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Integrating Inquiry Science and Language Development for English Language Learners

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Abstract: The traditional approach to the education of language minority students separates English language development from content instruction because it is assumed that English language proficiency is a prerequisite for subject matter learning. The authors of this article take the alternate view that the integration of inquiry science and language acquisition enhances learning in both domains. The report describes a conceptual framework for science–language integration and the development of a five-level rubric to assess teachers' understanding of curricular integration. The science–language integration rubric describes the growth of teacher expertise as a continuum from a view of science and language as discreet unrelated domains to the recognition of the superordinate processes that create a synergistic relationship between inquiry science and language development. Examples from teacher interviews are used to illustrate teacher thinking at each level. © 2002 Wiley Periodicals, Inc. J Res Sci Teach 39: 664–687, 2002

Over the past decade the number of language minority students in the United States has increased dramatically. Across the nation there are between 3.5 million and 5 million school age students whose primary language is not English (Council of Chief State School Officers, 1990; Macias, 1998). Almost 70% of these students are being educated in just five states—California, New York, Illinois, Florida, and Texas (August & Hakuta, 1997). The context for this study is California, where there are currently over 1.4 million K–12 English language learners, the majority of whom are Latino (California Department of Education, 1998). Although California is enriched by this linguistic and cultural diversity, it poses significant challenges for the education of students from diverse language backgrounds and their teachers.

The education of English language learners is complex because it involves teaching academic subjects to students while they are developing a second language (Rosebery, Warren, & Conant, 1992). The dominant instructional approach separates the teaching of English language from the

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teaching of academic content because it is assumed that proficiency in English is a prerequisite for learning subject matter (Collier, 1989; Cummins, 1981; Met, 1994). This is problematic because it may take as long as 7 years to acquire a level of language proficiency comparable to native speakers (Collier, 1989; Cummins, 1981). English language learners fall behind academically if they do not learn the content of the curriculum as they acquire English.

The result is that the majority of language minority students do not have access to rigorous subject matter instruction or the opportunity to develop academic language—the specialized, cognitively demanding language functions and structures that are needed to understand, conceptualize, symbolize, discuss, read, and write about topics in academic subjects (Cummins, 1981; Lacelle-Peterson & Rivera, 1994; McGroaty, 1992; Minicucci & Olsen, 1992; Oakes, 1990; Pease-Alvarez & Hakuta, 1992). In most English Language Development (ELD) classes, English language learners acquire basic social communication skills but less readily acquire the complex subject-specific language skills required for academic success. Academic subjects, such as science, have a linguistic register—norms and patterns of language use essential to the practice of the discipline (Halliday, 1978). The science register uses academic language features that 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 (National Research Council [NRC], 1996).

Unfortunately, most language minority students are relegated to remedial instructional programs focusing on the acquisition of basic skills that supposedly match their English-proficiency level (Garcia, 1988, 1993; Moll, 1992). It is not surprising that the academic progress of language minority students is significantly behind that of their native English-speaking peers. The most recently published National Association for Educational Progress report (National Center for Education Statistics, 2000) shows that in core academic subjects—mathematics, science, and reading—the scores of Latino students are on average 20 points below those of White students.

One solution is to teach academic subjects to English language learners in their native language while they acquire English language proficiency (Cummins, 1989; Garcia, 1997). However, a chronic shortage of bilingual teachers, particularly those who are also qualified to teach subject matter such as science or mathematics, means that few English language learners receive content instruction in their primary language (California Department of Education, 1998). In addition, English-only legislation in California now prohibits the teaching of academic subjects in English language learners' primary language (Proposition 227, 1998).

An alternative approach is to integrate the teaching of academic subjects with second language acquisition (Baker & Saul, 1994; Casteel & Isom, 1994; Lee & Fradd, 1998; Mohan, 1990; Rosebery et al., 1992; Snow, Met, & Genesee, 1991). The thesis of this article is that inquiry-based science is a particularly powerful instructional context for the integration of academic content and language development for English language learners. The development and use of language functions such as describing, predicting, hypothesizing, reasoning, explaining, and reflecting, parallel the processes used in the learning of science (Casteel & Isom, 1994; Lee & Fradd, 1998; Tough, 1985). Inquiry science, which promotes students' construction of meaning through exploration of scientific phenomenon, observations, experiments, and hands-on activities, provides an authentic context for language use (NRC, 1996).

Prior work on the integration of science with other subjects has focused on the integration of mathematics and science (Huntley, 1998; Woodbury, 1998) or the integration of science with reading and writing (Baker & Saul, 1994; Casteel & Isom, 1994; Gaskins, Guthrie, Satlow, Ostertag, Six, Byrne, & Connor, 1994; Glynn & Muth, 1994; Keys, 1994; Rivard, 1994). Analyses of issues related to the integration of second language development with inquiry instruction are in the early stages (Fradd & Lee, 1999). The contribution of this report is the description of a conceptual framework for integrating English language development with inquiry science and the development of a rubric to assess teachers' understanding of curriculum integration. The research focuses on how teachers perceive the connections between inquiry science instruction and language development as it relates to the education of English language learners. The two primary research questions are: (a) How do teachers conceive of science language integration? and (b) What are the cognitive demands that underlie the development of teacher expertise in domain integration? The literature on curriculum domain integration, the development of expertise in teaching, and cognitive complexity are used as a framework for a rubric that describes science–language integration as a continuum from isolated domain-specific instruction to fully-integrated synergistic instruction with the emphasis on commonalties in structure and process across domains.

The Integration of Inquiry Science and Language Development

English language development involves learning to speak, read, and write in a second language. This includes the learning of vocabulary, syntax, and lexical grammar, and the use of language in both social and academic situations. Research on second language immersion programs finds that contextualized, content-based instruction in students' second language can enhance the language proficiency of English language learners 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.

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. 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 in instruction. The use of language in the teaching of school subjects, however, is often decontextualized. Context-reduced or decontextualized language occurs when there is little other than the spoken language to provide information (McKeon, 1994). Examples include lectures, many of which provide little or no support for meaning; or students reading a book with no illustrations, having only the text to rely on to facilitate comprehension. This poses particular problems for students developing English language proficiency who rely heavily on context cues to understand a lesson. Because much of school language is context-reduced, English language learners often find themselves in a world of meaningless words.

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; i.e., they are contextualized (Baker & Saul, 1994; Casteel & Isom, 1994; Lee & Fradd, 1998; Rodriguez & Bethel, 1983; Rosebery et al., 1992; Stoddart et al., 1999). Thus, learners engage in authentic communicative interactions—describing, hypothesizing, explaining, justifying, argumentation, and summarizing—which promote purposeful language (Lee & Fradd, 1998). They can communicate their understanding in a variety of formats, for example, in writing, orally, drawing, and 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). In science, language serves to structure the way concepts are developed, organized, and communicated (Kaplan, 1986; Lemke, 1990; Newman & Gayton, 1964). Inquiry involves more than hands-on activities; it also involves active thinking and discourse around activities. In their work with language minority students, Rosebery et al. (1992) emphasized 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 heart of the approach is for students to formulate questions about phenomena that interest them; to build and criticize theories; to collect, analyze and interpret data; to evaluate hypotheses through experimentation, observation and measurement; and to communicate their findings. (p. 65)

The relationship between science learning and language learning 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. This synergistic perspective is a relatively new view of curricular integration.

Instructional Integration of Content Domains

The integration of subject matter domains has been described in three main ways: thematic, interdisciplinary, and integrated (Dickinson & Young, 1998; Huntley, 1998; Lederman & Niess, 1997, 1998; McComas & Wang, 1998). These approaches differ in the relative emphasis they place on a domain and the degree of integration of content and processes. Thematic instruction is characterized by the use of an overarching theme or topic to create relationships between domains (Dickinson & Young, 1998). For example, a thematic unit involving science, math, and language arts might be developed around a topic such as the ocean. In interdisciplinary instruction, content and processes in a secondary domain are used to support learning in the primary domain. For example, basic math skills can be applied in an inquiry science lesson. However, the resulting student learning consists primarily of new science concept understanding. Although there is an emphasis on the connections between domains, clear boundaries between domains are evident in interdisciplinary instruction (Huntley, 1998; Lederman & Niess, 1997).

In an integrated curriculum, the emphasis on each domain is balanced, with no dominant subject area. Huntley (1998) described integration between domains as "synergistic," where each domain complements and reinforces the other, resulting in enhanced learning in both domains.

The disciplines interact and support each other. In this sense, there is more than just equal treatment of the two disciplines; there is a synergistic union of the two disciplines, the result being an activity or curricular unit in which the interactions between the disciplines result in students learning more than just the mathematics and science content contained therein (Huntley, 1998, p. 322)

The view of integration presented in this article is based on Huntley's definition of synergistic integration. Effective language instruction enhances the learning of science concepts, and effective science inquiry instruction enhances language development and promotes the development of higher-order thinking skills. This approach aligns with work on the integration of reading and writing with science instruction (Baker & Saul, 1994; Casteel & Isom, 1994; Gaskins et al., 1994; Glynn & Muth, 1994; Keys, 1994; Lee & Fradd, 1998; Rivard, 1994). These authors emphasized the reciprocal processes in science and literacy learning and argued that this instructional approach strengthens both science knowledge and literacy development.

In viewing the teaching of science and language as a synergistic process, we support the view of bilingual educators such as Cummins (1994) and Met (1994), who argue that the teaching of English and subject matter content should be so integrated that "all content teachers are also teachers of language" (Cummins, 1994, p. 42) and "view every content lesson as a language lesson" (Met, 1994, p. 161). There is currently little information available, however, on successful approaches to preparing teachers to teach inquiry science to second language learners (Lee & Fradd, 1998).

The Development of Teacher Expertise in Domain Integration

The majority of teachers are not taught how to integrate the teaching of second language development with content matter instruction. Traditionally, in teacher education and staff development programs, 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, 1999; Stoddart, 1993). English Language Development (ELD) is a separate area of teacher certification, and most school districts have a distinct English as a Second Language (ESL) curriculum that is taught in isolated ESL classes by ELD teachers (Met, 1994). It is not surprising that teachers tend to view themselves as either subject matter teachers or teachers of language—but not both (Baker & Saul, 1994).

Most teachers, irrespective of years of teaching experience, therefore are novices at teaching a second language in the context of subject matter instruction. This is a new area of expertise. To begin to integrate language development with inquiry science instruction, teachers must understand the characteristics of the individual domains and also the connections between these domains. As novices in domain integration, most teachers are likely to begin with a focus on the surface features of each domain. As expertise develops, they will begin to recognize commonalties in structure and process across domains. This entails a shift in the complexity of teacher thinking, which the literature on the development of expertise describes as a shift from a restricted, global understanding to an elaborated, complex, situated knowledge which can be applied flexibly in instruction (Benner, 1984; Carter, Cushing, Sabers, Stein, & Berliner, 1988; Dreyfus & Dreyfus, 1986). This evolution of teacher understanding could be characterized as a shift from "knowing *that*" to "knowing *how*" (Dreyfus & Dreyfus, 1986; Kuhn, 1970; Polanyi, 1958). "Knowing that" understanding is characterized by a rule-governed, theoretical orientation, whereas "knowing how" is the flexible application of principles in practice. In the continuum from knowing that to knowing how, there is a movement from detached observer to involved performer, where decision making is contextually contingent and grounded in experience. Understanding of the conceptual connections between domains is fundamental to this shift (i.e., integration). This involves developing differentiated and complex reasoning about the interaction and interdependence of both domains (Baker-Brown, Ballard, Bluck, De Vries, Suedfeld, & Tetlock, 1992).

In the next section of this article, the conceptual model of science-language integration described above is integrated with the models of domain integration, the development of expertise, and cognitive complexity to provide the framework for a rubric of science–language integration.

Method

The context for this study is Language Acquisition through Science Education in Rural Schools (LASERS), a National Science Foundation–funded Local Systemic Change project in central California that prepares experienced teachers to provide inquiry science instruction to Latino students learning English as a second language. The science–language integration rubric was developed to provide a conceptual framework for teacher staff development activities and to gauge changes in teachers' beliefs and practice. The research proceeded in two phases: (a) the development of a five-level rubric based on the literature on the development of expertise (Dreyfus & Dreyfus, 1986), conceptual/integrative complexity (Suedfeld et al., 1992), and subject matter integration (Baker & Saul, 1994; Casteel & Isom, 1994; Gaskins et al., 1994; Glynn & Muth, 1994; Huntley, 1998; Keys, 1994; Rivard, 1994; Woodbury, 1998); and (b) the identification of exemplars of teacher thinking at each of the rubric levels drawn from interviews of teachers in the LASERS project.

Rubric Development

A rubric was developed to analyze teachers' understanding of science–language integration for three reasons: (a) The rubric affords researchers and others with a clear explanation of the phenomenon to be studied, (b) it provides a distinct and concise means to gauge an individual's level of understanding, and (c) it helps assess changes in reasoning or performance over time. In the context of education, a rubric generally refers to a set of criteria, usually on a continuum, designed to describe varying levels of performance on a given task or types of beliefs on a specific topic (Arter, 1993; Luft, 1999).

Rubric Framework

As Table 1 shows, the science–language integration rubric describes a continuum of reasoning based on models of the development of expertise (Dreyfus & Dreyfus, 1986) and cognitive complexity (Suedfeld et al., 1992). Both theories posit an increasing complexity of information processing and decision making as learners move from a basic, general understanding to elaborated, explicit knowledge and reasoning about integration. The rubric also incorporates the previously defined categorical views of integration (thematic, interdisciplinary, and integrated) into a developmental continuum, with thematic instruction representing the most basic level and integration the most complex. Table 1 summarizes the relationship among the three frameworks used in the construction of the rubric.

The Dreyfus model (1986) describes five levels of proficiency in the development of expertise with each level reflecting qualitatively different perceptions and modes of reasoning. Novice learners (Level 1) tend to rely on rule-based facts and features resulting in extremely limited and inflexible behavior. The advanced beginners (Level 2) recognize global aspects and show a limited consideration of situational elements. With more experience, the competent performers (Level 3) establish priorities, develop goals, and have an organized plan defined by flexibility and conscious reflection. Proficient performers (Level 4) are analytical, make decisions based on situational involvement, have an intuitive ability to perceive patterns holistically, and recognize commonalties across seemingly different contexts. In addition to making decisions based on a holistic, integrated understanding of situations, experts (Level 5) rely on their extensive background and experience to assess and respond to situations expediently.

Developing expertise in science–language integration involves more than an elaborated understanding about the individual domains of science and language. Whereas the Dreyfus model focuses primarily on the development of expertise within a particular domain, the conceptual/integrative complexity scale developed by Baker-Brown et al. (1992) provides the conceptual framing necessary to gauge teachers' understanding of the interaction and interdependent

Table 1
Framework for science–language integration rubric

	Development of Expertise	Conceptual/ Integrative Complexity	Curriculum Domain Integration	Science–Language Integration Rubric
Level 1	Novice: rule-based and inflexible	Unidimensional; no differentiation or integration	No integration	Separate content domains
Level 2	Advanced beginner: global	Plausibility of integrating content domains	Thematic instruction	Basic understanding; "knowing that"
Level 3	Competent performer: organized plan	Differentiated dimensions; consider possible conceptual connections	Interdisciplinary	Unidirectional
Level 4	Proficient performer: analytic decision making	Explicit conceptual connections/ recognition of shared attributes	Integrated	Reciprocal processes; "knowing how"
Level 5	Expert: flexible and responsive to context	Dynamic and synergistic; guided by overarching principle	Integrated	Elaborated integration; "knowing why"
Sources	Dreyfus & Dreyfus, 1986	Baker-Brown et al., 1992; Suedfeld et al., 1992	Dickinson & Young, 1998; Huntley, 1998; Lederman & Niess, 1997, 1998; McComas & Wang, 1998	

relationship between the domains of science and language. The conceptual/integrative complexity scale is a cognitive styles approach focusing on the conceptual structure of reasoning rather than on its content. It assesses complexity of information processing and decision making where complexity is defined and measured in terms of degrees of differentiation and integration. Differentiation refers to the acknowledgment of multiple dimensions within a domain and the taking of different perspectives when considering a domain. Differentiation is a necessary but not sufficient prerequisite for integration. Integration refers to the development of conceptual connections among differentiated dimensions or perspectives (e.g., science and language). An understanding of such connections is "inferred from references to trade-offs between alternatives, a synthesis between them, and a reference to a higher-order concept that subsumes them." (Suedfeld et al., 1992, p. 393).

Five key transitions of the conceptual/integrative complexity scale were integrated into the science–language integration rubric. Level 1 reasoning shows no evidence of either differentiation or integration of domains and a reliance on unidimensional rules for interpreting events or making choices. At Level 2, reasoning reflects a conditional acceptance of, or emergent recognition of other perspectives or dimensions and the plausibility of integrating them. Level 3 reasoning about science–language integration reflects a clear presentation of differentiated dimensions and the recognition that they could interact. However, one perspective could be considered dominant over the other. At Level 4, alternative perspectives or dimensions are held in focus simultaneously and are also presented in a reciprocal relationship. Integrative cognition takes a variety of forms, such as identifying a superordinate category linking the domains of science and language, or developing insights into the shared attributes of the two domains, or the recognition of conflicting goals or value tradeoffs. The unique characteristic of Level 5 reasoning is the presence of an overarching viewpoint which contains an explanation of the organizing principles (e.g., causal, theoretical) of the synergistic relationship between the domains of science and language.

In addition, the five-level science–language integration rubric incorporates the previously defined categorical views of integration (i.e., thematic, interdisciplinary, integrated) into a developmental continuum. For example, thematic instruction is represented in rubric Level 2, Beginning Integration. The interdisciplinary instructional approach is represented in rubric Level 3, Emerging Integration. The integrated instructional approach, where the interaction between science and language is synergistic, is represented in Level 4, Fundamental Integration, and Level 5, Elaborated Integration.

Rubric Levels. In developing the five-level science–language integration rubric, key characteristics and indicators of each level of the rubric were identified through the constant comparative method (Bogdan & Biklen, 1992). This is an inductive, qualitative process in which the development of expertise (Dreyfus & Dreyfus, 1986) and the conceptual/integrative complexity (Suefeld et al., 1992) continuums were tested against the teacher interview responses through review, coding, and identification of dominant themes.

As Table 2 shows, science–language integration is represented in the rubric as a continuum from Level 1 to Level 5. At Level l, No Integration, science and language are perceived as separate content domains. At Level 2, Beginning Integration, there is recognition of the possibility of science and language integration. Level 3, Emerging Integration, is characterized by a uni-directional view whereby either language or science is viewed as dominant. Level 4, Fundamental Integration, incorporates the view that science and language share underlying common processes (e.g., predicting, concluding, reporting); thus, there is a reciprocal relationship between science and language. At Level 5, Elaborated Integration, the interaction between science and language is perceived as interdependent and synergistic.

The science–language integration rubric presented in Table 2 represents a continuum of understanding constructed to address both the characteristics and the indicators of expertise at each level. The characteristics column reflects the development of expertise and integrated complexity literature (Baker-Brown et al., 1992; Dreyfus & Dreyfus, 1986) as applied to pedagogy. The indicators column reflects teachers' perceptions about science–language integration from interviews as well as the literature on how teachers' understanding of curricular integration is manifest in dialogue (Baker & Saul, 1994).

Exemplars of Teacher Conceptions

Interviews were conducted with 24 first- through sixth-grade teachers (21 female, 3 male) who participated in the LASERS summer school academy in 1998. The majority of the 24 teachers (19 of 24) had more than 3 years of teaching experience. The sample includes teachers with differing levels of participation in the LASERS project and a range of teaching experience. Therefore, they represent a range of perspectives on language-science integration. Each teacher was interviewed about his views on the integration of science and language. Each interview was

Table 2
Science–language integration rubric

	Characteristics	Indicators
Level 1: no integration	Domains are discrete and isolated—no awareness of the possibility of integration or connections between two domains of knowledge	States that science and language cannot be taught in the same lesson
	Domains are rule-governed, no understanding or consideration of context	Describes science and language teaching as a prescribed approach, with little or no reference to personal experience or reflection on integration
	No need or desire for change in understanding or use of integration	No plan for changing practice to include integration of science and language
		Describes instruction devoid of student input with little opportunity for student discourse or student-initiated inquiry
Level 2: beginning integration	Rudimentary understanding that integration of two domains is possible	Cites secondary sources (e.g., research, staff development) when defining integration; definition is incomplete or superficial
	Understanding of the theoretical basis for integration, but little or no knowledge of strategies for implementation	May indicate no personal practical experience implementing science and language curriculum
	No understanding of how theory relates to context in practice	Describes integration as sequential and domains may lack in-depth content
	Awareness of need to improve understanding and use of integration	Describes integration as thematic instruction (e.g., ocean as an organizing topic)
		Interest in exploring science–language connections
Level 3: emerging integration	Understands integration as a focus on one domain, using minimal content in the secondary domain to support content in the primary domain	Describes instruction as focusing on either science *or* language concepts; uses skills, e.g., vocabulary building or writing tasks, to connect domains
	Ability to clearly differentiation between domains, but with minimal understanding of common processes and concepts across domains	Describes language learning in narrow terms—does not discuss the concept of language development
	Emerging understanding of how to apply the theory of integration to instructional context	May indicate feeling uncomfortable with the challenge of applying integration in practice and describe ideas for further understanding and implementation
	Desire to increase understanding of integration and improve application of knowledge with ability to organize a plan of action	

Level 4: fundamental integration	Implicitly understands integration as a reciprocal relationship between two domains but the content in either domain may not be covered in depth	Provides a complete and accurate definition of science–language integration, with examples from instruction
	Identification of superordinate processes or concepts linking domains—discussion of the conceptual connections and processes in common between two domains—insights into shared attributes of different dimensions of domains	Discusses the value of using instructional approaches (e.g., experimentation whereby students make predictions, draw conclusions) and the use of academic language to strengthen the learning of both science and language
	Recognition of conflicting goals or value tradeoffs in integrating domains of knowledge	Recognizes that there are challenges involved in integrated curriculum (e.g., time to teach students the inquiry process)
	Ability to articulate a plan to apply new understanding to instructional practice	Describes a plan for curricular integration based on processes in common between domains
Level 5: elaborated integration	Thorough, explicit understanding of integration–extends description of integration to include value of reflection, with examples of analysis and contextual considerations across a variety of domains	Discusses the specifics of how and why integration can be applied to additional disciplines, refers to integration as a synergistic process
		Discusses using inquiry and contextualization as the framework for an integrated instruction and includes examples from practice
	Provides examples describing transfer and application of understanding of integration to novel situations and contexts	Description and discussion of integration is clearly articulated
	Uses a conceptual framework, such as inquiry, for understanding and implementing an integrated curriculum across two or more domains of knowledge—emphasis is on higher-order thinking skills that enhance learning	Addresses the value of integrating inquiry across subject areas and provides specific examples of higher-order thinking skills as an outcome of science–language integration

transcribed and four researchers read through the interview transcripts. The semistructured interview included the following questions:

- What do you consider are the features of effective science instruction?
- What experiences are necessary for students to become successful in learning science?
- What do you think would be effective instruction for English language learners?
- What experiences are necessary for students to become successful in learning language?
- What do you think are the most effective strategies for teaching science to English language learners?
- What are your thoughts about integrating science and language instruction?
- Was there a specific [integrated science–language] lesson that you felt was particularly successful, that your students really understood?

Exemplars representing teacher conceptions of science–language integration at each rubric level were drawn from the teacher interviews. This process of carefully deriving categories of teacher responses which emerge from the data is as much a part of the method as the final rubric itself. Using a constant comparative method (Bogdan & Biklen, 1992) similar to that used in the rubric level development, four researchers read through the 24 interview transcripts and identified a sample of teacher responses exemplifying the indicators and characteristics of each rubric level. Researchers then independently rated each of the exemplars to establish criteria. Where there was disagreement, researchers conferenced to reach a final consensus.

Science–Language Integration Rubric

In the following section we present an elaborated description of the development of teacher thinking over the five levels of the rubric. For each level we provide: (a) an overall rubric level description, followed by (b) a summary of the key themes for that level, and (c) exemplars to illustrate the key themes for that level. Individual teachers' responses represent variations on the themes described in the general description of each rubric level. Developing complexity in science–language integration is represented on a continuum of understanding that moves from a restricted view in which boundaries between domains are viewed as impermeable to an elaborated, differentiated perspective that acknowledges a reciprocal and synergistic relationship between domains.

Level 1, No Integration

Level 1 represents the view that science and language are separate domains. This level incorporates the Dreyfus and Dreyfus (1986) novice level, which represents an inflexible, rule-based perspective. Reasoning about science–language integration is restricted and responses reflect the belief that integration is not possible and alternative perspectives are not considered. (Baker-Brown et al., 1992). Individuals may describe domain boundaries as impermeable and present a compartmentalized view of science and language. Furthermore, there may be no indication of the need or motivation to change current understanding or to use an integrated approach. Ideas about a domain are presented as discrete and isolated.

Three themes characterize Level 1, No Integration: (a) no awareness of the possibility of integration or connections between science and language, (b) ideas about domains are rule-governed with no understanding or consideration of context, and (c) teachers may indicate that science and language cannot be taught in the same lesson. These themes are illustrated using teacher quotes in the following section.

No Awareness of Integration

> I don't know what language acquisition has to do with science yet. How is that going to come together? That did not become apparent to me.

This teacher response implies an understanding of the domains and processes of science and language as unrelated.

Rule-Governed Ideas about Domains

> [The] school's primary focus should be for students to learn English. Students really need to know English before they learn science.

This response reflects the belief that learning English is a prerequisite to learning science without consideration of science as a meaningful language learning context.

Teach Either Language or Science—Not Both

> It's too difficult to try to do both [science and language]. If your emphasis is trying to do both I think it's very difficult to be able to do that. I think it works a lot better for the kids if what you expect is language. . . . If it's the content you want to teach them, forget the language . . . teach them the content. There might be people who can do both but I think it's very difficult to actually do that. It all depends on what you want to emphasize to the kid. Do you want them to understand the lunar eclipse or do you want to make it such that they understand a language concept? I don't think you can do justice to both at the same time.

This response illustrates an understanding of science and language domains as compartmentalized and a belief that it is not possible to consider addressing two domains within one lesson.

Level 2, Beginning Integration

At Level 2, Beginning Integration, individuals recognize the plausibility of science–language integration. Their understanding, however, can be described as global or general, and undifferentiated. They are aware that integration could hypothetically occur (knowing that) but have a limited understanding and repertoire of strategies for implementation (knowing how), (Dreyfus & Dreyfus, 1986). Individuals begin to look at the issue of integration in a different way (moderate differentiation) but there is no consideration of the conceptual connections (Baker-Brown et al., 1992) between science and language.

Level 2 responses demonstrate a superficial understanding of integration—a belief that integration between domains is plausible—but show little if any knowledge of strategies for implementing integration. Teachers may not have the vocabulary, concepts, or experience to frame their discussion of integration and therefore discussion may be unfocused. At the same time, their responses show a beginning understanding of and attempts at implementing integration. This often translates to an instructional approach in which the connections between science and language are theme-based or include sequential, loosely related activities—described as thematic instruction by Dickinson and Young (1998). In addition, the practices described may lack in-depth coverage of science or language content and may not incorporate clear goals and learning objectives for the respective domains. Teachers at this level may also acknowledge a need to improve their understanding and use of integration. They may view integration as an activity in addition to content instruction rather than as a means to improve student learning through in-depth exploration of concepts.

The themes that characterize Level 2, Beginning Integration, are (a) a rudimentary understanding that integration of two domains is possible, (b) integration is described as sequential and domains may lack in-depth content, and (c) integration is described as thematic instruction whereby subject areas are organized around a topic or theme. These themes are illustrated using teacher quotes in the following section.

Plausibility of Science-Language Integration

> I've seen it [teaching of science and language within same lesson] done but it's sort of like . . . how can I put it? Well, I know it's been done because during the summer school they do "Into English" and "Hampton Brown" and primarily do it in a science-type way, so I know it's done. I bet in ways I do it, too, but I don't go into a lesson necessarily saying to myself, "I want them to understand a type of language lesson. Okay, contractions . . . we're working on contractions or something like that." I don't go into a lesson saying, "I've got to make sure they understand contractions along with the solar eclipse." You can use it . . . maybe I'm all totally wrong about it or something, I don't know, it's real tough.

In the process of relating an example from practice, this teacher realizes that elements of integration may have been present in the lesson, i.e., plausibility. However, the teacher did not consciously design the lesson to address specific learning goals in both science and language. This response reflects a Level 2 awareness that teaching integrated science is plausible, albeit difficult, and the lack of competence in deliberately planning lessons that integrate science and language (i.e., knowing that rather than knowing how).

Science–Language Integration as Sequential

> I think that students really understood that habitats have characteristics and that they are the same no matter what living thing they were talking about—the shelter, food, water, and air, oxygen—so that was good. They were able to say it orally and then they had to write it. And they included all of the components. . . . That is all we did, just science and ELD.

This response presents a conception of science—language integration as sequential: First the students do science, then they write about it. There is no evidence of understanding how these language forms serve a function in the learning of science.

Science–Language Integration as Thematic

> Maybe having a broad theme . . . something that's broad, like interactions. We interact with the table or the chair by sitting on it. We interact with each other by talking. It's really basic but there are lots of lessons around "What is an interaction?" and then we move into "Okay, nutrient interactions" and "Where are nutrients?" I don't know how to describe it . . . it's like building on top of something. I like the interactions unit, but I'd like to be able to do more.

In this response, the teacher is exploring her understanding of thematic connections and how they apply to practice. This type of Level 2 response shows an emerging understanding of integration as an idea, but not enough practical experience in implementation or reflection to describe integration in more than vague, general terms around the theme of nutrition.

Level 3, Emerging Integration

Teacher responses at Level 3, Emerging Integration, reflect an understanding of science–language integration as a one-way process in which there is an explicit focus on one domain, with the second domain used to support or facilitate the primary domain. The recognition of a relationship between domains signifies an emergent understanding of integration, but the relationship is expressed in a tentative manner. At this level, individuals recognize that there are different ways of integrating content areas but they tend to focus on only one area (Baker-Brown et al., 1992). For example, individuals may have an emerging knowledge of how to incorporate some science content in a language lesson or some language skills in a science lesson.

Teachers at this level are beginning to know how (Dreyfus & Dreyfus, 1986). They are beginning to reflect on how their beliefs and practice of integration have changed and evolved. They may discuss shared attributes (e.g., language functions such as writing, explaining, observing) that enhance learning across domains. As their ideas about integration are emerging, teachers are able to provide a few fairly general examples of integrated approaches from practice. However, their responses lack detailed expression of science–language integration as a reciprocal process. They do not discuss the use of a conceptual framework (e.g., inquiry) as a means for integrating domains.

The themes that characterize Level 3, Emerging Integration, are: (a) an emerging recognition of the relationship between science and language, where one content domain is foregrounded and the second serves as background; and (b) the use of instructional strategies such as vocabulary building, questioning, and/or writing to link science and language. These key themes are illustrated using teacher quotes in the following section.

Language Foreground/Science Background

> What I find is that in the language lessons you can use the content of whatever it is you're studying. Say you want them to learn about adjectives. Well, you have adjectives that describe the moon . . . that kind of thing, you can tie it in but it's still a language lesson . . . or if you want them to do comparatives, bigger, smaller, faster, shorter, the sentences or whatever they're working on have to do with the area of study, the moon is bigger than the earth . . . that sort of thing. It's very tricky . . . it works really well if it's all well done; unfortunately, it takes a lot of time and effort to put something like that together.

This response describes an integrated lesson that foregrounds the language concepts and science content serves as a background to facilitate language learning. In contrast, in the response that follows the teacher describes an integrated lesson in which learning of science concepts is dominant with the inclusion of vocabulary as the language portion.

Science Foreground/Language Background

> They will study how bones function, what purpose do they serve, how they're shaped and how they're put together enhances that function or makes you be able to walk and move.

> We'll learn a little vocabulary, not all 206 bones, but some vocabulary of some of the major bones. . . . We're collecting bones, so we can look at bones, so that we can look at them in the inside, we can cut them open. Then we can make enough observations to have something to talk about, to look at. Then we'll do some reading about bones; the observations will include trying to figure out what they're made out of. How to keep them healthy. Just some basic introductory types of things . . . there are some things to help them learn the vocabulary. Some little study sheets and worksheets.

Both of these teacher responses illustrate an understanding of integration as a one-way process, as observed in interdisciplinary instruction (Lederman & Niess, 1997). Level 3 responses do not include a discussion of science–language integration as a reciprocal process. However, in both cases the teachers demonstrate an awareness of strategies that can be employed to teach both science and language (e.g., writing).

Science–Language Instructional Strategies: Vocabulary, Questioning, and/or Writing

> I believe that science and language can be taught in the same lesson very easily. For example, I might do a short language lesson perhaps on the use of the conditional "would." "What would happen if . . . " I may teach that segment outside of my science lesson. On the other hand, I might use the science information that the kids already have such as the words that I am using in that language lesson. Though I am not teaching any new science at that time, I am using science language, science vocabulary, and science ideas for the kids to form their sentences with. I might say, "That water experiment we did the other day, what would have happened if . . . " and then have the kids giving me sentences using, "What would happen if I dropped water on a candle. What would happen if I . . . " So that students are still working within the language of the science lesson. Then when you are in the science lesson, it is easy to have them go back. So that when they are asking their real questions about what they are doing, they already have a template to plug those words into and they are used to using that language, they are familiar with it.

This response illustrates an emerging understanding of the use of a common process to integrate science and language learning. The teacher describes using questioning as a language function that is a shared attribute with science learning. Typical of Level 3, the teacher describes a single instructional strategy rather than a system of strategies, as a bridge between the two domains. However, there is no discussion of how this strategy serves to improve the learning of concepts in both science and language. Teacher responses at this level may also indicate a desire to enhance their understanding of science–language integration. This understanding deepens and is elaborated in the more extensive use of superordinate categories, such as processes and concepts, described in Level 4 understanding of integration.

Level 4, Fundamental Integration

At Level 4, individuals understand the dynamic, reciprocal relationship between science and language necessary for integrated instruction (Huntley, 1998). This understanding is seen in their discussion of the processes common to the domains of science and language, as well as superordinate categories that link the domains (Baker-Brown et al., 1992). The skill of identifying and discussing common processes and patterns across both science and language suggests that teachers are making decisions based on an understanding of the structural similarities between the domains (Dreyfus & Dreyfus, 1986). Responses at this level also indicate that teachers have developed strategies based on their personal experiences in implementing integrated science and language instruction. This understanding is expressed by providing clear examples from their practice. There is an explicit focus on the importance of academic language, language functions, and concept development. Furthermore, responses acknowledge both the complexities of integrating domains of knowledge (e.g., negotiating conflicting goals or value tradeoffs) as well as advantages (e.g., time to explore concepts in depth) (Baker-Brown et al., 1992). Although the knowledge and skills of integration may not be applied flexibly to domains outside science and language, there is a clear indication of thoughtful reflection about changes over time in beliefs about integrated practice. In addition, there may be a discussion of plans to improve their growing knowledge and expertise further in content integration to improve student learning outcomes.

Three themes characterize Level 4, Fundamental Integration: (a) understanding integration as a reciprocal relationship between the domains of science and language, (b) identification of a superordinate category (process and concepts) that links the domains of language and science, and (c) discussion of the value of using instructional approaches (such as student-generated predictions, conclusions) to strengthen the learning of both science and language. These key themes are illustrated using teacher quotes in the following section.

Reciprocal Relationship

> Science and language are connected . . . but teaching either one in isolation—even teaching science without working in a context is meaningless. I would say that they're connected. I personally like using science and I think that kids naturally gravitate toward scientific questions about the world. I think that you could also use literature and embed ideas so deeply in a piece of literature, in a story, in a context where kids also develop ELD. It works well to connect such closely related subjects. Science and language provide a cohesive learning context with the hands-on experiments and the science around plants and then having the English language development in addition—the transference. They need to feel it in their hands, to have those experiences and then to transfer it. When we talk about "flower" they have a context in which that exists. It's not just the word out in the world because that has no connection for them. I mean, a stem is something that we've been touching, drawing, playing with, working with, it's not just some thing that sits on a plant outside. It's part of what we've been doing. I find that if I don't talk about ideas, I don't internalize them so I think when students are exploring their ideas, thoughts and concepts they need the opportunity to write, reflect, talk, and figure out meanings together and have good discussions. Students need to have that language embedded in what they're doing and it seems hard for me to imagine doing ELD in a regular classroom without providing other rich experiences for them to connect to that language.

A coherent, elaborated discussion of the reciprocal relationship between science and language exemplifies teacher responses at Level 4. An understanding of a reciprocal relationship is inferred from the teacher's discussion of the processes in common between the domains of science and language, and illustrated by the teacher's use of experimentation as an instructional strategy for implementing an integrated approach to science and language. There is explicit acknowledgment of the advantage afforded by an integrated approach. This response highlights both the learning of science content and language development and notes that language functions help students to internalize ideas.

Processes in Common between Language and Science

> A good language learner makes predictions, a good language learner asks questions, and a good reader makes predictions and asks questions. A good reader figures out what the next question is going to be. A kid that knows how to read can guess the questions that a teacher is going to ask. A good science learner can do the same kind of thing. "Looking at this, these are the questions that come up." Those are strategies that are used in both science and language and in literacy and it ties so beautifully together, especially for the kids that have already been using science to learn language. In science there is so much opportunity for hands-on and so many opportunities for a child to become engaged. You're going to do predictions, try to justify what it is you're saying and offer proof. All of those things are also important language structures . . . language doesn't happen in a vacuum. If I combine science and a language lesson at the same time then I have the time to teach the science I want. Language, literacy, all of those . . . they're tools to learn about the world. Science is learning about the world. Take those tools and use them for the studies that we need to do.

This teacher response shows reflective analysis of her understanding of integration. Her explanation is grounded and informed by personal experience in implementing science–language integration in the classroom. She describes integration as a reciprocal process, using clearly articulated examples of both the conceptual and skill-based connections between science and language. Furthermore, she acknowledges that integrating science and language provides an effective means for her to teach and for her students to learn in both domains. Her understanding and applied experience extend beyond a knowledge of knowing that and becomes knowing how; she provides a rationale for why integration enhances learning in both domains.

Value of Instructional Approaches to Strengthen Learning Science and Language

> One thing I do is a lot of discussion. I don't think that you can have good inquiry science in a classroom without science conversation between the teacher and the group or the teacher and the individual, being facilitated. Those conversations are frequent and you find that the kids build on each other's conceptual understanding as they are talking. For example, with videos, let's say that I was studying interactions between animals. There are lots of good videos. The one that comes to mind is the *Survival of Life* series. Take a 5-minute video segment which shows a blind crawfish and a snail and how they interact together to protect each other within the environment. Turn the sound down, stop the video, and have the kids talk about what they have seen. . . . There's no narrating so they are working as observers. The important part is to have them provide the language . . . have them ask questions, have them generate notes, have them talk about what they think is going on. So that the class comes to a consensus as to what they think must be happening in that picture. Later, you can go back and let them hear the narration.

This teacher provides an example of how strategies such as structuring student discussions enhance learning in both science and language. At this level of expertise the teacher has both the understanding and the skills to implement integration effectively and to reflect thoughtfully on the dynamic relationship between her teaching and her students' learning. This response is an example of an advanced Level 4, lacking only a few indicators to rate it as Level 5 understanding (e.g., explicit identification of a framework, such as inquiry, for integration; discussion of integration across additional domains; use of language functions to promote higher-order thinking and concept development).

Level 5, Elaborated Integration

At Level 5, Elaborated Integration, individuals acknowledge the deeply interdependent relationship between science and language and view their interaction as dynamic. Individuals have developed a set of organizing principles to guide their decision making and use a conceptual framework for understanding specific interactions across and within domains (Baker-Brown et al., 1992). The integration of science and language is understood to enhance higher-order thinking in both domains. In addition, there tends to be a holistic perspective on the process of teaching and learning that enables individuals to adapt their behavior flexibly in response to specific contexts (Dreyfus & Dreyfus, 1986).

Teacher responses at Level 5 express a clear and elaborated understanding of how reciprocal integration guides the design and implementation of integrated science–language instruction. The interaction between science and language is viewed as synergistic, resulting in enhanced learning across domains. Teachers provide a thoughtful rationale for the effectiveness of integration and are able to draw on an elaborated and flexible repertoire of strategies for its implementation in a variety of situations and contexts. At this level there is an understanding of the importance of using an overarching conceptual framework such as inquiry for implementing an integrated curriculum across two or more domains of knowledge. Teachers know how to use a framework for teaching and also know why it affects learning. They may discuss how inquiry processes provide a context for the development and use of metacognitive processes (including language functions) to enhance students' understanding, and may also discuss the importance of providing students with opportunities to reflect on and guide their own learning. Teachers also recognize the value of reflection for analysis and improvement of their own teaching and use it as a technique to analyze their own practice.

In our analysis of teacher interviews we did not find solid, complete examples of Level 5 understanding of integration. Therefore, the quotations we present to illustrate this level of integration are an amalgamation of several teachers' responses that were each at a high Level 4 understanding of science–language integration. Level 5 exemplars are not contrived examples; rather, they are actual teacher responses, combined to reflect a clearly developed and articulated Level 5 understanding of integration. The exemplars represented in this section are the product or amalgamation of comments made by three or more teachers at different points in their interviews. Level 5, Elaborated Integration, is characterized by two main themes: (a) the use of a conceptual framework such as inquiry for understanding and implementing an integrated curriculum across two or more domains of knowledge; and (b) extension of the description of integration to include reflection, with examples of analysis and contextual considerations across a variety of domains.

Inquiry as a Conceptual Framework

> Inquiry science processes provide the context and opportunity to use academic language. I get much better student learning outcomes as a result of an integrated curriculum because students are engaged in a lot of hands-on projects which help develop higher-order thinking skills. The students need to touch and feel. They need to be actively involved. Instruction is not the teacher lecturing at them and them just taking notes or reading out of a book. Through inquiry, students learn the scientific processes and skills; they learn how to observe, classify, make predictions, and come up with hypotheses to explain why something happened. They read to learn and learn to write to communicate their scientific understanding with each other. I think that as kids are reporting to each other, as they put language to the thought process, they are discovering new concepts, they are generating

> academic language, they're having to speak about something that is not just playground oriented. Students practice how to defend their thoughts and opinions by providing supporting details. Through the interactive process between science and language, students develop critical thinking skills and learn in-depth content because they have opportunities to explore connections between science and language; in addition students learn differences between them.

Reflection and Extended Integration

> Language and science are interconnected. In both language and science, students practice reading and writing content information and how to express themselves in writing in order to communicate their ideas. Through this interactive process students generate discourse as they ask questions and figure out information either on their own or talking with other group members. The nature of the inquiry science interactions requires the use of higher-order language. The use of higher-order language enhances scientific understanding as it enables students to dialogue and make sense of abstract science concepts. The integration of language and science is a synthesis whereby science and language interact and support each other. The result of the synthesis is enhanced science and language understanding beyond the scope of learning science and language content separately. Applying this dynamic system in the classroom requires that I use a lot of different skills and alternate instructional strategies. For example, we need to have opportunities for field trips, even if it's just a 5-minute field trip out the door to do an observation in the garden. Kids need time to reflect and write and talk and discuss and learn . . . and there needs to be a tie-in to the real world. For example students can do a project on nutrition and analyze the food in their school cafeteria to learn about protein, carbohydrates, calories, etc. Science and language need to be tied in with all the curricular areas. If it's separate, then I don't think it is as effective because that's not the way the world works.

Both of these responses show a sophisticated understanding of integration. They provide clear evidence of understanding science–language integration as a synergistic relationship and give examples of how and why this approach to instruction enhances learning across academic domains. In both responses the teachers discuss the importance of using a framework for instruction (in this case, inquiry with hands-on experiences.) They provide a rationale to explain why this instructional approach leads to improved student learning in the form of higher-order thinking and the development of academic language, i.e., knowing why it works.

In the first quotation, the importance of students' role in generating their own learning through student-to-student and student-to-teacher interactions is recognized. The second quote points out that to implement science and language instruction effectively, a teacher needs to be flexible and able to employ a variety of instructional strategies. This quotation also emphasizes that integrated instruction makes connections between learning science and language with students' experiences in the real world. The teachers emphasize that relating academic science and language concepts to students' prior experiences and knowledge in other domains is an important component of an integrated approach to instruction.

Discussion

The traditional approach to educating English language learners, which separates the teaching of language from the teaching of science content, presents an unnecessary obstacle to the academic progress of language minority students. English language learners do not have to learn

English before they learn science. Engagement in scientific inquiry promotes the learning of academic English and science register, and the elaborated use of language is fundamental to developing a conceptual understanding of science content. The integration of authentic hands-on inquiry with linguistic and metacognitive analysis serves to promote the development of higher-order thinking skills. A synergistic view of language and science learning is consistent with the view of inquiry learning presented in the National Science Standards (NRC, 1996). This perspective, however, has not been well articulated in either teacher education or curriculum development, and thus teachers are rarely well prepared to offer integrated instruction. The research presented in this report is a first step in describing a practical model of science–language integration that could be used to inform both research and practice. The goal is to provide a lens to look at teacher thinking about science instruction for the rapidly increasing population of language minority students in the United States.

It is important to recognize that most teachers may function as novices when they encounter an approach to teaching which is outside the boundaries of their prior knowledge, education, and experience. The science–language integration rubric presented in this article thus describes a continuum based on the development of expertise that ranges from a view that science and language cannot be integrated to one that represents the relationship between science and language as synergistic. Teachers, irrespective of their years of teaching experience, are likely to develop several different conceptions of science–language integration as their understanding grows in complexity.

The progression outlined above was evident in the preliminary analyses of teachers' work in the LASERS summer staff development program. Before their participation, the majority of teachers viewed themselves as well prepared to teach either science or language, but not both. After their participation in the 5-week staff development program, the majority of teachers believed they had improved in the domain in which they had initially felt least prepared. This change in teacher understanding was typically represented by a shift from a restricted view of the connections between science and language (connected only by general themes) to a more elaborated reasoning about the different ways that teaching inquiry science and language development could be integrated. Teachers' more sophisticated views were characterized by the following components: (a) an emergent recognition of the relationship between science and language, (b) use of instructional strategies such as writing and questioning to link science and language, and (c) reflection on practice and the motivation to enhance the understanding of science–language integration. This progression was observed in both novice and experienced teachers. Their years of experience in teaching had little relationship to teachers' conception level of science–language integration.

It is not proposed that this is a developmental continuum, i.e., that teachers progress through all levels in a linear fashion. Teacher reasoning may move from a Level 1 to a Level 3, for example, without exhibiting Level 2. Instead, the rubric represents categories or ways of thinking about integration. The levels do represent an increasing sophistication in teachers' reasoning, and progress is likely to occur from less to more complex thinking. In the next research phase, the science–language integration rubric will be used to analyze shifts in teachers' beliefs and practice systematically as they are engaged in a range of science and language staff development activities. It will also be used to examine the relationship between teacher beliefs and practice—how teachers' views about science–language integration are reflected in their instructional decision making and the relationship between the different approaches to science–language integration and student learning outcomes.

The findings of this report suggest the need to rethink staff development activities and science teacher education. The artificial and rigid distinctions between the role of science teacher and language teacher must be broken down. All science teachers can benefit from understanding the function of discourse in the development of scientific understanding. The integration of science and language is not just an elaboration or a refocusing of a current approach; it involves a reconceptualization of what it means to teach science. The different approaches to integration described in the five-level science–language integration rubric provide a framework for preservice and in-service teacher staff development and curriculum development. Teachers can use the rubric and exemplars to examine and reflect on their own practice and as a guide in analyzing and planning instruction. The rubric can also be used by curriculum developers to design science units in which language is explicitly connected to concrete objects and hands-on activities.

This article focuses on the preparation of teachers to teach science to language minority students. It could be argued, however, that engaging teachers in the process of science–language integration is a vehicle for improving the teaching of science for all students. To understand the integration of language development and science inquiry, teachers need to differentiate between the characteristics of individual domains and also understand the structural and process similarities that support domain integration. This will involve them in a structural analysis of science instruction that focuses their attention on the relationships among physical action and models, science discourse, and metacognitive analysis. Frequently inquiry science is viewed as synonymous with hands-on instruction and the importance of discourse and reflection is overlooked. By simultaneously looking at both aspects, teachers deepen their understanding of the nature of science inquiry itself.

Finally, although this argument has been made in the context of science, it could be elaborated to include other subject areas such as mathematics and social studies. Teachers of all students, not just language minority students, need to know the importance of contextualization in the development of academic language. All students can benefit from learning experiences that enable them to use language functions such as describing, hypothesizing, reasoning, explaining, predicting, reflecting, and imagining in the learning of subject matter. The critical point is that language processes can be used to promote understanding of content across all subject matter domains, and that language use should be contextualized in authentic and concrete activity. In states such as California, where language minority students represent a significant percentage of the school-age population, methods of English language development should be integrated into all elementary and secondary subject matter methods classes and staff development programs. Integrated instruction will assist language minority students in mastering the English language and simultaneously improve their achievement in academic subjects.

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