CHAPTER 7

A FRAMEWORK FOR THE EFFECTIVE SCIENCE TEACHING OF ENGLISH LANGUAGE LEARNERS IN ELEMENTARY SCHOOLS

Trish Stoddart, Jorge Solis, Sara Tolbert, and Marco Bravo

ABSTRACT

This chapter presents a framework for effective science teaching for English language learners (ESTELL) based on two bodies of sociocultural research—the CREDE Five Standards for Effective Pedagogy and the integrated science, language, and literacy instruction literature—which provide converging lines of empirical evidence for a set of socially, culturally, and linguistically responsive instructional practices that have been demonstrated to improve the achievement of English language learners (ELLs). ESTELL is an instructional approach integrating the teaching of scientific inquiry, science discourse, and language and literacy development in a contextualized curriculum that is culturally, socially, and linguistically responsive. This chapter presents a review of the theoretical framework for ESTELL, empirical evidence of impact on ELLs' learning, and a set of instructional exemplars of ESTELL pedagogy.

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INTRODUCTION

The primary goal of science education reform is to improve student learning of science and make rigorous science content and high expectations accessible to all students, especially students from groups whose achievement has traditionally lagged behind that of majority culture students (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996). Despite two decades of "science for all" reforms, however, significant achievement gaps persist between Anglo European students and cultural and linguistic minority students (Lynch, 2001; Grigg, Lauko, & Brockway, 2006). Of particular concern is the rapidly growing population of students who do not speak English as a first language. By 2010, it is expected that 40% of the U.S. school-age population will be ELLs (NGA Center for Best Practices, 2000). In 2000, 68% of ELLs were concentrated in six states—California, Texas, New Mexico, New York, Florida, and Illinois—with the largest share being in California (Capps, Fix, Murray, Ost, Passel, & Hernandez, 2005). The number of ELL students, however, is growing rapidly in other parts of the country: Nevada (+354%), Nebraska (+350%), and South Carolina, South Dakota, Georgia, Alabama, Arkansas, and Oregon (+200%) (Batalova, Fix, & Murray, 2005). The under-achievement of ELLs is of increasing concern in school districts across the United States.

For at least thirty years, the achievement of ELLs has lagged behind that of native English speakers, and the gap continues to grow (Rodriguez, 2004). The 2005 National Assessment of Educational Progress (NAEP) showed an average 48-point difference in science scores between ELLs and native speakers of English: only 28% of fourth grade ELLs scored at or above the basic level in science, while more than double that number (71%) of native English speakers reached this achievement level (NAEP, 2005). The most recent statewide assessment of science knowledge on the California Standardized Testing and Reporting (STAR) exams shows that ELL students' performance was the lowest of any subgroup. In 2007, 89% of fifth grade ELLs scored as below proficient on the STAR test, while only 10% scored at the proficient level. Additionally, ELL students are significantly less likely than their Anglo European counterparts to pursue advanced degrees in science (Commission on Professionals in Science and Technology, 2007) or to perceive science as relevant to their lives outside of school (Aikenhead, 2001, 2006; Buxton, 2006; Hammond, 2001; Lee & Luykx, 2006; Lemke, 1990; Lynch, 2001; Rodriguez, 1997, 2004; Stanley & Brickhouse, 2001).

Part of the problem is that many ELLs do not have access to rigorous science instruction and often are relegated to remedial instructional programs focusing on the acquisition of basic literacy skills and facts aimed at improving student English proficiency levels instead of teaching high quality science content (Garcia, 1988, 1993; McGroaty, 1992; Moll, Amanti, Neff, & Gonzalez, 1992; Pease-Alvarez & Hakuta, 1992; Valdes, 2001). Understanding the powerful relationship between language, literacy, and science learning for ELLs is fundamental to the development of instructional programs that improve their science achievement. There is, however, currently a limited knowledge base on how to teach science to ELLs and how to prepare the teachers that serve them. (Lee & Luykx, 2004; Lynch, 2000; Stoddart, Pinal, Latzke & Canaday, 2002). Many science educators view language, literacy, and equity issues as beyond the scope of their work and assume that they will be addressed by others in the broader educational reform arena (Lee & Luykx, 2004). Language diversity and equity researchers, on the other hand, primarily attend to issues related to language development and social and cultural context and overlook the teaching of school subjects. As long as these two research agendas continue to operate independently, we cannot achieve the ultimate goal of improving science achievement for all students. There is a critical need to integrate research on the teaching of subject matter with research on student diversity (Darling-Hammond, 1996). In the context of science education, therefore, this will require developing a theoretical and practical knowledge base that integrates knowledge about the effective teaching of science content with knowledge about student language and diversity (Lee & Luykx, 2004). We find that there is much potential in such integration, as it can be mutually beneficial to both domains. As a first step, this chapter draws upon multiple sources of empirical evidence that outlines instruction proven to be effective science teaching for ELLs.

EFFECTIVE SCIENCE TEACHING FOR ELLS

The framework for the pedagogy presented in this chapter draws from sociocultural and Vygotskian theory (Bakhtin, 1981; Rogoff, 1990, 1995; Rogoff & Wertsch, 1984; Tharp, 1997; Tharp & Gallimore, 1988; Vygotsky, 1978; Wertsch, 1985, 1991). Sociocultural theory rests on the principle that learning is social activity, and that it is through the social interaction between the teacher and students and between students—more knowledgeable others—that learning occurs. Learning is enhanced when it occurs in contexts that are culturally, linguistically, and cognitively meaningful and relevant to students (Au, 1980; Deyhle & Swisher, 1997; Ladson-Billings, 1994; Lee and Fradd, 1998; Lemke, 2001; Rosebery, Warren, & Conant, 1992; Tharp & Gallimore, 1988; Warren & Rosebery, 1995). Two bodies of research, based on sociocultural theory, provide converging lines of empirical evidence for a set of socially, culturally, and linguistically responsive instructional practices that are effective in teaching science to ELLs. The first set of studies were produced by researchers from the U.S. Department of Education-funded Center for Research on Education Diversity and Excellence (CREDE) (Doherty & Pinal, 2004; Estrada & Imhoff, 2001; Hilberg, Tharp, & DeGeest, 2000; Saunders & Goldenberg, 1999; Saunders, O'Brien, Lennon & McLean, 1998; Tharp & Dalton, 2007). The second line of evidence is based on the work produced by researchers from five National Science Foundation (NSF)-funded research and development projects: Language Acquisition through Science Education in Rural Schools (LASERS); Seeds of Science, Roots of Reading; the Imperial Valley Project in Science; Science Instruction for All (SIFA); and Promoting Science among English Language Learners (P-SELL). These projects focused on integrated science, language, and literacy instruction for ELLs (Amaral, Garrison, & Klentschy, 2002; Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007; Holliday, Yore, & Alvermann, 1994; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Stoddart, 1999, 2005; Stoddart, Abrams, Gasper, & Canaday, 2000; Stoddart, Pinal, Latzke, & Canaday, 2002; Ku, Bravo, & Garcia, 2004). The authors of this chapter have integrated the findings of these two bodies of research to describe effective science teaching for ELLs.

The CREDE Five Standards for Effective Pedagogy

Researchers from CREDE identified five instructional practices, the CREDE Five Standards for Effective Teaching (CFSEP), which sociocultural theory indicated would improve the teaching and learning of cultural and language minority students and conducted a set of research studies to investigate the relationship between the CFSEP and student achievement. The CFSEP include (1) Joint Productive Activity, (2) Language and Literacy, (3) Connecting School to Students' Lives, (4) Complex Thinking, and (5) Instructional Conversation. These studies demonstrated that cultural and linguistic minority students in classrooms using the practices show significant gains in reading and mathematics achievement. In all the studies, teachers' use of the practices was recorded with the Standards Performance Continuum (Doherty, Hilberg, Pinal, & Tharp, 2002), and student achievement gains were estimated from standardized test scores (SAT-9) from two consecutive years. Teachers' overall use of the practices reliably predicted achievement gains in comprehension, language, reading, spelling, and vocabulary (Doherty et al., 2002). Students whose teachers used the practices extensively in their classroom organization showed significantly greater achievement gains on all SAT-9 tests than students whose teachers had not similarly transformed their teaching. These findings were replicated by Doherty, Hilberg, and Lee (2004). Doherty et al. (2002), in a quasi-experimental design that used a school in an adjacent catchment area as an untreated control group, showed the same patterns of vocabulary gains, exceeding a half a standard deviation in normal curve equivalent scores.

A set of studies by Estrada over a four-year period showed a positive relation between use of the CREDE practices and positive outcomes in first- and fourth-grade reading. Stronger implementation of the pedagogy produced higher student scores on tests of reading and the language of instruction. The vast majority of students in strong implementers' classrooms reached grade level in reading, whereas less than half did so in weaker implementers' classrooms (Estrada & Imhoff, 2001). Hilberg, Tharp, and DeGeest (2000) examined the efficacy of the CREDE practices in mathematics instruction. Two groups of Native American eighth grade students were randomly assigned to either CFESP or traditional conditions for a one-week unit on fractions, decimals, and percents. Students in the experimental condition outperformed controls on tests of conceptual learning at the end of the study and demonstrated better retention of unit content two weeks later.

Several highly successful and well-researched instructional models incorporate three or more CFSEP practices, including Opportunities through Language Arts (OLA), a language arts program for grades 3–5 developed by CREDE researchers in southern California (Saunders & Goldenberg, 2001); the Sheltered Instruction Observation Protocol (SIOP) program, also developed by CREDE researchers (Echevarria, Vogt, & Short, 2000); and Creating Sacred Places for Children (CSPC), a program for Native American Schools. Positive effects on student achievement have been reported and replicated for OLA (Saunders, 1999; Saunders & Goldenberg, 1999), and reported for SIOP (Echevarria et al., 2000; Echevarria, Short, & Powers, 2004).

Teachers' use of CREDE pedagogy also has been linked to factors critical to school performance, such as motivation, perceptions, attitudes, and inclusion. Predominantly Latino ELL students in classrooms where the CFSEP instructional practices were used only slightly or moderately spent more time on-task, perceived greater cohesion in their classrooms, and perceived themselves as better readers having less difficulty with their work, as compared to classrooms where the practices were not present at all (Padron & Waxman, 1999). Native American students in mathematics classes integrating the practices reported more positive attitudes toward mathematics (Hilberg et al., 2000). Findings, replicated over two years with two cohorts of students (Estrada & Imhoff, 2001, 2002), indicated that, across language programs, peer inclusion in social choices was greater in classrooms in which students participated in more peer joint productive activities (or peer collaboration).

Although the CFSEP have been shown to be effective in the teaching of reading and mathematics, they have not been articulated in science instruction. Other lines of research, however, that focus more specifically on teaching science to ELLs have identified instructional approaches that parallel those of the CREDE standards (Amaral et al., 2002; Baker & Saul, 1994; Casteel & Isom, 1994, 2005; Lee and Fradd, 1998; Lee et al., 2008; Rosebery et al., 1992; Stoddart, 1999; Ku et al., 2004). The research on science for ELLs points to the need for an integration of the teaching of scientific inquiry, science discourse, and language and literacy development in a contextualized curriculum that is culturally, socially, and linguistically responsive.

Integrated Science, Language, and Literacy Pedagogy for ELLs

The promotion of an integrated pedagogy for ELLs is particularly important because the teaching of school subjects, such as science, to ELLs is typically separated from the teaching of language and literacy (Collier, 1989; Cummins, 1981; Met, 1994). It is assumed that ELLs need to be proficient in English before being introduced to more rigorous instruction in the content areas. This is problematic because it may take as long as seven years to acquire a level of language proficiency comparable to native speakers (Collier, 1989; Cummins, 1981). ELLs fall behind academically if they do not learn the content of the curriculum as they acquire English. The amount of time it takes to acquire grade-level English proficiency, however, can be accelerated with the integration of content and language teaching for language minority students (Thomas & Collier, 2003). Research on second language immersion programs finds that contextualized, content-based instruction in students' second language can enhance the language proficiency of ELLs with no detriment to their academic learning (Cummins, 1981; Genesee, 1987; Lambert & Tucker, 1972; McKeon, 1994; Met, 1994; Swain & Lapkin, 1985). The subject matter content provides a meaningful context for the learning of language structure and functions, and the language processes provide the medium for analysis and communication of subject matter knowledge. Inquiry science, therefore, is an excellent context for learning language and literacy.

The context of language use refers to the degree to which language provides learners with meaningful cues that help them interpret the content being communicated; visual cues, concrete objects, and hands-on activities (Krashen,1985). Inquiry science instruction engages students in the exploration of scientific phenomena, and language activities are explicitly linked to objects, processes, hands-on experimentation, and naturally occurring events in the environment, that is, they are contextualized (Baker & Saul, 1994; Casteel & Isom, 1994; Lee and Fradd, 1998; Rodriguez & Bethel, 1983; Rosebery et al., 1992; Stoddart et al., 2002). Thus, learners engage in authentic communicative interactions—describing, hypothesizing, explaining, justifying, arguing, and summarizing—which promote purposeful language (Lee & Fradd, 1998; Warren, Ogonowski, Ballenger, Rosebery, & Hudicourt-Barnes, 2001). They can communicate their understanding in a variety of formats, for example, in writing, orally, by drawing, and by creating tables and graphs (Lee & Fradd, 1998). The contextualized use of language in inquiry science instruction also promotes the understanding of science concepts (Rosebery et al., 1992). An analysis of the language of science serves to understand how language structures the way science concepts are developed, organized, adapted, and communicated (Baquedano-López, Solís, & Kattan, 2005; Kaplan, 1986; Lemke, 1990; Newman & Gayton, 1964). Inquiry involves more than hands-on activities; it also involves active thinking and discourse around activities. Rosebery et al. (1992), in their work with language minority students, emphasize the role of language and discourse in content learning by using the processes of argumentation and collaborative inquiry to guide students into examining scientific claims and the nature of proof.

The relationship between science learning and language and literacy learning, therefore, is reciprocal and synergistic. Through the contextualized use of language in science inquiry, students develop and practice complex language forms and functions. Through the use of language functions such as description, explanation, and discussion in inquiry science, students enhance their conceptual understanding (Stoddart et al., 2002). This is a synergistic approach to teaching and learning in which language and literacy development is contextualized in scientific inquiry projects that promote understanding through collaborative work and discourse between teachers and students. As discussed above, this integrated pedagogy brings together instructional practices—language and literacy contextualized in inquiry science that through discourse and cooperative learning supports the development of scientific understanding—that are aligned with the CFSEP.

Over the past decade, five NSF-funded research and development projects—LASERS; Seeds of Science, Roots of Reading; the Imperial Valley Project in Science; SIFA; and P-SELL—have produced research on the relationship between the integration of science, language, and literacy instruction and ELL student achievement in science, language development, reading, and writing. These studies all have reported significant improvements in ELL science and literacy achievement as a result of the interventions.

Language Acquisition through Science Education in Rural Schools (LASERS), an NSF-funded local systemic change project with seven school districts in central California with large numbers of ELL students, used inquiry science as a context for implementing pedagogy that integrated language and literacy development into cognitively demanding science learning using an instructional approach that emphasized cooperative learning and cultural and linguistic contextualization (Stoddart 1999, 2005; Stoddart et al., 2002). In LASERS, the development of scientific understanding is promoted through the integration of contextualized science inquiry and discourse supported by the teacher through hands-on science activities and science talk. In a series of studies using both performance and standardized assessment, ELL students in LASERS classrooms showed significant achievement gains. In three consecutive summer schools, 1,200 limited English proficient students made significant gains in academic language and science concepts measured on the Woodcock Munoz standardized assessment of academic language and concept maps (Stoddart, 1999). Students also were tracked over three years in two participating school districts. Students (n = 1,300) who were in a LASERS-trained teacher's classroom for one or two years scored significantly higher on the SAT-9 in reading, language, mathematics, and science than students who were not in a LASERS-trained teacher's classroom (Stoddart, 2005).

The NSF-funded Seeds of Science, Roots of Reading project involved science educators and literacy educators in creating and testing an integrated literacy–science curriculum. Reading instruction, including texts, routines for reading, word level skills, vocabulary, and comprehension instruction, was integrated into inquiry-based science (Cervetti et al., 2007). The integrated curriculum was tested in 20 second- and third-grade classrooms over the course of either four or eight weeks against 24 comparison classrooms (12 where science was taught alone and 12 where literacy was taught alone). Students were assessed pre- and post-instruction on science understanding, science vocabulary, and reading comprehension in science. The researchers found positive outcomes for ELLs not only in the area of science knowledge, but also in literacy and vocabulary development, when measured against the comparison groups. Equivalent gains were made by ELLs on all science measures and most literacy measures in comparison to their English-speaking counterparts.

Analysis of the Science Instruction For All (SIFA) project data describes the impact of an instructional intervention designed and implemented to promote achievement of science and literacy among culturally and linguistically diverse students located in the greater San Francisco Bay Area (Baquedano-López et al., 2005; Bravo & Garcia, 2004; E. E. García & Baquedano-López, 2007; Ku, Bravo, & Garcia, 2004; Ku, Garcia, & Corkins 2005; Solís, 2005). Over the course of three years, the SIFA study implemented a curricular intervention in six schools with twenty-one teachers in third- and fourth-grade classrooms, in which each classroom received a year of literacy and science integrated instruction. The study focused on two science units at grades 3 and 4 in which science and literacy assessments were administered at the onset and at the end of the intervention. The results indicate participating students, regardless of linguistic and cultural background, experienced significant growth in their science achievement and understandings of scientific writing. The curriculum had a positive effect on the studentsí achievement and learning of science among students whose home language was either Chinese or Spanish.

The Imperial Valley Project in Science was also an NSF-funded Local Systemic Change initiative in a large school district in southern California. Working primarily with fourth- and sixth-grade students, Amaral et al. (2002) studied the effects of instruction that allowed students to conduct first-hand science investigations and keep a science journal to reflect on science activities and develop writing proficiency. The instructional focus was based on the idea that hands-on science activities establish an authentic purpose and offer increased opportunities for the development of writing skills (Holliday et al., 1994). The study led to significant gains among ELLs in both science knowledge and literacy abilities. Each subsequent year, over the four-year period in which students remained in this intervention, resulted in significant gains in science achievement. Using results from the state's science assessment, these researchers noted mean result increases for both fourth- and sixth-grade ELLs.

The P-SELL project implemented an integrated science and literacy curriculum in Florida for third-grade ELLs in urban elementary schools within an environment increasingly driven by high-stakes testing and accountability; the project examined students' science achievement at the end of the first-year implementation. The study involved 1,134 third-grade students at seven treatment schools and 966 third-grade students at eight comparison schools. Students who received the integrated science and language curriculum showed a statistically significant increase in science achievement over students in the comparison group (Lee et al., 2008). The treatment students also showed a higher score on a statewide mathematics test, particularly on the measurement strand emphasized in the intervention, than did comparison students. The NSF-funded P-SELL project also focused on integrating the teaching of science with English language development for ELLs in seven urban elementary schools in the southeast United States. Pre- and post-instruction assessment of science learning of 818 ELLs in P-SELL classrooms showed significant improvements in science understanding compared to control group students (Lee et al., 2008).

Findings from these five research and development projects all indicate that these integrated curriculum has a positive impact on the science learning and language and literacy development of ELL students.

INSTRUCTIONAL EXAMPLES OF ESTELL PEDAGOGY

In developing the framework for ESTELL, the authors drew on the practices described in the CFSEP and science, language, and literacy integration literature. Both of these approaches emphasize the importance of cultural contextualization in the effective teaching of diverse students and the importance of discourse and cooperative learning in promoting cognitive development. The ELL science literature also emphasizes the synergistic relationship between science inquiry, language and literacy learning, and the development of children's scientific understanding. The framework described in this chapter draws on both of these bodies of literature to describe Effective Science Teaching for English Language Learners (ESTELL). In an ESTELL classroom, teachers and students work together on real scientific inquiry. Activities are rich in language, with teachers developing students' capacity to speak, read, and write English and develop the special language of science. The curriculum is taught through meaningful activities that relate to the students' lives and experiences in their families and communities. Teachers challenge students to think in complex ways and to apply their learning to solving meaningful problems. Teachers and students converse: The basic teaching interaction is conversation, not lecture. A variety of activities are in progress simultaneously, including individual work; teamwork; practice and rehearsal; and mentoring in side-by-side, shoulder-to-shoulder, teacher–student work. Students have systematic opportunities to work with all other classmates.

Below, we present instructional exemplars of the integrated ESTELL practices. Each section foregrounds a specific approach—for example, language and literacy or scientific discourse—but each of these examples reveals a synergistic, integrated (not discrete "add-on") approach or strategy for instruction. The exemplars include: (1) Integrating Science, Language, and Literacy Development; (2) Engaging Students in Scientific Discourse; (3) Developing Scientific Understanding; (4) Collaborative Inquiry in Science Learning; and (5) Contextualized Science Learning.

1. Integrating Science, Language, and Literacy Development

The development of English language and literacy for ELLs involves learning to speak, comprehend, read, and write in a second language. This includes the learning of vocabulary, syntax, and lexical grammar, and the use of language and literacy for both social and academic functions. Research on second language development has emphasized the importance of the contextualized use of language (Cummins, 1981; Genesee, 1987;

Lambert & Tucker, 1972; McKeon, 1994; Met, 1994; Swain & Lapkin, 1985). Contextualization of language use refers to the degree to which language provides learners with meaningful cues that help them interpret the content being communicated: visual cues, concrete objects, and hands-on activities. In primary language development, children begin to understand utterances by relating them to sensory motor activities and the physical context (Krashen, 1985). In the development of a second language, this relationship needs to be explicitly communicated during instruction. By integrating language and literacy with the exploration of scientific phenomena, language activities are explicitly linked to objects, processes, hands-on experimentation, and naturally occurring events in the environment, that is, they are contextualized (Baker & Saul, 1994; Casteel & Isom, 1994; Lee & Fradd, 1998; Rodriguez & Bethel, 1983; Rosebery et al., 1992; Stoddart,1999). The development of science literacy is a social process and part of recognizable cultural expectations for communicating about the natural world (Roth & Lee, 2003).

ESTELL instruction around language and literacy development works to provide students with opportunities for written or verbal language expression *and* development in a contextualized science activity. Students have opportunities to collaborate with peers and the teacher, and the teacher assists students' language development by questioning, listening, rephrasing, or modeling. There is a particular focus on promoting authentic science literacy (graphing data, recording observations, reading and writing expository texts, illustrations, etc.) using science reading materials/references/illustrations for learning science; science language, including science discussion; and the systematic use of scientific vocabulary. Opportunities for literacy practices germane to science provide a context for authentic uses of literacy and increase the likelihood that students will build fluency in these literacy practices. Teachers of ELLs also use the integrated science, language, and literacy lessons as an opportunity for native language development and primary language support.

Example 1a: Integrating Science and Language Development: Life Science, Second Grade

The following example describes an elaborated implementation of the ESTELL approach. All of the ESTELL elements for the integration of science and language development are covered, including attention to authentic science literacy, oral science discourse, science vocabulary use, and the primary language support.

> Ms. D. engages the students in a discussion about bees and pollination. Ms. D. sits next to a large color drawing of a flower and a bee, and the students are seated on a rug in front of her. Ms. D. asks students to look at the picture

> and tell her what they notice about the bee. She repeats students' responses and asks them for more information. For example, one student says, "There is orange stuff on the back of his legs." Ms. D. replies, "Yes, it's a yellow-orange powdery stuff called pollen." She proceeds to tell students about a bee's role in pollination as she points to parts of the flower and bee. Students respond with questions and comments about this process. Ms. D. then tells students that they are going to write a "morning message" together about bees, pollination, and flower parts. Throughout the writing exercise, Ms. D. points out the language structure of the message as they write it; for example, pointing to the beginning of the first sentence, she asks students, "Why did I begin writing here instead of here?" A student replies, "Because it's a story," and Ms. D. says, "Yes, it's the beginning of a paragraph." The message they write describes the pollination process and the function of the various parts of flowers in this process (e.g., the colors of the petals attract bees, the stamen contains pollen, etc.). Ms. D. asks students to read the paragraph in English and Spanish, stopping to ask and answer questions as needed. Ms. D. also leads students through a game in which she asks them to identify words within the words in the "morning message" (e.g., "men" in "stamen").
>
> Ms. D. then transitions into a hands-on activity: dissecting a flower. She tells students what the goals are for the activity and models the process for them. Ms. D. places a large diagram of a flower and points to the flower parts on the diagram as she describes what she would like students to do. Students are told to create sections on their paper to place the flower parts on. Each student is given one flower, a hand lens, and paper. Ms. D. and her teaching assistant help students as they work. Ms. D's interactions with students incorporate substantial inquiry discourse; she asks students to talk about the parts they identify, asking what the function of the part is, where they would find pollen, and so forth. Ms. D. also helps students to make discoveries that extend beyond the assignment. One student, for example, finds a "baby flower" and seed, and takes them apart, and another uses her hand lens to compare the parts of her flower with a flowering plant in a corner of the room. After completing the dissection of their own flowers, placing the parts into categories, and labeling them, students take their hand lenses and examine other students' flowers. Students appear to be very engaged in the activity. After completing the primary assignment, students are seen using their hand lens to examine other students' flower parts and are heard discussing what they have found.

This teacher has developed a thorough understanding of how to design and implement an integrated science and language lesson. The design and implementation of the lesson uses a substantial amount of science inquiry and a range of language activities designed to engage students and advance their learning in science and language. The language and literacy activities are contextualized by being related to observations of pictures and examination of flowers. The lesson covers in-depth science and language content, and the implementation provides students with an opportunity to reflect on their learning. Students are provided with tools to participate in both science inquiry and writing about that inquiry. While there was an initial focus on writing a "message" that does not correspond to scientific forms of data observation and recording, the teacher related authentic science literacy tasks by having students write about their pollination observations.

Example 1b: Integrating Science and Primary Language Development: Life Science, Third Grade

The following example describes how the role of the primary language can be instrumental to maintaining student engagement during science activities that often rely on technical or new science language. The use of the primary language is important when appropriate; it facilitates the development of conceptual understanding and provides a link to the development of English as an additional language. In the following example, a third-grade classroom is involved in the examination of plant life through an experiment using seed pods. This observation takes place mid-way through implementation of a lesson. The teacher begins this observation by eliciting several types of science knowledge and observations, but principally by (1) having students review what they have learned so far in this lesson, and (2) having students make conceptual connections to observations, including making predictions of what they might observe next. The following exchange occurs after several previous student contributions.

Teacher: After they were pollinated, what changes did we see with the plants?
Student: It start . . . um, the () the () petals they start to getting long they start to () I can't–
Teacher: [points to board] Fall off?
Student: No seca . . . I don't know how to say it in Eng–
Teacher: Well, tell me in Spanish.
Student: Um, se secaron, secaron [translation: *they dried, dried*].
Teacher: Se secaron [translation: *they dried up*].
Student: Secaron [translation: *dried*].
Teacher: Muy bien, se secaron [translation: *good, they dried up*]. It dried and it fell off, right? [writes on board]
Student: Yeah. [a few students] It dried and fell off.
Teacher: OK, then we started to see a part of the plant we'd never seen before.

The student in this example is encouraged by the teacher to switch from speaking English to Spanish, which allows the student to participate in the sharing of observations about seed pods. The teacher repeatedly uses key science vocabulary while eliciting information and observations from students, including such key words as *petals, pollen/pollinate/pollination/pollinated, buds, leaves, flowers, stems, roots,* and *seeds.*

2. Engaging Students in Scientific Discourse

In addition to being a discipline, science activities are achieved through a social process where the language used for competent participation requires specialized ways of talking, writing, and thinking about the world in scientific ways (Cervetti et al., 2007). Learning and doing science is not just a process of acquiring a set of facts, principles, and procedures; it also involves using the language of science in ways of talking and representing the natural world through discourse, interaction, and collaboration. Science is a discourse about the natural world: "Biology is not plants and animals. It is language about plants and animals . . . . Astronomy is not planets and stars. It is a way of talking about planets and stars" (Postman, 1979, p. 165). Learning science and talking about science are, therefore, interrelated. The discourse of science has its own vocabulary and organization that are embodied in the ways scientists think and communicate about their work. Language mediates and structures the ways in which scientists think about and investigate problems. These processes include formulating hypotheses, proposing alternative solutions, describing, classifying, using time and spatial relations, inferring, interpreting data, predicting, generalizing, and communicating findings (Chamot & O'Malley, 1986; National Science Teachers Association, 1991). The use of these language functions is fundamental to the process of inquiry science (NRC, 1996). By engaging in scientific discourse, students learn how to think about science, how to "do" science, and, consequently, develop their own scientific understanding.

Instructional conversations (ICs) are an example of an effective instructional arrangement for teaching students through dialogue (Dalton, 1998; Tharp & Dalton, 2007). These conversations can be achieved when the teacher organizes the classroom to accommodate conversation, articulating a clear academic goal for guiding conversation, ensuring student talk is more prevalent than teacher talk, guiding all talk to incorporate students' contributions, monitoring student comprehension of their talk, and by carefully scaffolding dialogue. The goals of ICs are to lead students to develop more complex and elaborated levels of understanding of academic concepts, activities, tasks, and practices. Effective ICs are those that are responsive to a range of both student comprehension levels and the types of contributions they make. Practices in ESTELL, therefore, highlight the role of the teacher in scaffolding students within their zone of proximal development to encourage scientific reasoning and dialogue. The teacher elicits and models conversation that requires scientific reasoning to involve students in sustained discussion on science topics. The teacher elaborates, recasts, and connects student ideas and invites students to follow up on others' talk. Students have opportunities to interact with peers and the teacher, while the teacher assists students' language development by questioning, listening, rephrasing, or modeling. (Chapin, O'Connor, & Anderson, 2003; O'Connor & Michaels, 1996). Through these group discussions, students begin to examine and reformulate a range of ideas and develop more complex understandings (Baquedano-López et al., 2005).

Example 2a: Instructional Conversation: Nature of Science, Fifth Grade

Students have just completed an investigation into gravity and acceleration. Their question was, "Do balls of different weights, masses, and sizes fall at different rates?" Their results were inconsistent. The teacher leads the students in a discussion on experimental error related to the investigation.

Teacher: (to Student 1) Tell us what happened during your group's investigation.

Student 1: Well, we got different results for each trial. During two trials, all the balls fell at the same rate. During one trial, the tennis ball fell first.

Teacher: (to all students) Did anyone else experience this?

Student 2: Yes, the same thing happened in our group.

Students 3: We didn't.

Student 4: Our group found that all the balls fell at the same rate.

Teacher: Can anyone explain what might have been going on here? How is it possible that you could have gotten different results for each trial? Students 1 and 2 got different results, but Students 3 and 4 found that the balls fell at the same rate each time. What does that mean?

Student 5: Maybe they conducted the experiment wrong?

Teacher: What do you mean? How could the experiments have been conducted differently? You all have the same materials.

Student 6: Yes, but we went outside to conduct our investigation, and it was kind of hard to tell which ball was falling first. The ping pong ball was taken by the wind when we dropped it, which made it fall slightly after the other two.

Student 2: Well, it seemed like in our group we kind of expected the tennis ball to land first, so maybe we could have let that one go like half a second before the ping pong ball, you know? It's like we wanted it to win.

Teacher: So what could you do differently to eliminate these sources of experimental error next time?

The teacher in this example involves students in a scientific discussion on experimental error. His approach to questioning is such that he encourages students to respond to each other and engage each other in a discussion on the importance of precision and accuracy of measurement in a scientific investigation. He uses instructional conversation to encourage the students to reach this conclusion without giving them the answer directly.

Example 2b: Instructional Conversation: Life Science, First Grade

Students have been studying the animal kingdom and learning about the various things that animals need for survival (i.e., food, shelter, water, etc.). Today, Ms. H. is leading a discussion on the types of food animals eat to help students understand that differences among animals are related to differences in their means of survival: In this case, that the shape of animals' teeth is related to the type of food that they eat. Ms. H. gives each group two models of an animal jaw bone (one herbivore and one carnivore) and asks them to make three observations about the differences between the two jaw bones. As students work in their groups, Ms. H. walks around to each group and facilitates dialogue among the student groups, engaging each group in a thoughtful discussion of the differences in animal eating habits. As she travels from group to group, Ms. H. connects student responses, facilitates clarification of claims, and revoices student ideas. Ms. H. intervenes as a facilitator, not as a knowledge producer. Students generate science knowledge through dialogue tied to a hands-on investigation.

Lin: This guy—he likes to eat plants!
Ms. H.: Lin thinks that Model A is from an animal that eats plants. Do you agree with her?
Jon: Yea, because his teeth are more smoother.
Ms. H.: Okay, Jon says the teeth on Model A are smoother than the teeth on Model B. Is that what you are saying, Jon?
Jon: Yes, this one is smoother than that one.

In this excerpt, the teacher's role is to revoice, encourage participation, and connect student–student responses. Notice that she does not intervene to correct scientific reasoning, that is, students' use of anthropomorphic reasoning, but allows students to engage in their own sense-making dialogue to understand scientific concepts.

3. Developing Scientific Understanding

ELLs can and need to be challenged to think critically about science concepts and topics to develop higher-order understandings. Too often, ELLs are relegated to remedial instructional programs focusing on the acquisition of basic skills that supposedly match their English-proficiency level and are not engaged in intellectually challenging activities (Garcia, 1988, 1993, 1997; Moll, 1992; Valdes, 2001). ESTELL integrated language, literacy, and inquiry science practices promote the development of English language and literacy while simultaneously promoting the development of students' scientific understanding. According to Padilla, Muth, and Padilla (1991), the same problem-solving processes are used whether students are conducting science experiments or reading assigned science texts. The cognitive strategies they use in both include making inferences, drawing conclusions, making predictions, and verifying predictions. The teaching of language arts with science, therefore, engages students in the development of thinking processes as they predict, classify, and interpret (Carin & Sund, 1985). Baker (1991) has talked about this as developing metacognitive skills (e.g., formulating conclusions, analyzing critically, evaluating information, recognizing main ideas and concepts, establishing relationships, applying information to other situations). The integration of scientific inquiry with contextualized scientific discourse promotes the development of students' understanding and promotes habits of mind inherent to science work.

In ESTELL, the teacher designs activities that promote complex reasoning of science concepts by having students make judgments about the value of data and consistency of individual and collective thinking. Students have opportunities to reflect and evaluate their own and others' scientific reasoning. The teacher designs and promotes student-led inquiry by having students share and evaluate their research design, findings, and implications of their investigations, and the teacher provides feedback.

Example 3a: Developing Scientific Understanding: Physical Science, Third Grade

The following example from third grade describes a lesson on the scientific method using an activity with paper airplanes. The example scores high in promoting several ESTELL practices, including collaborative inquiry and language development. It is an exemplary case of promoting complex scientific processes and thinking through guided inquiry.

> The teacher opens the lesson by showing a six-minute video that he created that (1) describes the concepts of air pressure and lift; (2) introduces the lesson in which students will develop and test out paper airplanes; and (3) introduces the three steps of the scientific method (i.e., hypothesis, experiment, and conclusion) and describes why it was important for students to use it in this lesson. In the video, keywords are presented both orally and visually. After the video, the teacher creates a list on the board with students about the processes of scientific inquiry and what each means for their inquiry activity about flight. The teacher also explains how students should record their findings on their method worksheet, which includes sections for them to record their hypotheses, findings, and

> conclusions. Students work in small groups to discuss, design, and create three paper airplanes. When they complete their airplanes, they go into the hallway to test out each airplane twice and measure how far they flew. Students record their results and observe the flight tests of other groups. Students write down their observations on their method sheet and are asked by the teacher to, within their small groups, compare their hypotheses with their findings and generate some conclusions about why their airplanes flew those distances. Finally, students are asked to discuss within their groups if their hypotheses were correct, and tie their findings back to the scientific concepts of air pressure and lift.

This lesson supports ESTELL practices that challenge student thinking because it orients students to more complex engagement of science concepts and supports the examination of student investigations through repeated feedback. The teacher provides clear expectations for testing out the merits of their observations, connects the scientific method to the activity, and structures time for students to discuss and evaluate their findings based on the initial standards for evaluation.

Example 3b: Developing Scientific Understanding: Life Science, Sixth Grade

Students in sixth grade are studying a unit on single-celled organisms. The teacher asks students to investigate bacteria levels in the school. In small groups, students formulate hypotheses about where they think the most bacteria collects, and identify three places from which they will collect bacteria to be grown in three separate petri dishes. During the next week, students chart the growth of their bacteria samples. Students then measure their samples and analyze their results to determine which sample grew the most bacteria and decide whether or not their hypotheses were correct. Finally, students present their findings to the rest of the class. Then, individual group findings are compiled to generate class findings, and groups are asked to evaluate their group findings in light of class findings. Each group then reports their new conclusions to the whole class with an explanation of why they changed their views, if they changed their views.

In this example, the teacher engages students in an open-to-guided inquiry investigation in which students are required to formulate their own hypotheses and determine their sources of data collection. Students engage in all aspects of the inquiry cycle. Their investigation is tied to what they have been learning and is designed to facilitate increased understanding of the unit on monerans.

4. Collaborative Inquiry in Science Learning

Research in effective instruction for ELLs has demonstrated that students and teachers working together in groups on a joint product increases content understanding, language acquisition, and literacy development (August, 1987; Brown, Metz, & Campione, 1996; Doherty, Hillberg, Pinal, & Tharp, 2003; Genessee, 1999; Johnson & Johnson, 1989; Kagan, 1989; Slavin, 1987; Dalton, 1998; Strong, 1983, 1984; Tharp & Gallimore, 1998). Working in groups also provides more opportunities for ELLs to use language in authentic social contexts. When effectively monitored by the teacher, group members can help scaffold each other, allowing for each individual to participate at a level appropriate to their language development (Herrell & Jordan, 2004; Kagan, 1989). Additionally, scientists do not conduct their work in isolation. Scientific inquiry is conducted in communities of practice. Science is a social endeavor, whereby scientists collaborate to collect data and write up findings, as well as submit findings to the larger scientific community for further evaluation and review.

Collaborative inquiry combines principles of cooperative learning, distributed expertise, and legitimate peripheral participation with principles of inquiry science instruction so that students work together in small groups, where each group member is expected to perform a specific task while all students collaborate in a science inquiry investigation or related activity (Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, 1993; Lave & Wenger, 1991; Meyers, 1993). Students are expected to create a tangible or intangible learning product through collaborative inquiry. Some examples of tangible products include an investigation proposal, a lab report, a data chart, etcetera. Examples of intangible products include sustained participation in a discussion involving scientific reasoning, an informal oral report to the class about a group's progress or preliminary findings in an inquiry task, etcetera.

ESTELL focuses on promoting effective learning communities through inclusive and collaborative student engagement. Collaborations occur between teacher and students, but more emphasis is placed on student–student interactions in small groups or pairs. However, the role of teacher in collaborative inquiry is not passive. The teacher works closely with each group to ensure that all students are participating within their appropriate zones of proximal development; s/he monitors students' engagement with the task and scaffolds them through questioning and prompting to keep them actively interacting with both content and language. The teacher promotes the creation of learning products, including artifacts, processes, procedures, or findings about science. The teacher supports student sharing, evaluation, and feedback of class products. Additionally, the teacher regulates the quality of the product, tangible or intangible, to ensure that students have accomplished both the science learning and the literacy and language learning goals at hand. Collaborations can take many forms: shared ownership, authorship, use, or responsibility for a collaborative product or tasks. In ESTELL, however, there is a particular disciplinary focus with regard to collaborations in science that promote collaboration, sharing of science authority, and specific science productions.

Arranging students in groups or promoting collaboration alone is insufficient to increase learning outcomes. Particular attention must be given to the learning task at hand, and the promotion of English-proficient students and teachers as scaffolds for less English-proficient students is crucial (August, 1987; Genessee, 1999; Genessee, Lindholm-Leary, Saunders, & Christian, 2005; Jacob, Rottenberg, Patrick, & Wheeler, 1996). Organizing students in groups to engage in the completion of a carefully prepared joint science learning task can also fail to achieve the desired outcome if equitable participation among all group members is not monitored by the teacher (Lee & Luykx, 2006; Kurth, Anderson, & Palinscar, 2002). Social stereotypes and other inequities can negatively affect the nature of student–student interactions. Therefore, the teacher must take measures to ensure each group member is encouraged to engage with the group and provided with opportunities for substantial participation in the creation of the joint product.

Example 4a: Collaboration and Production: Physical Science, Second Grade

Second-grade students have been studying simple machines and recently completed an investigation with levers. Using lab materials, they explored the fulcrum, effort, and load of a class-1 lever. Students investigate the levers in small groups. Each group was asked to detail their findings from tests they conducted using spring scales to determine the relationship between the fulcrum, effort, and load of a class-1 lever. The groups enter their findings on a chart. As the groups work, the teacher goes around to each group to probe for more detailed responses, asking them to think through their ideas, to make predictions and justify them. Each group presents their chart to the whole class and discusses their findings. All group members participate in the presentation. The teacher leads the class in a discussion and helps them to identify shared conclusions across groups. Following this, the teacher asked the students go back into their small groups to further investigate how class-1 levers are used to form a see-saw, hammer claws, scissors, and pliers. Each group is given a different item: a model see-saw, a hammer, scissors, or pliers. Then groups present their findings, explaining how levers are used to form the item their group investigated.

This example shows how the teacher promotes student collaboration in which all students are involved in the levers activity, with the clear expectation that students themselves can generate scientific observations and conclusions. Students produce collaborative products and shared understandings of the relationship between fulcrum, effort, and load of a class-1 lever. Concepts are then tied to common household items so that students participate in a contextualized application of knowledge produced in the first activity.

Example 4b: Collaboration and Production: Earth and Physical Science, Fifth Grade

Fifth grade students have been studying different types of water contamination and pollutants. They go on a field trip to a local watershed. In small groups, students collect water samples from different areas in the watershed, note the turbidity of the water in each sample, and record the temperature of the water samples at the time of collection. Students bring the data back to the classroom and conduct tests on the samples, including chlorine, copper, hardness, iron, nitrate, pH, and phosphate tests to determine levels of the various pollutants in each sample. The students then decide how they will represent the data—as a chart, a graph, a table, etcetera—and then create the representation and enter the data. Then students in their groups discuss the data and preliminary findings and prepare to present their work to the rest of the class.

In this activity, students collaborate to contribute to the collection of the data set and work together on the analysis of the findings. Students are working together on all aspects of the investigation, from sample collection, to testing, to presentation of findings. Collaborative products include the results and data table generated and the group presentation to the rest of the class.

5. Contextualized Science Instruction

Effective science instruction for ELLs requires that complex concepts are connected to hands-on investigations or familiar cultural models through inquiry-based learning activities. ESTELL pedagogy advances teaching beyond physical hands-on activities or isolated inquiry investigations and extends it to include the purposeful integration of students' *funds of knowledge* from home, school, or community (Gonzalez & Moll, 2002; Hammond, 2001; Ladson-Billings, 1995; Moll et al., 1992). As such, contextualized science instruction provides a framework for integrating the other four components of ESTELL pedagogy. Implementing the first four components in decontextualized and discrete ways prevents optimal implementation of the ESTELL pedagogy.

Contextualization, in this context, means the systematic incorporation of sociocultural resources, existing prior knowledge from everyday life experiences, or funds of knowledge into science practice. The teacher relates science learning to the world that surrounds students and makes connections to local, regional, and global science issues and investigations.

The teacher may also initiate and develop science projects that promote student expertise and leadership in issues related to local physical, geographic, and/or ecological science phenomena (e.g., leadership/ activism in local environmental contexts). Whenever possible, teachers involve family and community members as science experts and/or in the investigation of community-related science issues. ESTELL practices are also responsive to both continuities and discontinuities between students' social, linguistic, and cultural backgrounds and the Western scientific worldview. In ESTELL, science learning is also contextualized through the use of the tools, inquiry processes, and discourse used by scientists in their work (Barad, 2007; Latour, 1999; Lemke, 1990; NRC, 1996).

Contextualization is crucial to establishing the relevance of particular science topics as students participate in meaningful activities that are tied to their own questions, experiences, and concerns, and build on their own cultural, linguistic, and intellectual resources.

Example 5a: Contextualization: Environmental Science, Sixth Grade

Students in a predominantly agricultural community have completed an investigation on household pesticides and are now learning about how some pesticides used in farming pose a serious health threat to migrant farm workers. Using data collected and published by the California Department of Health Services (CDSH), students create pie graphs to represent the percentage of pesticide-related illnesses that were attributed to various industries (e.g., agricultural industry, 54.3%) and the ethnicity of agricultural workers affected (e.g., 85% Latino). Students then participate in a jigsaw reading of the peer-reviewed journal article, "Pesticide-related Illness among Migrant Farm Workers in the United States" (Das, Steege, Baron, Beckman, & Harrison, 2001) in the *International Journal of Occupational Environmental Health*. Using the assigned section of the article, each group member is required to research one of the following subtopics in an expert group: demographic characteristics of migrant workers, causes of pesticide-related illness, reporting incidences of pesticide-related illness, and pesticide-related illness prevention. After expert groups meet, group members return to their original group to teach their home group members about their topic of expertise. The following day, their teacher, Mr. Z., has invited representatives from the Environmental Protection Agency, the Environmental Working Group, and the United Farm Workers to come and talk to the class about how the chemical makeup of the more harmful pesticides affect the human body and to share their current organizing efforts to protect workers from such pesticides. Then groups create a public service announcement and poster to educate people in their community about pesticide-related illness prevention and reporting.

The students in this agricultural community research a science topic that is both socially and culturally relevant. In this case, although they are not involved in an empirical investigation, they must distill information from a scholarly journal and present their findings to both group members and, later, to their community in the form of a poster and public service announcement. Also, the teacher brings in local experts so that students both further develop their expertise on the topic of pesticides and human health and at the same time increase their awareness of community resources in the area.

Example 5b: Contextualization: Physical Science, Fourth Grade

Students in Ms. T.'s classroom will begin to learn about the Doppler Effect the following week. Ms. T. and her students live in a large urban community. Throughout the day, it is common to hear sirens or honking horns while the students are in class. The students are accustomed to waiting for the noise to fade and then continuing on with the lesson. Ms. T. asks her students to listen carefully three times to passing noises, such as sirens, over the next few days and draw a picture or keep a journal log to record what they hear. This activity is assigned in preparation for the upcoming unit.

The following week, Ms. T. asks her students to share their entries with each other in small groups and discuss their experiences listening to passing sounds in their neighborhoods. She asks them to make hypotheses about why it is that sounds seem to get louder and then fade. Then she introduces an activity in which students work in groups to make Doppler balls using a buzzer, a battery holder, a foam-filled baseball, and a 9-volt battery. Once students make their Doppler balls, they record observations about the sound of the buzzer when it is stationary, when it is moving toward them, when it is moving away from them, and when the they run to and from the stationary ball. After students have completed the activity, they share their results with the class. Ms. T. then introduces the official scientific term for what it is that the students have now discovered: "the Doppler Effect."

In this example, the teacher uses experiences familiar to her students to introduce a scientific concept. The example is culturally appropriate for the community, since the students live in a large urban area in which sirens are common street noises. The teacher might have chosen other types of examples, such as airplanes taking off, but many of her students may not have had a personal experience with this sound, since there is no major airport in the community. To introduce the new science topic, Ms. T. deliberately chooses an example that she knows most or all of her students can relate to, and then she provides opportunities for students to offer their own examples after conducting a community investigation. Additionally, the teacher engages students in a direct investigation of the Doppler Effect using familiar materials. Students participate in an investigation of the science topic using Doppler balls before the topic is officially introduced. In this way, Ms T contextualizes her lesson on the Doppler Effect through the use of a concrete, hands-on experience and involves students as community researchers.

CONCLUSION

The research and instructional practices discussed above demonstrate that the integration of ESTELL pedagogy into science teaching is a powerful model for improving ELL achievement. The challenge is to prepare novice teachers to effectively use this instructional approach in their classrooms. Most teachers, however, are not prepared to teach academic content to diverse learners (Bryan & Atwater, 2002; Lee & Luykx, 2004; Rodriguez & Kitchen, 2005). The majority of teacher education programs do not model an integrated approach to instruction, and in the coursework there is little connection between learning to teach science and the use of culturally responsive pedagogy. Subject matter teaching methods are taught with little emphasis on integrating the language and culture of the student population being served (Dalton, 1998; Fradd & Lee, 1995; Stoddart, 1993a). Issues relating to cultural and linguistic diversity, when taught, are presented in separate courses and often focus on social conditions, not pedagogy (Met, 1994; Zeichner, 2003). Finally field experiences are often disconnected from, and not well coordinated with, the university-based components of teacher education (Wilson, Floden & Ferrini-Mundy, 2001), and contradictory views of teaching and learning are frequently manifested by the schools and teacher education program (Stoddart, 1993b). If novice teachers are to learn to effectively teach science to diverse learners, there must be coherence between their own learning experiences of science content, the pedagogy taught and modeled in science teacher education methods courses, and the models they observe in their field placements.

The next steps in the elaboration of ESTELL pedagogy is to develop a coherent model of teaching and coaching for novice teachers that integrates ESTELL pedagogy at every stage of teacher preparation and induction, from prerequisite science content courses, to the science teaching methods courses in the credential programs, to the clinical setting of student teaching and the first year of teaching. It is only through such coherent, integrated programs of teacher preparation that novice teachers will develop the knowledge and skills to effectively teach science to ELLs.

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