Teacher Change in Beliefs and Practices in Science and Literacy Instruction with English Language Learners

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Abstract: This study examined patterns of change in beliefs and practices as elementary teachers learned to establish instructional congruence, a process of mediating academic disciplines with linguistic and cultural experiences of diverse student groups. The study focused on six bilingual Hispanic teachers working with fourth-grade, mostly Hispanic students. The results indicated that teacher learning and change occurred in different ways in the areas of science instruction, students' language and culture, English language and literacy instruction, and integration of these areas in establishing instructional congruence. The results also indicated that establishing instructional congruence was a gradual and demanding process requiring teacher reflection and insight, formal training, and extensive support and sharing. Implications for further research in promoting achievement for all students are discussed. © 2003 Wiley Periodicals, Inc. J Res Sci Teach 41: 65–93, 2004

As the U.S. student population becomes more culturally and linguistically diverse, the role of teachers in ensuring that all students achieve high academic standards is becoming increasingly demanding (National Center for Education Statistics [NCES], 1999; U.S. Department of Commerce, 1993). A challenge facing teachers of students acquiring English as a new language (English language learners; ELLs) is enabling these students to learn academic content across subject areas, as the students simultaneously acquire English language and literacy (August & Hakuta, 1997; Chamot & O'Malley, 1994; García, 1993; NCES, 1999). Even when students are declared English proficient, they may still be acquiring communication and interactional patterns of the mainstream, monolingual English-speaking peers. For this reason, we use a broad definition of ELLs whose first language, communication and interactional patterns, and prior experiences differ from the mainstream (Waggoner, 1993).

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The existing knowledge base for promoting academic achievement with ELLs is limited and fragmented. In the case of science education, although reform documents highlight "science for all" as the principle of equity and excellence (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996), they do not provide a coherent conception of equity or suggest strategies for achieving equity (Calabrese Barton, 1998; Eisenhart, Finkel, & Marion, 1996; Lee, 1999a; Rodríguez, 1997). On the other hand, the multicultural education literature emphasizes issues of cultural and linguistic diversity and equity, with little consideration of academic disciplines (Banks, 1993; Delpit, 1988; Gay, 2002; Villegas & Lucas, 2002). In addition, bilingual education and English to Speakers of Other Languages (ESOL) programs focus primarily on literacy development in the context of English language proficiency, with limited attention to subject area instruction such as science (August & Hakuta, 1997; Chamot & O'Malley, 1994; García, 1993).

A complex set of teachers' beliefs and classroom practices is required to enable ELLs to attain challenging academic standards while developing English language and literacy (McLaughlin, Shepard, & O'Day, 1995). Such teacher beliefs and classroom practices need time and extensive support to develop (Cochran-Smith & Lytle, 1999a; García, 1999; Wilson & Berne, 1999).

This study examined patterns of change in beliefs and practices in elementary teachers who shared elements of the language and culture of their students, as they learned to relate science to their students' background experiences while promoting English language and literacy development. The study addressed teacher learning and change within the framework of instructional congruence, a pedagogy that merges academic content with students' language and culture to promote high academic standards for all students (Lee & Fradd, 1998, 2001). Specifically, the study highlights the challenge in establishing instructional congruence when academic disciplines such as science are potentially incompatible with students' cultural values and practices as well as when the two areas are compatible. The study focused on six bilingual Hispanic teachers working with fourth-grade, mostly Hispanic students in inner-city classrooms. Results offer implications for further research in enabling academic achievement for all students, including ELLs.

Teacher Change in Establishing Instructional Congruence

Since the early 1990s, we have been conducting research to examine effective instruction in promoting science learning and English language and literacy development with elementary students from diverse languages and cultures, including bilingual Hispanic, bilingual Haitian, and monolingual English language groups. The initial goal was to learn how teachers, who shared elements of the language and culture of their students, incorporated these shared understandings into their instruction to promote students' achievement in science and literacy. We started the research with the construct of cultural congruence—when teachers and students share the language and culture, teachers tend to communicate and interact in culturally congruent ways that promote students' participation and engagement (Au & Kawakami, 1994; Gay, 2002; Trueba & Wright, 1992; Villegas & Lucas, 2002). Extending the literature on cultural congruence and culturally relevant pedagogy (see the summary in Osborne, 1996; Ladson-Billings, 1994, 1995), we developed the framework of instructional congruence, the process of merging academic disciplines with students' linguistic and cultural experiences to make the academic content accessible, meaningful, and relevant for all students (Lee & Fradd, 1998, 2001). This framework guided the research presented here, while the results of the research tested and refined the framework. It also served as a theoretical and practical guide for curriculum development, teacher professional development, and instructional practices.

Instructional Congruence Framework

The instructional congruence framework maintains that effective subject area instruction should combine consideration of students' cultural and linguistic experiences with attention to the specific demands of academic disciplines. Academic disciplines such as science have ways of producing and evaluating knowledge that have been defined by the Western tradition (AAAS, 1989, 1993; NRC, 1996). Students from diverse languages and cultures, on the other hand, bring to the classroom their ways of constructing knowledge in their home and community. When cultural and linguistic experiences are used as intellectual resources, students with limited science experience and those from diverse languages and cultures are capable of conducting science inquiry and appropriating science discourse (Rosebery, Warren, & Conant, 1992; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001).

However, a substantial body of literature in multicultural science education indicates that some students' home cultures include practices, forms of talk, and interactional norms that are sometimes discontinuous with modern Western science (Arellano, Barcenal, Bilbao, Castellano, Nichols, & Tippins, 2001; Atwater, 1994; Jegede & Okebukola, 1992; McKinley, Waiti, & Bell, 1992; Solano-Flores & Nelson-Barber, 2001). Such discontinuities require students to shift between different types of knowledge, practices, and discourse if they are to have access to school science without abandoning their home culture. For example, although science inquiry is a challenge for most students, it may present additional challenges in cultures that do not encourage students to engage in the practice of science inquiry by asking questions, designing and implementing investigations, and finding answers on their own. Certain cultural values and practices may dispose students to accept teachers' authority unquestioningly rather than explore or seek alternative solutions. Validity of knowledge may be evaluated according to the authority of the source rather than the validity of the content. To the degree that teachers and other adults are respected as authoritative sources of knowledge, students may be reluctant to raise questions or challenge the knowledge claims or reasoning of adults if their culture considers this to be a sign of disrespect. As a result, some students may not practice questioning and inquiry at home or at school.

The instructional congruence framework highlights the importance of developing congruence, not only between students' cultural expectations and classroom interactional norms, but also between academic disciplines and students' linguistic and cultural experiences. It emphasizes the role of instruction (or educational interventions) as teachers explore the relationship between academic disciplines and students' cultural and linguistic knowledge, and devise ways to link the two to make science accessible and meaningful for all students.

In our research, to establish instructional congruence for effective science and literacy instruction with ELLs, teachers need to integrate knowledge of (a) science disciplines, (b) students' linguistic and cultural experiences, and (c) English language and literacy. By establishing instructional congruence, teachers make science meaningful and relevant while also promoting English language and literacy for ELLs.

As part of standards-based reform aimed at high achievement and equity, the research is based on the definition of science in standards documents (AAAS, 1989, 1993; NRC, 1996; for summary, see Lee & Paik, 2000, and Raizen, 1998). Major components of science learning include: (a) science concepts and big ideas (i.e., "common themes" in AAAS, 1989, and "unifying concepts and processes" in NRC, 1996) in terms of patterns of change, systems, models, and relationships; (b) science inquiry as students ask questions, design investigations, and find answers; (c) science discourse and multiple representations using various written and oral communication forms; and (d) scientific habits of mind in terms of the values, attitudes, and worldviews in science. These four components are not linear or discrete, but related in complex and interactive ways.

Teachers also need to recognize who the students are in terms of their linguistic and cultural experiences related to science disciplines. Teachers use students' home language to enhance comprehension and understanding in social and academic contexts. Teachers also engage in culturally appropriate communication and interactional patterns and use cultural artifacts, examples, analogies, and community resources (Au & Kawakami, 1994; Gay, 2002; Trueba & Wright, 1992; Villegas & Lucas, 2002). Studies considering academic disciplines with linguistic and cultural practices are emerging in mathematics (e.g., Adler, 1995, 1998; Brenner, 1998), science (e.g., Fradd & Lee, 1999; Lee & Fradd, 1996a, 1998; Warren & Rosebery, 1996; Warren et al., 2001), literature (e.g., Lee, 2001), and social studies (e.g., McCarty, Lynch, Wallace, & Benally, 1991).

Working with ELLs, the research promotes English language and literacy development based on the standards for students learning English (International Reading Association [IRA] and the National Council of Teachers of English [NCTE], 1994) and English as a new language (Teachers of English to Speakers of Other Languages [TESOL], 1997). According to the TESOL standards, English language proficiency involves social and academic language in formal and informal settings (Cummins, 1984; Fradd & Larrinaga McGee, 1994). Social language is characterized as interpersonal and dependent on the culture of the communication, such as tone of voice, facial expressions, body movements, and turn taking. Academic language is characterized as linguistically rigorous and cognitively demanding. It is also the language of school instruction where understanding depends on knowledge of academic content and genre.

Although this article focuses on students in the process of acquiring the language, culture, and discourse of the U.S. mainstream, issues discussed here are applicable, to varying degrees, to other student groups who have also been marginalized in science education, including those from low socioeconomic status (SES) backgrounds. Indeed, the interplay of language, culture, and social class is complex. Individuals from certain cultural backgrounds share cultural values regardless of SES; yet, SES differences manifest within the same culture (e.g., Lee, 1999b). In addition, the status of non-English languages in the context of the mainstream presents further complexities (Gutiérrez et al., 2002).

Teacher Change

The emerging literature on teacher change has only recently begun to consider issues involving culturally and linguistically diverse students across subject areas (Cochran-Smith, 1995a,b; Wilson, Peterson, Ball, & Cohen, 1996). The literature on multicultural education and bilingual/ESOL instruction provides some insights about areas of uncertainty and potential contention in the process of teacher learning and change, to be discussed next.

Culturally relevant teaching may sometimes be incompatible with mainstream practices. According to the multicultural education literature, school knowledge represents the ''culture of power'' of the dominant society (Au, 1998; Banks, 1993; Delpit, 1988, 1995; Reyes, 1992). The rules of participation in school are largely implicit and tacit, thus making it difficult for students who have not learned the rules at home (Heath, 1983; Moje, Collazo, Carillo, & Marx, 2001). For students who are not from the culture of power, teachers need to provide explicit instruction about that culture's rules and norms, rather than expect students to figure out these rules on their own. For example, in discussing skills-oriented and process-oriented approaches to literacy development, Delpit (1988, 1995) and Reyes (1992) pointed out that students of African-American and Hispanic backgrounds need to learn the forms of literacy through explicit skills-oriented instruction within relevant and meaningful contexts, even though a more open-ended, process-oriented approach may predominate in the mainstream. Whereas students need explicit guidance, they also need opportunities to take initiatives, engage in explorations, and incorporate meanings they bring to the learning process. Thus, teachers are challenged to meet the learning needs of diverse students, while also preparing them to function competently in the mainstream (Delpit, 1988; Ladson-Billings, 1994, 1995).

With ELLs, English language and literacy development is integral to subject area instruction (Lee & Fradd, 1998). English language proficiency involves the conventions of literacy, such as vocabulary, syntax, spelling, and punctuation in social and academic contexts. Subject area instruction provides a meaningful context for English language and literacy development, whereas language processes provide the medium for understanding academic content (Casteel & Isom, 1994; Lee & Fradd, 1996b; Stoddart, Pinal, Latzke, & Canaday, 2002). Unfortunately, a majority of teachers are unprepared to integrate English language and literacy instruction with subject area instruction (Baker & Saul, 1994; Stoddart et al., 2002). Most teachers are unaware of integration between science and language or have only a rudimentary understanding of this integration. In addition, those who attempt to integrate the two areas face challenges in helping ELLs develop English language and literacy and learn academic concepts in a new language of instruction (Adler, 1995, 1998; Rollnick, 2000; Rollnick & Rutherford, 1996; Setati, Adler, Reed, & Bapoo, 2001).

The teacher change literature indicates three key issues which we believe are essential in establishing instructional congruence. First, change involves modifications in teachers' beliefs about academic content, children's abilities to learn academic content, the role of language and culture in instruction, and the teachers' own self-efficacy, as well as modifications in teaching practices (Clark & Peterson, 1986; Fennema et al., 1996; Franke, Fennema, & Carpenter, 1997; Guskey, 1986; Thompson, 1992). Second, change involves continuous, reflective, and generative processes, as teachers become ongoing learners (Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Richardson, 1994; Richardson & Placier, 2001; Wood, Cobb, & Yackel, 1991). In environments where teachers are encouraged to reflect on their practices in relation to student learning, they gain new insights about the instructional process. Finally, to engage in self-sustaining and generative change, teachers need to learn how to operate on principled understandings, not routines or superficial procedures (Fennema, Franke, Carpenter, & Carey, 1993; Little, 1993; Richardson & Anders, 1994; Richardson & Placier, 2001). They require access and opportunities to gain an understanding of principled ideas about teaching and to apply them across academic tasks, student groups, and classroom settings.

Purpose of the Study

Instructional congruence requires that teachers integrate academic disciplines with students' linguistic and cultural experiences to promote academic achievement. Teachers may recognize that academic disciplines, such as science, and certain cultural values and practices are sometimes incompatible. They need to develop a complex set of beliefs and practices to resolve such dilemmas and challenges, as they promote academic learning along with English language and literacy development. Instructional congruence in our research focuses specifically on science and English language and literacy for ELLs.

In this article, we present insights from six bilingual Hispanic teachers who taught fourth-grade Hispanic students in inner-city classrooms. We describe how the teachers gradually learned to incorporate their understandings of students' language and culture to promote both science learning and English language and literacy development with ELLs throughout their participation in a 3-year research project (Fradd, Lee, & Sutman, 1995–1998). We also describe patterns of change in the teachers' beliefs and practices as they learned to establish instructional congruence.

Method

Research Context and Participants

The research took place in a large urban school district in the Southeast United States. According to the school district statistics during the 1997–1998 year (the third and final year of the research), 52% of the student population was Hispanic, 33% Black non-Hispanic (including Haitian), 13% White non-Hispanic, and 2% Asian/Native American/multicultural. District-wide, 70% of elementary students were in free or reduced lunch programs, and 22% were designated as "limited English proficient" (LEP), the official term used by the state to indicate students receiving special English language and literacy instruction in ESOL programs. The state did not offer bilingual education, and all subject area instruction was carried out in English in regular classrooms.

As part of a larger research project, this study included six teachers who provided a consistent and comprehensive corpus of data over the 3-year period of research. They were recommended by their principals for excellence in teaching and commitment to their students. Teacher participation was voluntary and no compensation was given in terms of money or graduate credit. All six teachers were born in Cuba and came to the United States at various ages from infancy to adolescence. Although all were fluent in English, Spanish was their first language. The group included 1 male and 5 female teachers. Their teaching experience ranged from 3 to 12 years. All the teachers had elementary education as their initial teaching credential in the United States. During the project period, 4 were pursuing advanced degrees, including 2 in educational leadership, 1 in ESOL, and 1 in educational technology.

The six teachers worked with fourth-grade students at two elementary schools. At one school during 1997–1998, the ethnic composition was 92% Hispanic, 5% White non-Hispanic, 2% Black non-Hispanic, and 1% Asian/Native American/multicultural; 85% of the students were receiving free and reduced lunch programs; and 48% were identified as LEP. At the other school, the ethnic composition was 80% Hispanic, 18% White non-Hispanic, 1% Black non-Hispanic, and 1% Asian/Native American/multicultural; 49% were receiving free and reduced lunch programs; and 16% were identified as LEP. The first school served approximately 1500 students in Grades Kindergarten through 5, and the second school approximately 1000 students.

The students at these two schools represented variations within the Hispanic student group in the school district. At one school, many of the students were first-generation immigrants from low SES backgrounds. Many were in ESOL programs and needed instructional modifications and support in English to be able to participate in the fourth-grade curriculum. At the other school, the majority of students were born in the United States and were from low to middle SES backgrounds. During the 3 years of the research, the six teachers at the two schools taught ESOL classes, inclusion classes with students with disabilities, and regular classes.

The degree of congruence in language and culture between the teachers and their students requires explanation. For example, there would be differences between the teachers who were native to Cuba and their students who were from diverse Hispanic backgrounds including South and Central America and the Caribbean Islands. Although Spanish was the first language of all of the teachers and most of the students, there would be differences among various dialects of Spanish. Whereas differences would exist between the teachers and students given that they came from various parts of the Spanish-speaking world and immigrated at varied ages, it is expected that the teachers would be sensitive to general issues pertaining to acculturation and acquisition of English as a new language. Based on the cultural congruence literature, these shared understandings would foster the establishment of instructional congruence.

Instructional Materials

Although the initial intent of the research was to use existing instructional units, it is difficult to find materials that address science education standards (Ball & Cohen, 1996; Lynch, 2000; National Science Foundation Directorate for Education and Human Resources, 1996). Most science materials do not consider instructional needs of culturally and linguistically diverse students (Lee, 1999a; Lynch, 2000). The National Science Foundation (1998) emphasizes the importance of culturally relevant curriculum materials that recognize ‘‘cultural perspectives and contributions so that through example and instruction, the contributions of all groups to science will be understood and valued’’ (p. 29). In addition, although integration of literacy as part of subject area instruction is important for ELLs, most science materials lack a focus on English language and literacy development (Fradd, Lee, Sutman, & Saxton, 2002; Yore, Holliday, & Alverman, 1994). Thus, material development became a necessity for implementation of the research. Based on existing curriculum materials (Berkheimer, Anderson, & Blakeslee, 1988; Berkheimer, Anderson, Lee, & Blakeslee, 1988; Lee, Eichinger, Anderson, Berkheimer, & Blakeslee, 1993), the research team designed instructional units on the water cycle and weather, two key topics in the district science curriculum at fourth grade (see Fradd et al., 2002, for details). The materials development team consisted of scientists, science educators, bilingual/ESOL educators, district administrators in science and mathematics, and consultants representing the students’ languages and cultures. The teachers from this research also participated in the revision and refinement of the units based on their insights and perspectives from classroom implementation.

The units focused on three areas to be consistent with the framework of instructional congruence. First, the units emphasized science achievement based on standards documents (AAAS, 1989, 1993; NRC, 1996). The water cycle unit focused on melting, freezing, evaporation, boiling, condensation, precipitation, and the water cycle. Building on the water cycle unit, the weather unit focused on science concepts of weather, measurement of weather conditions in local settings, and the reading of newspaper weather maps. The culminating lesson in the water cycle unit and the lesson on wind in the weather unit highlighted big ideas, such that simulations of the water cycle and wind are models of natural phenomena; the water cycle and wind are systems that have subsystems; the water cycle and wind are cycles that continue over and over; and patterns of change with water (in the water cycle) or air (in wind) are caused by heating or cooling. Students learned science concepts and big ideas by engaging in science inquiry. The weather unit generally contained more complex science concepts and inquiry processes than the water cycle unit. Within each unit, earlier lessons were more structured, whereas later lessons were more open-ended to encourage student-exploratory science inquiry.

Second, the two units emphasized the importance of relating science to students’ linguistic and cultural experiences. For example, the units provided key science terms in Spanish. The units used both metric and traditional (i.e., ‘‘bilingual’’) systems of measurement to assist students who knew one system from their home country to learn the other system. The weather unit involved weather conditions, such as temperature differences or hurricane and tropical weather patterns, in various countries of students’ origin from the Caribbean Islands and Central and South America. Because most of the lessons involved supplies that were inexpensive household items, teachers encouraged students to perform science activities with their families at home. Considering cultural diversity as a resource, the two units encouraged various group formations to enable students to perform individually and independently as well as to work collaboratively in small and large groups (García, 1993).

Finally, the units emphasized English language and literacy based on the standards documents for students learning English (IRA/NCTE, 1994) and English as a second language (TESOL, 1997). The TESOL standards are not designed to stand alone, but to be used in combination with other content standards such as science (NRC, 1996). In this context, the water cycle and weather units focused on the three goals from the TESOL standards: (a) to use English to communicate in social settings, (b) to use English to achieve academically in content areas, and (c) to use English in socially and culturally appropriate ways (TESOL, 1997, p. 9). The IRA/NCTE Standards for the English Language Arts were also used to support inquiry from a literacy development perspective, viewing literacy as a set of tools to engage in science inquiry and to foster conceptual understanding (Sierra-Perry, 1996). For example, to enhance students' communication and comprehension, the units emphasized multiple representational formats in oral and written communication, such as drawings, pictures, data tables, charts, graphs, and figures.

For each unit, teachers were provided with the teachers' guide (including transparencies and supplementary materials), copies of the student book, and science supplies. Each unit was designed for 10 weeks' duration, assuming 3 hours of instruction per week.

Teacher Professional Development

The goal of professional development was to enable the teachers to teach science by using commonalities between their culture and language and their students' backgrounds. Science instruction was also intended to promote students' English language and literacy. Because the research was designed to learn from the insights and perspectives of the teachers in testing and refining the instructional congruence framework through classroom implementation, professional development was not prescriptive. Instead, the project personnel and the teachers collectively made decisions about topics and agenda. Although initially the project personnel organized the meetings, teachers gradually increased their level of involvement. Over time, collaboration between the teachers and the project personnel was established to share insights, reflections, and suggestions (Fradd et al., 1997).

Extensive opportunities for professional development were provided in multiple ways, including four full-day workshops each year, school-site meetings to address specific needs and concerns, and conversations with teachers in small groups and individually on a regular basis. After classroom observations, teachers provided their feedback and insights about the lessons.

Areas of emphasis for professional development evolved over the 3-year period. At the beginning of the research, the teachers openly expressed their lack of confidence in their own science knowledge and science instruction. In response to the teachers' request, the initial area of emphasis was science instruction. During the workshops, the teachers engaged in hands-on inquiry of the water cycle and weather, learned to explain key science concepts and big ideas, and shared teaching strategies for promoting science learning. They examined student learning based on videotapes of selected students during elicitation sessions, students' work samples, and paper and pencil tests of the two units. They discussed science standards documents (AAAS, 1989, 1993; NRC, 1996) and incorporated their insights and reflections into the ongoing revision and refinement of the two units.

As the teachers were gaining knowledge in science and science instruction, professional development started to focus on relating science to students' language and culture. We took multiple approaches: personal and general on the one hand, and conceptual and practical on the other. We started the discussion with the teachers by sharing our observations of teacher–student interaction and communication in their classroom practices. Then, we invited the teachers to reflect on their personal experiences as new arrivals in the United States acquiring English as a new language and learning the mainstream values and practices. Based on the teachers' awareness and sensitivity about issues of language and culture, we asked them to read about and discuss major conceptual issues, including cultural congruence (e.g., Au & Kawakami, 1994), instructional conversations (e.g., Rueda, Goldenberg, & Gallimore, 1992), and culturally relevant pedagogy (e.g., Delpit, 1988). Then, we asked the teachers to incorporate their understandings of students' language and culture in classroom implementation, particularly focusing on: (a) how to consider students' cultural experiences, artifacts, analogies, examples, and community resources; (b) how to consider their interactions and communication with bilingual Spanish-speaking students; and (c) how to use students' home language to promote English language and literacy development and science learning.

With many ELLs in their classrooms, the teachers emphasized English language and literacy as part of science instruction. Using the TESOL standards (1997) as a guide, they discussed strategies to promote social and academic language. For example, the teachers discussed the importance of oral communication of science activities in small and large group instruction. They also discussed how to promote written communication using multiple representational formats. A scoring rubric was developed to assess students' progress in acquiring scientific language in oral and written forms. Using this rubric based on 0–6 scoring criteria (6 being the highest), the teachers assessed students' writing samples in terms of "form" (accuracy in grammar, spelling, and general conventions of language use) and "content" (specific knowledge and understanding of science) (see Fradd & Lee, 2000, for details).

As the research progressed, the emphasis was on testing and refining the framework of instructional congruence. As the teachers related science to students' language and culture, they realized the power and impact of merging the two areas on student learning. They also realized that the areas might sometimes be potentially incompatible. Using specific examples from classroom practices, they discussed the tensions and dilemmas involved in incompatibility and the importance of enabling students to become bilingual and bicultural between science disciplines and their home language and culture.

Data Collection and Analysis

The research employed primarily qualitative methods. Based on the literature and our previous research, we developed the observation guideline and interview protocols with teachers. Multiple data sources were gathered using the instructional congruence framework.

First, the two researchers visited the classrooms once a week for every teacher during the 3-year period. We established consistency in data collection before visiting classrooms separately. We kept running records of teacher–student exchanges in two parallel columns of fieldnotes, recording teachers' communication and behavior in the left column and students' communication and behavior in the right column. In taking fieldnotes, we focused on the following aspects of the lesson: (a) student engagement in scientific understanding, inquiry, and discourse; (b) teacher–student communication and interaction in culturally congruent ways, integration of students' cultural experiences and examples in instruction, and use of students' home language to enhance understanding; and (c) student development of English language and literacy in terms of reading and writing activities in the science lesson, use of grammatical and graphic conventions to enhance students' use of standard English, and adaptations of communication (verbal, gestural, written, and graphic) to enhance understanding. After classroom observations, we obtained teachers' feedback and insights about the lessons.

Second, we conducted individual interviews at the beginning and at the completion of the research, and focus group interviews at each school site at the end of the second year. The constructs used as the guideline for classroom observations (see the paragraph above) were also used to develop interview protocols. Across all of these interviews, two common sets of questions were addressed. One set examined teachers' beliefs in the importance and their confidence in the areas of (a) science knowledge and science instruction, (b) incorporation of students' home language and culture in science instruction, and (c) English language and literacy development as part of science instruction. A comparable set of questions addressed teachers' self-reports of instructional practices in each of these three areas. For example, teachers indicated whether and how important they believed it was to consider students' linguistic and cultural experiences in science instruction, how confident they felt in doing so, and what instructional practices or strategies they used in their classrooms. The research examined teachers' beliefs in importance (i.e., value) and their confidence (i.e., self-efficacy), because their teaching practices might be related to how important they believed each area was and how confident they felt teaching it. All the interviews were tape-recorded and transcribed.

Finally, we took notes about teachers' feedback, insights, and reflections at professional development meetings. We also recorded informal conversations with teachers in small groups and individually outside the classroom settings.

The data were analyzed primarily using qualitative methods (Erickson, 1986; Miles & Huberman, 1994; Strauss & Corbin, 1990). Verbal data from the interviews and informal conversations were used to examine teachers' beliefs, whereas classroom observation data were used to examine teachers' instructional practices. In accordance with the instructional congruence framework, teachers' beliefs and practices were categorized into each of the four areas: (a) science instruction, (b) students' language and culture, (c) English language and literacy, and (d) integration of the three areas in establishing instructional congruence.

The two researchers read the data sets to identify major patterns and themes related to changes in teachers' beliefs and practices over time. For the classroom observation data, data from individual teachers were analyzed each year. In the final stage of data analysis, major patterns and themes from each teacher's data were combined into a matrix in terms of all six teachers, four areas of investigation, and 3 years of the research. Then, major patterns and themes related to changes in teachers' beliefs and practices were identified with all the six teachers over the years. Emerging patterns and themes were verified or modified as new confirming or disconfirming evidence was identified. Vignettes of classroom events that were representative of these patterns and themes were obtained. The same analytic procedures were applied to the interview data as well as notes at professional development meetings and informal conversations. Multiple data sources allowed triangulation of data to examine changes in teachers' beliefs and practices in establishing instructional congruence.

Results

The results indicate overall commonalities across the six teachers, although there were some variations. We present the results for the group of teachers, rather than develop case studies of individual teachers. We describe specific ways in which the teachers changed their beliefs and practices to meet students' learning needs in science, language and culture, English language and literacy, and integration in establishing instructional congruence. We describe the process of teacher change in the context of professional development activities.

Science Instruction

Beliefs. All of the teachers stressed the importance of science learning for their students. Initially, the teachers' responses were broad and general as they emphasized the need for science in understanding natural phenomena, in satisfying one's own curiosity, in participating in an increasingly technological society, and in preparing students for future employment.

Change occurred gradually as teachers observed that students, including ELLs, successfully learned science based on the results of classroom assessments, paper and pencil tests of all students, and elicitations of selected students. They also observed that students were interested in learning science and were excited to engage in hands-on inquiry. One teacher stated the value of science instruction with ELLs as follows:

> I feel guilty that for so long we haven't emphasized science with ESOL students. With a focus on literacy and English proficiency, we restricted their learning opportunities in science. I realize that ESOL students have learned a great deal of science, and they have also developed literacy and English proficiency as well. It amazes me how much they can learn science and how much they enjoy science.

At the completion of the research, the teachers focused on the importance of science for ELLs in school and at home. Some highlighted their students' motivation to learn science; as one said, ''Science has a strong value, especially since many of these students did not have much science before. It's important they like it and want to learn it. They are going to need science for the rest of their lives.'' Others emphasized the need to teach science in the school curriculum and to integrate science with other subject areas. One teacher said, ''Science is really important for ELLs. Science is usually placed on the bottom of the list of things to teach during the day, but it's the subject that the students get turned on to. You can also use science to teach other subjects.'' Still others highlighted the connection between school and home through science; as one teacher said, ''Because their parents don't speak English, these students are helping their parents and teaching their parents what they learn in science. The water cycle and weather are relevant topics to talk about at home. We are making an important impact on the lives of these students and their families.''

All the teachers lacked confidence in their knowledge of science and science instruction at the start. Initially, 5 of the 6 teachers expressed apprehension and dislike of science. One said, ''I didn't do well in any science subjects. I was afraid of science and math.'' Another spoke about her experience of school science:

> All I remember about science courses is science vocabulary and memorizing facts. I read the science books over and over. Once I took the test, I did not remember anything. We did not do any hands-on activities that we are doing in this project. I have this clear memory of how much I disliked science.

Most teachers said that before their participation in the research, they had relied on textbooks to teach science and had little experience with hands-on activities. For most teachers, it was their first time teaching through hands-on science. For these teachers, learning to teach science involved overcoming the lack of confidence in their knowledge of science and science instruction.

As they continued participating in the research, professional development focused on formal training of science as well as sharing of teaching experiences. They engaged in hands-on activities, gained science knowledge, discussed teaching strategies, explored alternative ways of teaching science, and applied their insights and reflections to the ongoing revision and refinement of the two instructional units. The teachers expressed confidence and appreciation of science knowledge. As one said:

> I have become more confident. I am excited like the kids. I think I enjoy science more than my kids. I can explain the weather. I went on a picnic last weekend, and I explained about humidity, clouds, rain, and the water cycle. I think about science and relate it to everyday experience, which I had never done before. It has made me a student-teacher. It's true. I am not afraid of making a mistake. Always before, I was turned off.

The teachers also became more comfortable with science instruction and felt more confident in meeting the learning needs of their students. One stated:

> It has given me a new meaning for teaching science. I have learned a lot about science, more than I can tell you. I have learned things that I never paid attention to. I also feel that I have the background knowledge to teach science. I listen to the students, build on their ideas, and encourage them to ask questions. When I did not have the knowledge, I was nervous about not being able to answer their questions. With the background knowledge, I can organize instruction to meet their needs, not my needs.

Practices. Initially, the teachers' mode of instruction focused on procedures for conducting science activities. Teachers typically spent most of a class period describing the materials and procedures of an activity, having students conduct the activity in small groups as part of whole-class instruction, and asking students to share group findings in class. The teachers did most of the talking, while asking for student answers in the form of single words or short phrases using a cloze procedure. For example, when a teacher was discussing how to cause changes in states of water, she said, "So we added . . ." and the students responded, "Heat." Thus, teachers seemed to perform science activities and cover content without monitoring or scaffolding students' understanding.

Once the teachers became familiar with science activities, they began to focus on science vocabulary and simple concepts with their students through recitation. Teachers asked students for specific answers that could be judged as correct or incorrect (e.g., "At what temperature does ice melt?") rather than asking students to give their reasoning and explanations or share ideas. Teachers guided student responses as they repeated, restated, and clarified student statements. For example, a teacher led the class to explain the water cycle as follows:

> Teacher: What can we say at the beginning, what occurred here? We started with . . .
> Class: Water.
> Teacher: Water, okay. The water . . .
> Class: Evaporated.
> Teacher: Evaporated?
> Class: Into water vapor.
> Teacher: Water vapor, then it . . .
> Class: And then, and then condensed.
> Teacher: Condensed?
> Class: Back to water.

Although instruction focused on science vocabulary and simple concepts, there was some initial development of interrelated concepts and big ideas. For example, throughout the water cycle unit, some teachers highlighted the relationships between heating/cooling and changes of states of water during melting, freezing, evaporation, and condensation. Outside the science instruction time, when the teachers and students conversed naturally during informal interactions, the teachers engaged in elaborated communication about students' understandings of science (e.g., condensation on the windows in the classroom or on the outside of a bottle of cold water). Through these informal interactions the teachers started to probe and extend students' science discourse and construct more student-centered communication.

During the third year, the teachers made connections between concepts and emphasized big ideas of patterns, systems, models, and relationships. For example, after the lessons on the water cycle and wind, the teachers helped students understand how these two phenomena were similar and different in terms of the water cycle and wind as systems, water cycle and wind simulations as models of natural phenomena, relationships between heating/cooling and patterns of change, and the continuous process in a cycle. The teachers also engaged in a new type of science discourse, as they probed students' ideas and encouraged students to elaborate, explain, or justify responses. As students came to understand science and make connections between science concepts, the students asked meaningful, substantive questions that enriched class discussion. For example, when the class was discussing how the condensation of water forms clouds in the sky or on a high mountain, a student asked why air temperature on a high mountain is colder than that on the lower ground, even though the air on a high mountain is closer to the sun.

Whereas 5 of the 6 teachers used hands-on science as a means for developing more complex understandings of science concepts and big ideas, one teacher stressed science inquiry by encouraging students to ask their own questions, design and carry out their own plans, and find their own answers. As students gained experience in science inquiry, they asked meaningful and relevant questions that led to deeper levels of inquiry. For example, students in one class conducted an experiment in small groups in which they observed that the temperature of black cloth was warmer than that of white cloth when both were left in the sun for 30 minutes. During class discussion of the results, a boy asked, ''What would happen if we compared thick white cloth and thin black cloth?'' Instead of answering the question directly, the teacher asked the class which variables they would manipulate to answer this question. After some discussion, the students identified the variables of color and thickness. The teacher led them to think about possible answers to their classmate's question, stressing that, ''The only way that you can find out is to actually do the experiment and see what happens.'' This led to the development of extension activities based on students' own questions.

Summary. To establish instructional congruence, it is critical that teachers have adequate knowledge of the subject and the ability to teach it. This may seem obvious but it is an important issue with elementary teachers who are generally unprepared to teach science. With the current efforts toward standards-based instruction, teachers need to learn new ways of teaching science to promote scientific understanding, inquiry, and discourse that differ from their own earlier socialization of school science as students. The challenge is even greater with ELLs because subject area instruction such as science tends to be ignored owing to the perceived urgency for English language and literacy development. The teachers in the research initially expressed apprehension about science and felt unprepared to teach it, despite their commitment to effective instruction. Over the years, as the teachers emphasized the importance of science for ELLs and became more confident in their knowledge of science and science instruction, they also learned to promote science learning with their students, including many ELLs.

Students' Language and Culture

Beliefs. All of the teachers stressed the importance of understanding students' prior knowledge and experiences. However, some teachers were uncertain about how students' language and culture related to a subject like science. One said, "I don't see how students' culture has anything to do with science. I don't see the connection. Science is science, and everyone learns science regardless of culture." Others were reluctant to use Spanish in science instruction because state and district policies specified English as the language of instruction in regular classroom programs. Most were uncomfortable talking about language and culture in general and, particularly, their own experiences coming to the United States and learning English as a new language.

A critical incident occurred when we asked the teachers to reflect on their personal experiences of immigration. While sharing their common experiences as new arrivals in the United States, they became more open to discussing issues of language and culture. One teacher described efforts to acculturate into the mainstream and acquire English: "I was the only Hispanic and Spanish-speaking student in my class, and I tried very hard not to look different from other kids. I remember how embarrassed I was when I pronounced like 'yellow' for Jell-O."

As the teachers described their experiences learning English and assimilating to the mainstream, they realized that they had tucked these insights away as a part of the assimilation process. This process of sharing and reflection led to affirmation of their identity. They also recognized the need to promote feelings of comfort and pride in being bilingual for their students. With this awareness, the teachers began consciously and explicitly to consider students' linguistic and cultural experiences in science instruction. One said, "Culture is very relevant to science instruction. It gives me something else to tap into, another way, a type of prior knowledge."

At the completion of the research, all the teachers were emphatic about the importance of students' language and culture in science instruction. One teacher said:

> It seems strange to say, but through these units I learned about the importance of culture in instruction. Even though I was culturally congruent with my students, I was not aware of the value of it. Now I am more conscious of its relevance and importance. When you become aware, you think about the students' backgrounds and you have an understanding of what the students bring to the class, so you know what to expand on.

While recognizing shared cultural understandings, the teachers also stressed the variations within different ethnolinguistic groups and among individual students, their own limitations in understanding such variations, and the danger of overgeneralization and stereotyping. One said:

> Think of the Hispanic culture as an umbrella with a lot of microcultures underneath. The way each country's government is organized influences the students' microcultures. Another influence is the educational levels of the parents, the parents' views, and their economic levels. All of these factors influence the culture and the understanding students bring to school. Being a part of the Hispanic umbrella, we can understand those differences. But we also have limitations in our understanding. We don't know everything about each of the microcultures.

From the beginning, the teachers expressed confidence in their understanding of their students' language and culture. Some teachers related their personal experiences to students' learning needs; as one said:

> I can relate to my students because I had a similar experience that they are going through. . . . I think my students are able to relate to me and my teaching because my native culture is their native culture. Since we belong to the same culture, I think there is a fit.

The teachers also pointed out that their shared understanding would enable them to promote student learning. One stated:

> A teacher should be aware of the students' background, culture, and be able to bring the subject matter to them so that they can understand it. It is important to know where the students are coming from, what they think about science, and what their prior experiences have been. It becomes easier when the students share the same culture. It's easier for us too, because we share the culture with them. For example, if a teacher does not understand, she would lose the ESOL students, not only because of the language but also the way she would put it across.

Practices. From the start, the teachers communicated and interacted with their students in culturally appropriate ways. For example, teachers and students engaged in multiparty, overlapping, and simultaneous talk, particularly when students were actively engaged in classroom tasks. Within academic contexts, the teachers engaged in social talk with students, made humorous comments, and expressed a sense of concern for the well-being of the students and their families. Based on shared understanding of communication and interaction, the teachers created a positive learning environment that was conducive to student participation.

Initially, the teachers did not communicate in Spanish during instruction. As they became aware of the strengths of shared understandings with their students, they began to use Spanish to promote science learning as well as English language and literacy development. Even the teachers who had been hesitant to use Spanish became convinced of the need to use both languages when they considered it to be appropriate. Teachers also used students' home experiences to promote understanding of science. For example, in discussing water vapor and steam, a teacher said, ''When your mom boils *arroz* (rice) and *frijoles* (beans), she talks about *vapor* (steam).'' In discussing humidity, another teacher said, ''When your dad talks about how the air feels in the morning after it rains, he uses words like *humedo* (damp).'' In both cases, students responded enthusiastically and showed a better understanding of the science concepts than when teachers used only English terms. By using cognates such as *vapor* and *humedo*, students were connecting cultural and linguistic resources jointly to support their learning.

The teachers used their shared cultural examples and experiences to enhance students' understanding of science. For example, in introducing a thermometer, a teacher asked the class, ''When you have a fever, what temperature does your mother look for? What number does she expect to see on the thermometer?'' Some students said 38, 39, or 40, whereas others said 98, 100, or 102. The teacher wrote down the two sets of numbers on the board. When students looked puzzled by the wide range of numbers, the teacher placed the transparency of a thermometer graphic on an overhead projector. The teacher asked the class to compare the two sets of numbers on the board with the two sides of the thermometer on the transparency. Students observed that the set of numbers 38°–40° on the Celsius side corresponded to the other set of numbers 100°–104° on the Fahrenheit side. The teacher and students recognized that the thermometer was ''bilingual, just like us'' and named it ''the bilingual thermometer.'' In this example, the teacher incorporated students' home and cultural experiences (e.g., having the temperature taken by a parent) as valuable resources in learning science. The teacher also related the students' bilingual proficiency to ''bilingual'' temperature readings. In addition, by connecting two languages with two measurement scales, the teacher introduced the big ideas of patterns (e.g., two sets of temperature readings on the two scales) and systems (e.g., two language systems and two measurement systems). Overall, the teacher helped students connect personally meaningful and culturally relevant experience with linguistic awareness.

Summary. To establish instructional congruence, teachers need to relate academic content to students' languages and cultures, so that the academic content becomes meaningful and relevant for the students. The teachers in the research, who shared elements of their students' language and culture, had intuitive and spontaneous understanding of the students' experiences. As they came to emphasize the importance of students' language and culture, they noted variations as well as commonalities between themselves and their students and among students of various Hispanic backgrounds. In teaching science, the teachers communicated and interacted with their students in culturally appropriate ways, used key science terms in Spanish, and applied cultural artifacts, examples, analogies, and community resources.

English Language and Literacy

Beliefs. From the start, all the teachers stressed the importance of literacy instruction, particularly for Hispanic students learning to read and write in English. Initially, teachers' awareness of literacy instruction was broad and general in terms of reading and writing about science content and activities (i.e., "beginning integration" according to Stoddart et al., 2002). One teacher said, "After we do the activities, we read about the science background information in the book. Then, I have the students write about the activities." The teachers did not discuss what kinds of linguistic scaffolding they provided to foster student learning or what learning outcomes they expected from students during reading and writing.

Change occurred gradually through professional development opportunities, as teachers discussed and practiced integration of English language and literacy with science instruction. They emphasized oral communication using hands-on activities because these activities offered concrete contexts for English language and literacy development as well as science learning. In the example below, a teacher described how she used a hands-on activity to help her ELLs distinguish two English terms, steam and smoke, that caused learning difficulties both conceptually and linguistically:

> Science instruction is related to literacy. For my students who aren't at the level where they can read or write in English, it is a challenge. But the hands-on activities and the vocabulary development work together. For example, as we do an activity, we talk about "steam" and they see steam, and we talk about "smoke" and they see smoke. Then, they make the connections and they understand the difference between steam and smoke.

At the completion of the research, the teachers emphasized the importance of hands-on inquiry to create meaningful contexts for both oral and written communication, as one said:

> Science is an important vehicle for literacy. When they do hands-on inquiry, it is easier to talk about the activities. That's where we can promote oral communication. When they have experienced it, it is also easier to think and write about what they did. This is where written communication comes in.

Teachers also emphasized the need to teach literacy across subject areas because the development of academic language could be fostered in subject areas. Some highlighted unique strengths of science instruction, in that students tended to be curious to learn science and hands-on inquiry could promote students' abstract thinking. One teacher said:

> In language arts, we are teaching language and literacy more explicitly. In the content areas, like science, it is more incidental. I think we should be teaching literacy more explicitly in all content areas. Literacy development is more effective in the content areas because the vocabulary and academic content promotes literacy development.

The teachers expressed confidence in their ability to teach literacy as part of science instruction. From the beginning of their participation, most teachers said they liked to teach language arts and felt confident in literacy instruction. One said, "Elementary teachers are more comfortable with language arts than other subject areas because instruction focuses heavily on reading and writing, especially for my kids."

As the teachers became more aware of the need to teach literacy as part of science instruction, they also became more confident in integrating the two. At the completion of the research, one teacher said, "Literacy has blended into science instruction. Now it is literacy instruction as much as science instruction. I catch moments to teach literacy whenever appropriate. I integrate science and literacy in ways to strengthen both areas."

Practices. In the beginning, teachers engaged students in reading about science content and writing about science activities. They did not emphasize specific aspects of literacy to promote social and academic language development in any consistent or systematic manner. Assisted by professional development activities focusing on integration of literacy as part of science instruction, they became aware of the importance of such integration and emphasized literacy explicitly and creatively. Over time, several major patterns of science and literacy integration emerged among the teachers.

First, the teachers promoted both oral and written communication as they made adaptations of literacy instruction to meet students' learning needs. Science instruction provided a meaningful context for English language and literacy development, whereas language processes provided the medium for understanding science. For example, a lesson on freezing involved an activity to observe and measure the change in volume when water turned to ice. The lesson used the terms *increase* and *decrease* to indicate the change in volume. Realizing the difficulties her ELLs had with these terms, a teacher asked the class to give other words to describe the change, and the students said "go up" and "go down." The teacher allowed the students to use both sets of words interchangeably. In another class where students were more English proficient, a teacher asked the class to give scientific words. The students responded with terms such as *expand* and *contract*. In both classes, the teachers promoted English language proficiency while assisting students in understanding science concepts.

As another example, after some discussion about humidity in the weather unit, a teacher showed paper towels to the class and asked three students to demonstrate each of three humidity conditions: dry, 50% humid, and saturated. With the teacher's assistance, one student put a few drops of water on a towel to illustrate "dry," another put water on about one half of a towel for "50% humid," and still another put water on an entire towel for "saturated." The teacher asked the class to describe the three paper towels using the terms they had just discussed. The class responded with terms such as *dry*, *a little wet*, and *rainy*. One student said, "I can explain differently. One is dry, one is damp, and one is soaked." Another said, "The soaked one is also drenched." After the teacher gave the definition of humidity in terms of the amount of water vapor in the air, she extended the discussion to conditions in which evaporation would occur more easily and conditions in which it would more likely rain. Then the teacher asked the students to form small groups and explain to each other the meaning and relevance of the new vocabulary terms they were acquiring. In this example, by promoting students' social, everyday language the teacher provided the foundation for academic language in science. The teacher also encouraged English language and literacy development in various participation formats, including individual class demonstration, whole group discussion, and small group activities and discussion.

Second, teachers helped students acquire the conventions of English language and literacy, including syntax, spelling, and punctuation, in social and academic contexts. For example, teachers asked the students to write in complete sentences using capital letters, periods, and other writing conventions correctly. In comparing two or more objects or sets of results, teachers taught comparison words including superlatives. The students discussed when to use "-er" and "-est" (e.g., "warmer" or "cooler" temperature) and when to use "more–less" and "most–least" (e.g., "more" or "less" humid). In addition, the students also learned that symbols such as plus and minus were used to graphically illustrate the concepts of more and less (e.g., with regard to rainfall).

Finally, the teachers used multiple representational formats in oral and written communication to promote both literacy and science learning. They encouraged students to discuss ideas, findings, and conclusions in large and small groups. They also encouraged students to communicate ideas through drawings, an activity that helped students make careful observations and descriptions. As students gained experience in using science discourse, teachers promoted the use of written forms of communication, particularly data tables, charts, and graphs. These mathematical representations enabled students to find patterns in data and draw conclusions. Using multiple representational formats, the teachers guided students in building comprehensive understandings of science.

In summary, to establish instructional congruence with ELLs, English language and literacy development must be integrated with subject area instruction. Yet, most teachers are unprepared to promote English language and literacy development as part of subject area instruction (Baker & Saul, 1994; Stoddart et al., 2002). The teachers in the research initially treated literacy in broad and general terms as they engaged students in reading about science content and writing about science activities. Gradually, they came to focus on specific aspects of English language and literacy in the context of science instruction. Science instruction provided a meaningful context for English language and literacy development, whereas the focus on language development enhanced understanding of science (Casteel & Isom, 1994; Lee & Fradd, 1996b; Stoddart et al., 2002).

Integration in Establishing Instructional Congruence

Beliefs. As the teachers gained knowledge of science and the notion of cultural congruence, they realized the power of incorporating students' language and culture in science instruction. As illustrated by many of the vignettes in the Results section so far, these were generally related to cultural experiences, examples, artifacts, and community resources that emerged from the environments. At the same time, the teachers realized that science disciplines and students' culture could sometimes be in conflict. Such conflicts generally involved cultural values and practices related to epistemology of science. The teachers identified three areas in which incompatibility occurred.

First, teachers noted that some cultures might not promote questioning or inquiry and that such cultural values would have an effect on student learning. One said:

> I think students' culture has a lot to do with learning science. If you are brought up in a culture where you don't ask questions, then it could be a difficulty. Many of our kids don't ask "why" questions because questioning is not an appropriate behavior at home. . . . It comes back to us, the teachers. If we encourage questioning, we can get kids asking why. Eventually, they may learn to ask and answer their own questions.

Second, they commented on the conflict between teacher authority and student autonomy. One teacher stated:

> We Latinos need structure and discipline. Most homes are big on that. We have established rules that are meant to be followed. That is good in science because science requires discipline. There are certain steps or rules to follow to get to the answer you are trying to find. On the other hand, it is not good in science because the students have to learn to be independent and not just listen to authority.

The teachers also found it difficult to relinquish control and enhance student autonomy, as one explained:

> I had to make my students understand that I didn't know everything. I think it was a cultural thing because when I told them I didn't know everything, it was a shock. . . . It's cultural for me, too. Sometimes I find myself wanting to tell them the answers because I know that's what they expect. It has taken me longer to get into inquiry where they start to ask questions and find out their own answers because it feels so unnatural. The reason it has taken long is partly me because I want to tell them and to direct them, and partly the students because they want me to tell them the questions and answers.

Finally, teachers pointed out the conflict between group collaboration and individual performance: "Science is collaboration in sharing ideas and data. My students enjoy working in groups and interacting with others. It is important that students know how to work with others. But I am also aware that they have to learn to do things independently."

Practices. Establishing instructional congruence was a gradual and demanding process. Teachers faced two major challenges: (a) articulating science disciplines with students' linguistic and cultural experiences, particularly when the two were incompatible; and (b) integrating science, students' language and culture, and English language and literacy in ways that were meaningful and relevant for their students. Even when the teachers gained knowledge in each of the three respective areas and emphasized important connections among them (as described throughout the Results section), integration required insight, reflection, and professional decisions.

Initially, teachers provided instruction in ways they perceived as culturally congruent. Major patterns included teacher-explicit instruction, whole group participation, and teacher authority and control. In guiding students through explicit instruction, the teachers orchestrated the class as a whole. Even when students worked in small groups, the teachers organized the groups as part of the entire class and encouraged collaboration and teamwork. This teacher-explicit, whole group participation seemed effective initially in ensuring that all students engaged in the tasks. Through reflection and sharing of ideas about how to establish instructional congruence, the teachers became aware that this instructional practice limited students' opportunities to take initiative, gain autonomy, and perform independently. The teachers gradually made the transition from cultural congruence to instructional congruence, as described below.

First, while maintaining control and explicitness, teachers encouraged students to take initiative. For example, in discussing temperature patterns around the world, a teacher asked the class to make some generalizations about temperatures near the equator and the poles. Students talked about the temperatures around the equator being warmer than at the poles. One student stated that temperatures on the equator were warmer than anywhere else. Another disagreed by saying, ‘‘How can you think that temperatures on the equator are always warm? I am from Quito, Ecuador. Ecuador in Spanish means ‘equator.’ I have stood on the equator because it runs right through my country. And I can tell you the temperature isn’t always warm. It’s often cool.’’ From this addition to the discussion, the teacher led the class to consider that elevation as well as latitude is an important factor influencing weather conditions. In this example, a student related the topic of the class discussion to his experience in his first language and home country. Based on the meanings he constructed, he took the initiative to ask questions and engage in debate using evidence. Then the teacher incorporated his contribution in promoting the class’ understanding of science concepts.

Second, although the teachers found it difficult to relinquish control, they promoted students’ autonomy. For example, a teacher asked the class to explain why humidity was higher in the morning than in the evening, as indicated on local newspaper weather maps for several consecutive days. In the middle of the discussion, a student said to the teacher, ‘‘Just tell us the answer.’’ The teacher responded, ‘‘You are here to figure out the answer.’’ Gradually, as students realized their responsibility in learning science, they started to ask for clarification: for example, by saying ‘‘You lost me. I don’t understand what you’re saying,’’ and ‘‘Could you help me figure this out?’’ They also started to question and challenge others’ ideas, including the teacher’s.

Finally, the teachers encouraged their students to work individually and independently, while also valuing the teamwork and collaboration that most students preferred. For example, after three students had recorded their findings about a science activity on a video to play for the class, one of the boys realized that a girl sitting nearby had not had an opportunity to participate. Taking the girl by the hand, the boy brought her to the table in front of the video camera and guided her in making a presentation from the words she had written on her paper. This was the first time the girl, who was new to the class, had spoken out loud. She seemed to enjoy watching herself on the video as the other students clapped and cheered.

Instructional congruence integrates academic disciplines and students’ language and culture. The following example illustrates how a teacher established instructional congruence by articulating science with students’ language and culture while promoting English language and literacy development with ELLs. A lesson in the weather unit presented the concept of the uneven heating of the earth’s surface. Because the lesson involved comparing temperatures, the teacher integrated language development by engaging the class to use comparative terms. The teacher compared students’ heights with terms such as *the taller of the* two and *the tallest of the three*. After stating the rule for using ‘‘-er’’ and ‘‘-est’’ with one-syllable words, the teacher asked the class to make comparisons using ‘‘warm–warmer–warmest’’ and ‘‘cold–colder–coldest.’’

Using a world map, the teacher asked the class about temperature differences among five places in the northern hemisphere (the North Pole, England, Spain, Florida, and Haiti). The teacher asked the class to compare the average temperature of Florida (where the school was located) with those of the other four places and to create a continuum from coldest to warmest. He then posed the question: ‘‘What is the pattern of temperature differences?’’ After some discussion, the students concluded that the places closer to the equator were warmer.

The teacher then extended the discussion to include South America, the birthplace of many of the students. He asked students to locate on the world map the capital cities of Colombia, Peru, Chile, Brazil, and Argentina. Students became excited when the teacher asked how many of them came from each of these countries. The teacher asked the class to create a temperature continuum from coldest to warmest among the five cities, based on students' own knowledge of having lived in these cities. After considering the pattern of temperature differences in light of this new information, the students concluded that, in general, places in the southern hemisphere also were warmer the closer they were to the equator. One student commented that he had thought places closer to the "south" (meaning the South Pole) would be warmer. Several other students also admitted similar misunderstandings.

Several students asked questions as they related the lesson to their prior knowledge and personal experiences. One said, "Colombia is close to the equator, but when I visit my grandma in Bogotá in summer, it is cool there. Why?" The teacher pointed out the color-coded areas indicating altitude on the world map, and the students realized that Colombia contains high mountainous regions. Based on this knowledge, the class discussed temperature differences at higher and lower elevations. Another student asked why another city close to the equator sometimes got cool and chilly even though it was not on a mountain. Through this discussion, students recognized that other factors such as proximity to the ocean and frontal activities also influenced temperatures.

This example highlights several important aspects of instructional congruence. The lesson began with language instruction, preparing students to understand and communicate science concepts. Organizing information along a continuum enabled students to identify a pattern of language use ("-er" and "-est" for comparisons) that corresponded to a pattern of temperature differences (coldest to warmest). By using examples from South America, the teacher adapted the lesson to build upon students' prior cultural knowledge. The teacher then used students' knowledge as a resource to help them recognize global weather patterns. As students related new knowledge to their prior knowledge and personal experiences, they came to recognize their misunderstandings and replace them with scientifically accurate representations. In addition, the teacher created a classroom atmosphere that encouraged students to raise questions about exceptions to general patterns, challenge established interpretations, and validate their understandings based on evidence. In this example, the teacher's adaptation of content to build upon students' prior cultural knowledge, combined with the establishment of discourse conventions promoting scientific inquiry, led to deeper learning than would have been possible through the simple transmission of information.

In summary, to establish instructional congruence, teachers need to integrate science, students' language and culture, and English language and literacy in ways that are meaningful and relevant for the students. As the teachers in the research reflected on elements of shared language and culture with students, they emphasized the importance of cultural congruence. They also realized that students' language and culture was sometimes incompatible with science disciplines. The teachers struggled to negotiate areas of incompatibility and bridge cultural views with science disciplines. Gradually, they embraced the notion of instructional congruence as a guide for their instructional practices.

Discussion and Implications

The research examined the process of change as teachers tried to establish instructional congruence in science and English language and literacy with their students, including many ELLs. This is an exploratory investigation of the framework of instructional congruence as it pertains to the teacher change literature.

Discussion

Whereas the student population is becoming increasingly diverse culturally and linguistically, the teaching force in the United States consists primarily of White female teachers (NCES, 1999). A majority of teachers working with ELLs believe they are not adequately prepared to meet their students' learning needs, particularly in academically demanding subjects such as science and literacy (NCES, 1999). Even those teachers who have the knowledge of science, students' language and culture, and English language and literacy may still experience difficulties integrating these areas, especially when certain cultural views may be incompatible with academic disciplines.

The increasing diversity of the student population requires integration of students' cultural and linguistic backgrounds with academic disciplines. Nevertheless, the literatures on academic disciplines and cultural differences among students and teachers have remained largely isolated from each other. The framework of instructional congruence merges discipline-specific and diversity-oriented approaches, recognizing both the compatibilities and incompatibilities between science disciplines and students' backgrounds. When teachers mediate science with students' linguistic and cultural knowledge, it helps make science accessible and meaningful for students without sacrificing scientific accuracy.

Instructional congruence in science and literacy for ELLs presents multiple challenges to teachers. In establishing instructional congruence, change in teachers' beliefs and practices occurred in different ways. Initially, all of the teachers lacked confidence in their knowledge of science and their ability to teach science; many expressed apprehension of and a dislike for science. The intervention for science instruction required formal training and extensive support. Although the teachers considered aspects of language and culture important in building rapport with their students, they initially saw little relation between students' language and culture and science learning. By encouraging teachers to reflect on their personal experiences as immigrants to the United States, the intervention led to affirmation of their own language and cultural identities. With this increased awareness as a critical incident, they emphasized cultural congruence and incorporated their understandings of language and culture in science instruction. Because of the immediate concern with science, and then language and culture, English language and literacy did not become a focus of the intervention for some time. Although literacy instruction was broad and general initially, teachers gradually came to focus on specific aspects of English language and literacy in the context of science instruction.

Integration of students' language and culture with science disciplines presented additional challenges. The teachers often incorporated students' cultural experiences, examples, and artifacts to make science accessible and relevant. At the same time, they realized tensions and dilemmas when science disciplines were sometimes incompatible with students' culture. Incompatibilities were often rooted in cultural values and practices related to epistemology of science. All six teachers tried to reconcile incompatibilities, although it was easier for some teachers or in some situations depending on teachers' beliefs about the proper balance between teacher-centered and student-centered instruction, the extent of students' prior knowledge and experience with science, and the level of cognitive difficulty of science tasks. The teachers made instructional decisions that they considered necessary and effective in meeting students' learning needs.

The results provide important contributions to the literature on teacher learning and change, particularly involving students from languages and cultures that differ from the mainstream language and culture of the United States. First, intervention led to change in both beliefs and practices (Fennema et al., 1996; Franke et al., 1997; Richardson & Anders, 1994; Richardson &

Placier, 2001). Although teachers' levels of confidence differed among the three areas, their confidence and practices within each area were generally consistent (e.g., low confidence and less effective practices) and changes in confidence and practices seemed to occur in parallel.

Second, as teachers gained insights into the notion of instructional congruence, they engaged in ‘‘practical inquiry’’ of the teaching and learning process (Richardson, 1994). Although the framework of instructional congruence offered a guide for their instruction, the teachers tested and refined the framework based on their reflections and insights from their own teaching and sharing of ideas with others. Thus, change was a reflective and generative process (Franke et al., 1998; Richardson, 1994; Wood et al., 1991).

Finally, in establishing instructional congruence, the teachers developed fundamental understandings that students' language and culture had important bearings on science learning, that the two areas were sometimes incompatible, and that English language and literacy development was part of science instruction with ELLs. Based on these understandings, the teachers implemented instruction in ways that respected students' language and culture while promoting science learning and English language and literacy development. Thus, teachers learned to operate on principled understandings, not just routines or procedures (Fennema et al., 1993; Little, 1993; Richardson & Anders, 1994; Richardson & Placier, 2001).

Implications for Further Research

This study is exploratory in examining the teacher change process within the framework of instructional congruence. It involved six elementary teachers who were born in Cuba, came to the United States at different ages, and spoke Spanish as their first language. They worked with students who were from diverse, mostly Hispanic backgrounds, including South and Central America and the Caribbean Islands, and spoke various dialects of Spanish. The teachers received instructional materials and extensive support from the research project. The characteristics of participants and the research context limit generalization of results to other settings and groups of participants.

The results suggest several areas for further research. One area involves examining specific areas of compatibility and incompatibility between science disciplines and home languages and cultures of diverse student groups. A related question involves how teachers resolve tensions and dilemmas when incompatibilities occur. Students of all backgrounds should be provided with learning opportunities to explore and construct meanings based on their own linguistic and cultural resources. At the same time, some may need more explicit guidance to recognize how their linguistic and cultural experiences might be in conflict with scientific knowledge and practices. Teachers need to be aware of students' differing needs when deciding the extent to which they provide explicit instruction or encourage students to take the initiative. Further research could examine what is involved in explicit instruction, when and how to be explicit, and how to determine appropriate scaffolding for specific tasks and students.

Although instructional congruence can be powerful as both an interpretive framework and an instructional guide, it requires that teachers have knowledge of both academic disciplines and student diversity. Students bring rich experiences and resources from their home languages and cultures that may not be easily recognized in the science classroom. This presents a major challenge to teachers who may not have the cultural knowledge necessary to identify students' learning resources (Lee & Fradd, 1998; Moje et al., 2001; Warren et al., 2001). Even teachers with the relevant cultural knowledge may not recognize it as such, or may be unsure of how to relate students' experiences to science, particularly when the incompatibilities between the two are large. In our current research, we are examining effective approaches to curriculum development

(Fradd et al., 2002) and professional development that enable teachers to articulate the relation of science disciplines with students' linguistic and cultural practices.

Another area for further research involves variations among teachers and students. This research involved teachers who shared elements of their students' language and culture but had limited knowledge of science and science instruction. Results may be different with teachers who have adequate knowledge of science and science instruction but limited understanding of students' language and culture. Valuable information can be gained by including teachers who have different levels of knowledge in science and science instruction, students' language and culture, and English language and literacy development. Similarly, variations among students need to be examined. This research involved fourth-grade, mostly Hispanic students at various levels of English language and literacy development. The process of establishing instructional congruence may be different with students from other linguistic and cultural backgrounds. Even within the same ethnolinguistic group, there may be differences owing to gender, socioeconomic status, and other factors. Careful consideration of these variations may reveal common patterns as well as differences across or within groups.

Still another area for further research involves linking teacher change with student outcomes. It is important to examine how teacher change influences students' academic achievement as well as language and cultural identities (Ladson-Billings, 1994, 1995). It is equally important to examine how student outcomes, in turn, influence teachers' beliefs and practices. In addition, it is important to examine how different kinds of teacher knowledge may be associated with different areas of student outcomes (Carpenter, Fennema, & Franke, 1996). The interplay of teacher change and student outcomes may provide the most valuable insights into effective instruction and student learning (Fradd & Lee, 2000; Fradd et al., 2002; Lee & Fradd, 2001).

The process of establishing instructional congruence in this study offers insights for promoting science and literacy achievement for ELLs. The current knowledge base in the literature is insufficient for application with teachers and students from a range of linguistic and cultural backgrounds. To improve educational practices, it is necessary to involve teachers in the development of a knowledge base. The practical knowledge of individual teachers from diverse languages and cultures can be incorporated into the development of the theoretical knowledge of teaching (Cochran-Smith & Lytle, 1999b; Ladson-Billings, 1994, 1995).

The research reported here is based on our work with six teachers who were committed to providing effective instruction for students from diverse languages and cultures, including ELLs. Based on these results, our current research involves scaling-up efforts by examining the process and impact of an instructional intervention with large numbers of teachers and students from diverse backgrounds at 12 elementary schools in 2 school districts in 2 states (Lee & García, 2000–2004). The knowledge base from our research over the past decade and relevant literature can be shared with teachers from a variety of backgrounds to promote academic achievement of all students, particularly those who have traditionally had limited opportunities in subject areas such as science.

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