focus group interview data was employed to complement statistical data and to better understand teachers' conceptions of how literacy could be incorporated into science instruction.

Quantitative Analysis

From the 53 participating teachers, 47 pre-questionnaires and 52 post-questionnaires were collected. Out of 53 teachers, one pair of teachers team-taught in an inclusion class, and another pair taught collaboratively in a bilingual class setting, thereby reducing the pool of available classrooms for observation to 51. Of these, 40 underwent observation in fall 2001 and 47 in spring 2002. Classroom observation data were analyzed using both quantitative and qualitative methods, although this paper presents only the quantitative results.

There was considerable missing data, particularly with regard to classroom observations, due to difficulties in scheduling classroom visits with some teachers and the fact that several teachers were on maternity leave during either the fall or the spring semester. Recent simulation studies suggest that multiple imputation and maximum likelihood estimation are far superior (i.e., produce less bias and greater power) to traditional missing-data-handling methods (Enders & Bandalos, 2001; Graham & Schafer, 1999; Schafer & Graham, 2002). Thus, missing data on the teacher questionnaires were handled via multiple imputation, and classroom observation statistics were estimated using maximum likelihood (see Schafer & Olsen, 1998, for an accessible overview of multiple imputation and Schafer & Graham, 2002, for an overview of general missing-data issues).

The changes in teacher responses between the pre- and post-questionnaires were analyzed using dependent *t* tests and Cohen's *d* effect sizes. Similarly, the changes in observation ratings between fall 2001 and spring 2002 were analyzed using dependent *t* tests and Cohen's *d* effect sizes.

Qualitative Analysis

Focus group interviews were conducted with 47 teachers at the beginning of the school year and 52 at the end of the school year. Qualitative analysis of the interview data proceeded with initial descriptive codes being assigned to teachers' responses. Related codes were then grouped according to categories and common themes (Bogdan & Biklen, 2003). Illustrative quotations representing each theme and subtheme are highlighted in the results section.

Results

Presented in this paper are both the quantitative and qualitative results from multiple data sources with teachers, including focus group interviews, pre- and post-questionnaires, and classroom observations. Results are based on: (a) qualitative analysis of focus group interviews prior to and after instruction, (b) statistical analysis of teachers' self-ratings on the pre- and post-questionnaires, and (c) statistical analysis of observation-based ratings of instructional practices in fall 2001 and spring 2002. Results are presented in terms of teachers' initial beliefs and practices, followed by change in teacher beliefs and practices following the intervention. Synthesis of the findings and implications for teacher practice will be provided in the discussion section.

Teachers' Beliefs

Several key themes related to teachers' goals for literacy instruction and the extent to which teachers integrated literacy in science were revealed. In response to the question, "What is your goal for literacy instruction?" teachers cited "reading comprehension" most prominently on both the pre- and post-interviews. Responses included, "[Students] need to know how to read, and understand what they're reading," "literacy is being able to understand, to interpret, and comprehend," and more directly, "literacy is comprehension." Secondly, in both pre- and post-interviews, teachers commented on the goal of literacy as having students "read on grade level." Responses reflecting this theme included, "to make everybody literate at their grade level," "the ideal situation is to bring them to their grade level," and "reading on your grade level." Third in terms of importance was the theme, "all literacy skills." Responses substantiating this theme included, " reading, writing, listening, and speaking," "reading, writing, listening, all of those skills together," and "to me it's basically communication—you communicate through reading, you communicate through writing, you communicate when you talk, and literacy is all of those." Again, these three themes figured extensively during both pre- and post–focus group interviews.

In response to the question, "How do you promote literacy in science instruction?" teacher responses on the pre–focus group interviews suggested that teachers chiefly incorporated literacy during science by "integrating science related stories" and "using trade books with science themes" to spark student interest. Also prominent, but to a lesser degree, was the response that teachers had students "write in response to science activities," such as having students "write about the steps of an experiment," "write conclusions and results of an experiment," and engage in "science journaling."

In response to the same question during the post–focus group interviews, teachers' responses reflected a broader conceptualization of literacy in science instruction. Whereas their responses on the pre-interviews were generally surface level (limited to basic, literal reading and writing during science instruction), teacher responses during post–focus group interviews were not only more varied and greater in number, but were also more integrated with science and other curricular areas. Similar to their responses during the pre-focus group interviews, teachers commented on incorporating trade books and other science-related literature in instruction, as well as on having students "write to explain" science activities.

However, during the post-interviews, teachers also related various other ways of integrating literacy in science instruction. First, literacy was incorporated in more cognitively enriching and demanding ways. For example, teachers related having "students write to explain scientific phenomena," using "questioning for discussion," and using "higher order questions" to which students responded both orally and in writing. Second, literacy was contextualized within the broader scope of science instruction. Teachers discussed how they "create science vocabulary activities," "do graphing activities," have students "write up science fair projects," and "write biographies of famous scientists." Third, literacy was emphasized in terms of gathering scientific information through various sources, including library research, the Internet, videos, newspapers, and magazines. Finally, literacy was related to other content areas and was useful, for example, in identifying key science vocabulary in other content areas, and in using poems and other literary devices to teach science terms or concepts.

Teachers' awareness of integrating literacy and science during focus group interviews was consistent with their questionnaire responses. At the beginning of the school year, teachers emphasized the importance of integrating reading and writing (M = 4.58, SD = .50) and grammar (M = 4.51, SD = .66) in science instruction. Also high (though slightly less so) were teachers' perceptions of their own knowledge of how to integrate reading and writing (M = 4.24, SD = .81) and grammar in science instruction (M = 4.16, SD = .90) (see Table 2).

Significance tests of mean scores between fall 2001 and spring 2002 indicated a statistically significant increase in the importance that teachers ascribed to integrating reading and writing in science instruction after their participation in the research (fall M = 4.58, SD = .50; spring M = 4.74, SD = .48); analysis yielded a small effect size (d = .21). Teachers' self-reported knowledge levels and the importance they assigned to integrating grammar in science instruction did not show a statistically significant change (see Table 2).

Table 2

Teachers' Beliefs: Significance Tests between Fall 2001 and Spring 2002

Construct	**Teachers' reports of:**	**Fall**		**Spring**		***t***	***p***	**Cohen's d (effect size)**	***d*** [a] **(magnitude)**
		M	*SD*	*M*	*SD*				
Reading & writing	Importance	4.58	.50	4.74	.48	1.54	.14	.21	small
	Knowledge	4.24	.81	4.16	.67	-.58	.58	.08	less than small
Conventions	Importance	4.51	.66	4.56	.69	.45	.66	.06	less than small
	Knowledge	4.16	.90	4.10	.74	-.44	.67	.06	less than small

[a] $d > .20$ is "small" effect size; $d > .50$ is "medium"; and $d > .80$ is "large."

Instructional Practices

The two constructs for the Literacy in Science Instruction domain included: (a) Reading and Writing in the Context of Science and (b) Linguistic Scaffolding, wherein teachers adjusted their level and mode of communication (written, graphic, verbal, and gestural) to enhance students' understanding of science. The means of observation ratings for these two constructs during fall 2001 and spring 2002 are presented in Table 3. In addition, the relative frequencies for observation ratings for the two constructs are presented in Table 4.

Table 3

Instructional Practices: Significance Tests between Fall 2001 and Spring 2002

Construct	**Fall**		**Spring**		***t***	***p***	**Cohen's *d* (effect size)**	***d*** [a] **(magnitude)**
	M	*SD*	*M*	*SD*				
Reading & Writing	2.57	1.17	2.47	1.12	-.60	.55	.08	less than small
Linguistic Scaffolding	3.23	1.01	3.52	0.86	2.02	.05	.29	small

Note. The classroom observation guideline includes an additional scale, Conventions of Language and Literacy. This scale is used for annotations of classroom events, but not rated given that more explicit correction is not always better.

[a] $d > .20$ is "small" effect size; $d > .50$ is "medium"; and $d > .80$ is "large."

Table 4

Instructional Practices: Frequencies of Likert Scale Ratings in Fall 2001 and Spring 2002

	Fall ratings (Percentages)					**Spring ratings (Percentages)**				
Construct	1	2	3	4	5	1	2	3	4	5
Reading & Writing	5.0	47.5	35.0	10.0	2.5	8.5	48.9	29.8	12.8	0
Linguistic Scaffolding	2.5	17.5	42.5	22.5	15.0	2.1	10.6	29.8	48.9	8.5

In fall 2001, the mean of observation ratings for Reading and Writing in the Context of Science Instruction was 2.57 (*SD* = 1.17) (see Table 3). Teachers often implemented one or more of the literacy (reading and writing) activities that were already included in the instructional materials. Some teachers made substantial connections between the literacy activity and the science concept under exploration (35% of all observations were rated a score of 3; see Table 4), while others did not make such connections (47.5% were rated a score of 2). In one classroom, a teacher included multiple literacy activities beyond those provided as part of the lesson and made substantial connections between science and literacy (2.5% were rated a score of 5). In a few classrooms, no literacy activities were observed in the context of the science lesson (5% were rated a score of 1).

The mean of observation ratings for Linguistic Scaffolding was 3.23 (*SD* = 1.01). In most of the observed lessons, there was at least one significant activity or event in which the teacher communicated at and slightly above students' level of linguistic competence, either with small groups of students or with the whole class (42.5% were rated a score of 3). Some teachers recognized the diversity of students' levels of English-language proficiency, appropriately structured activities to reduce the language load required for participation, used language appropriate to students' levels of communicative competence, and provided linguistic scaffolding to build students' understanding and discourse skills. In several classrooms, teachers used a variety of communicative modalities (written, graphic, verbal, and gestural) to provide scaffolding for students throughout the lesson, and students were observed to provide linguistic scaffolding for their peers (15% were rated a score of 5). In contrast, in one observed lesson, the teacher's level of communication was either too high or too low, or was not varied to accommodate students with different levels of proficiency (2.5% were rated a score of 1).

Significance tests of mean ratings between fall 2001 and spring 2002 indicated that there was a statistically significant positive change for the construct Linguistic Scaffolding (fall $M = 3.23$, $SD = 1.01$; spring $M = 3.52$, $SD = .86$); analysis yielded a small effect size ($d = .29$). No statistically significant change was found for the Reading and Writing construct (see Table 3).

Discussion

As evidenced by their responses on the pre-questionnaire at the beginning of the school year, most teachers strongly emphasized the importance of promoting literacy in science instruction and expressed a high level of knowledge about how to do so. As was highlighted in the previous section, teachers' comments during the focus group interviews suggested that elementary education generally focuses on more basic skills, including reading and writing. Based on their responses on both the pre- and post-questionnaires and during the focus group interviews, the teachers by and large felt confident about their instructional practices in literacy. Teachers' particular emphasis on English language and literacy development with ELLs may be a function of their teaching in a state that implements the English-only policy and holds schools accountable on statewide, high-stakes assessments in literacy.

Based on analysis of the teacher questionnaire responses, teachers placed greater emphasis on the importance of reading and writing in science instruction at the end of the school year (following the intervention) than they had at the beginning. In addition, compared to their generally surface-level conceptions of reading and writing in science during pre–focus group interviews, teachers expressed a broader and more integrated conceptualization of literacy in science during post–focus group interviews. Moreover, based on analysis of teacher instructional practices, teachers provided linguistic scaffolding to enhance scientific understanding more effectively during spring 2002. The statistically significant positive change reported at the end of the results section is testimony to this. However, in spite of this, teachers did not express that they became more knowledgeable about or skilled at fostering literacy on the post-questionnaire. This may be because increased knowledge about literacy resulting from professional development created in teachers an awareness of the need for improvement in a domain in which they formerly felt relatively confident. That is, the more they learned about the importance of making literacy a part of school science, the less assured they may have felt about their skills to incorporate it adequately into their science instruction. As opposed to leaving teachers feeling better equipped to integrate literacy and science, professional development may have served primarily to make them aware of the limits of their knowledge.

Conclusions and Implications

The results of this study contribute to the emerging literature on professional development for teachers of culturally and linguistically diverse learners. Professional development activities that focus on the intersection between specific content areas and student diversity are essential but demanding. Elementary teachers require extensive support to expand both their subject-matter knowledge and knowledge of content-specific teaching strategies so that their students are able to develop a deep understanding of science, conduct scientific inquiry, and engage in scientific discourse (Garet et al., 2001; Kennedy, 1998). In addition, they need assistance to help ELLs and other students with limited literacy to become English proficient within the context of science instruction (Baker & Saul, 1994; Casteel & Isom, 1994; Lee & Fradd, 1998; Stoddart et al., 2002). Such integration enables these students to learn science through hands-on and inquiry-based activities, while they also develop both literacy skills and English proficiency through authentic and communicative language activities.

This study involved the first year of an intervention that has been implemented as part of a larger research effort. Our results offer insights for professional development endeavors. Although teachers expressed more elaborate and coherent conceptions of literacy in science and provided more effective linguistic scaffolding in the spring as compared to the fall, they require continuing support to actually implement reform-oriented practices. Our first-year implementation of professional development efforts centered on communicating the purpose of the project with teachers and providing them with guidance on how to teach the science lessons. Further professional development efforts will involve helping teachers develop deep understandings of science content and knowledge of content-specific teaching strategies (Garet et al., 2001; Kennedy, 1998).

Further professional development endeavors may involve more intensive efforts to help teachers promote English language and literacy with students, who have varying levels of English proficiency and limited literacy development, as part of science instruction. For example, these endeavors might include helping teachers develop a repertoire of reading comprehension strategies to assist their students in interpreting informational texts in science (Guthrie, Schafer, Von Secker, & Alban, 2000). Other efforts could include demonstrating to teachers how they can help students develop writing skills in the context of explaining scientific phenomena (García, Bravo, Dickey, Chun, & Sun-Iminger, 2002) and develop other conventions of written English in reporting scientific data. Additionally, efforts could include helping teachers provide different kinds of scaffolding (verbal, gestural, written, graphic) to enhance students' understanding of science.

The large-scale nature of the intervention complicates our professional development efforts. Schoolwide professional development allows teachers to develop common goals, share instructional materials, and exchange ideas and experiences (Garet et al., 2001; Kennedy, 1998). On the other hand, schoolwide implementation inevitably includes teachers who are not interested in or who even resist participation, unlike programs comprised of volunteer teachers seeking opportunities for professional growth (Blumenfeld, Fishman, Krajcik, & Marx, 2000; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, in press; Supovitz & Zeif, 2000). Additionally, the intensity of professional development activities may be compromised due to limits on the number of days teachers may be out of their classrooms, the difficulty of finding large numbers of substitute teachers, the pressure to prepare for high-stakes assessments, or other such constraints. In our research, these challenges were magnified by state policies, such as the English-only policy toward ELLs (and the corresponding lack of institutional concern for maintenance or development of students' home languages) and high-stakes assessments and accountability. These challenges are even more formidable in inner-city schools, where teaching staff is unstable, teacher attrition is high, and consequences of failing in the accountability system are serious (Hewson et al., 2001; Spillane et al., 2001). The impact of this “integrated” intervention on teachers’ beliefs and practices should be considered in the context of limited professional development opportunities and current educational policies.

The results of the study suggest areas for further research. The instrument development aspect of this study makes contributions but has limitations as well. As part of our larger project, instruments to measure teachers’ beliefs (questionnaires and interview protocols) and practices (the classroom observation guideline) in the domains of science, literacy, and students’ home language and culture were developed. Since literacy is only one of the three domains under examination as part of our larger project, it may not be realistic to expect to account for the totality of variables comprising the literacy domain, in addition to the many variables making up the science and home language and culture domains. As a result, the literacy constructs measured in this study might reflect an oversimplification of this research area. In addition, these constructs require further operationalization, such that they may be measured comparably using multiple data sources. Further refinement with respect to the conceptualization and operationalization of literacy in the context of science may be continued in future research.

Our larger project employs a longitudinal research design to examine the long-term impact of the intervention on teachers’ beliefs and practices. The longitudinal design will allow us to explore the extent to which teachers are able to generate and sustain new ideas for effective practices and what kinds of professional development efforts are required to produce teacher change (Franke, Carpenter, Levi, & Fennema, 2001; Richardson & Placier, 2001). Eventually, it will be important to examine the impact of professional development on student learning and achievement, as well as the relationship between teacher change and student achievement (Cohen & Hill, 2000; Kennedy, 1998).

This study analyzed the data and reported the results for the entire sample of teachers. Disaggregation of data will provide insights about specific groups of teachers or students. For example, future research may examine beliefs and practices between teachers who share the language of their students and those who do not. Further research may also investigate teacher data in terms of students’ ethnicity, home language, socioeconomic status, and English-language proficiency. Although our continued research can provide initial insights, studies to examine such questions will require larger numbers of teachers and students to enable disaggregation of data by various subgroups.

A major limitation of the research is the absence of a control or comparison group to establish the causality of the intervention on change in teachers’ beliefs or practices. However, it would be difficult to select a control or comparison group using an experimental or quasi-experimental design. If there is no high-stakes assessment and accountability in science, science is sometimes taught minimally in elementary schools, particularly in inner-city schools where culturally and linguistically diverse students tend to be concentrated (Spillane et al., 2001). If the control or comparison group receives significantly less science instruction than the experimental group, this in itself, rather than the effectiveness of the intervention, could account for any observed differences in outcomes. Even when a control or comparison group can be found, it will require extensive incentives for the schools to participate when the research may not produce meaningful benefits for the control group (Slavin, 2002).

A strength of this research is the use of a longitudinal design to examine the long-term impact of the intervention. Our continued research will indicate areas in which teacher change is most pronounced, as well as those areas most resistant to change. The longitudinal design will also allow us to examine whether and how teachers are able to generate and sustain new ideas for effective practices and what kinds of professional development efforts are required to produce teacher change (Franke, Carpenter, Levi, & Fennema, 2001; Richardson & Placier, 2001). Eventually, it will be important to examine the impact of professional development on student learning and achievement, as well as the relationship between teacher change and student achievement (Cohen & Hill, 2000; Garet et al., 2001; Fishman, Marx, Best, & Tal, in press; Supovitz, 2001). All teachers should be involved in professional development opportunities in order to enable their students to achieve high academic standards. Schoolwide implementation of this research involves all third-, fourth-, and fifth-grade teachers at the six participating elementary schools. State and district policies significantly influence this research, especially as efforts to scale up the intervention continue. Such scaling up necessitates careful examination of policy influences on the intervention itself, on teachers' beliefs and practices, and on student learning. As a result, important insights for further scaling up of this intervention and others like it are possible. The findings will contribute to developing effective professional development approaches that promote the science and literacy achievement of all students, including those who are culturally and linguistically diverse.

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