*Promoting Science Instruction and Assessment for English Language Learners

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Introduction

In the current climate of high-stakes assessment and accountability, science has a unique status compared to other core school subjects, such as reading, writing, and mathematics. Overall, in today's school curriculum, science is emphasized far less than other subjects (Hewson, Kahle, Scantlebury, & Davies, 2001; Spillane, Diamond, Walker, Halverson, & Jita, 2001). As states turn more and more to assessments for accountability purposes, what gets tested largely determines what gets taught in the classroom (McNeil, 2000). When science is not part of statewide assessments, science is taught to a minimal degree or is not taught at all during the elementary grades. Even when science is part of statewide assessments, the types of science knowledge and abilities being tested might not validly assess content area knowledge for all learners (Abella, Urrutia, & Shneyderman, 2003; Solano-Flores & Trumbull, 2003).

Although accountability systems impact the school learning of all students, the impact is greater with some students, including those learning English as a new language, referred to as "English Language Learners" (ELL's) (McNeil, 2000). Beyond the challenges faced by their English proficient peers in learning science, ELL's also need to develop English language proficiency. In addition, those with

limited literacy or little schooling in their home countries need to develop general literacy. Complex issues abound in high-stakes assessments and accountability, such as who counts in accountability systems, how to make assessment accommodations, and how to assess content knowledge separate from English proficiency or general literacy (National Center for Research on Evaluation, Standards, and Student Testing, 1996; Ruiz-Primo & Shavelson, 1996; Shepard, Taylor, & Betebenner, 1998). Yet, ELL's bring cultural and linguistic resources that can be valuable in learning science, but may not be easily recognized by the mainstream (Lee & Fradd, 1998; Moje, Collazo, Carillo, & Marx, 2001). For example, in classroom settings that capitalized on students' prior knowledge as intellectual resources, Haitian immigrant students engaged in scientific inquiry and participated in animated arguments about natural phenomena in ways consistent with both Haitian culture and scientific practice (Warren et al., 2001).

This paper addresses issues of science instruction and assessment with ELL's. First, the importance of science learning for all students, particularly ELL's, is stressed. Second, the current status of science instruction and assessment for ELL's is reviewed. Finally, effective policies and practices for science instruction and assessment that enables ELL's to become effective learners are described. This paper focuses on English as a Second Language (ESL) or English to Speakers of Other Languages (ESOL) programs, two among the variety of educational programs to promote English language proficiency for ELL's. The paper underscores that even when science is not a part of statewide assessment and accountability systems, participation in science instruction can promote literacy development and English language proficiency for all students, particularly ELL's.

The Importance of Learning Science for ELL's

Science education standards documents generally agree on what all students should know and be able to do in science in order to become educated members of society (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996; for summary, see Lee & Paik, 2000; Raizen, 1998). These documents define science in a comprehensive manner that includes not only scientific understanding and inquiry, but also how science is related to personal, social, cultural, economic, and historical perspectives. Although science is important for all students, it is particularly beneficial for ELL's not only in science learning, but also in literacy development, English language proficiency, mathematics, communication, and habits of mind (e.g., critical thinking, empirical verification), to be described next.

Science Learning

As a study of natural phenomena in everyday life, science offers significant learning opportunities. In particular, hands-on science can promote student engagement, interest, curiosity, and excitement in learning about natural phenomena (NRC, 2000). For students who have limited prior experience in science, hands-on science offers the context for life experience in the classroom setting as well as enrichment for further learning. Hands-on science also reduces the burden of language use, thus allowing students to focus on science content. For students with limited exposure to literacy, concrete experiences build the basis for complex and abstract thinking. As students relate their prior knowledge and experience to newly constructed knowledge, science learning becomes meaningful and relevant.

Science encourages students to be inquisitive about natural events, ask questions, and devise plans for answering these questions. Some students may have difficulty with inquiry if they come from cultural backgrounds where they are expected to unquestioningly accept teachers' authority, rather than

questioning, exploring, or seeking alternative solutions (Atwater, 1994; Fradd & Lee, 1999a; Hodson, 1993; Losey, 1995; McKinley, Waiti, & Bell, 1992; Nelson-Barber & Estrin, 1995; Swift, 1992). To the degree that teachers are respected as authority and sources of knowledge, students may be reluctant to raise questions if their culture considers this to be a sign of disrespect. In fostering scientific inquiry with these students, teachers need to provide instructional scaffolding that integrates the students' cultural values with scientific practices. As the students engage in scientific inquiry, they gradually learn to generate explanations or models for observed patterns with natural phenomena based on evidence and logic, not based on the authority of teachers or other adults. Students also learn to perform individually and independently, as well as work collaboratively in groups.

Literacy Development and English Language Proficiency

Literacy development involves abilities well beyond being able to speak, listen, read, and write. Literacy involves learning to think and reason. Language functions (e.g., describing, hypothesizing, explaining, predicting, and reflecting) develop simultaneously with science inquiry and process skills (e.g., observing, describing, explaining, predicting, estimating, and inferring). In this sense, hands-on science promotes thinking and reasoning that involves both literacy and science learning (Amaral, Garrison, & Klentschy, 2002; Casteel & Isom, 1994; Fradd, Lee, Sutman, & Saxton, 2002; Hampton & Rodriguez, 2001; Lee & Fradd, 1996a; Stoddart, Pinal, Latzke, & Canaday, 2002).

Literacy development occurs along a continuum from preliterate, with little or no exposure to text, to the age- and grade-appropriate development necessary for academic achievement. Preliterate students require a great deal of support in academic learning. Science enables them to associate real-world objects and events with symbolic representations. Students progress from describing "here and now" events, to reporting "what happens" for those who are not present at the events, and then to

hypothesizing about "what will happen." Through this process, students move from simple and concrete to more complex and abstract ways of thinking.

In addition to general literacy, students need to acquire English language proficiency to effectively participate in mainstream classrooms. Developing literacy and proficiency in two or more languages promotes cognitive flexibility and capabilities (Cummings, 1984, 1986; Gándara, 1999). In learning science, students may start by observing, imitating, and interacting with others and gradually learn to perform independently. Through this process, students communicate about science in other languages as well as in English. In addition to promoting academic achievement, the use of students' home languages enhances their cultural and linguistic identities (García, 1999; Moll, Diaz, Estrada, & Lopes, 1992).

Mathematics Learning

Mathematics is an integral part of science. To conduct science inquiry, students need to measure weight, volume, length, temperature, speed, and many other properties of objects and events. Students also need to use statistics and probability concepts for data analysis and interpretation. In addition, they need to know how to record and present data in multiple formats including graphs, charts, tables, figures, and drawings. Thus, students become precise and accurate in taking measurements, apply mathematical concepts, identify patterns and anomalies in data, and use multiple representational formats for data displays. The ability to represent and interpret information across a range of contexts is an essential skill that educated members of society use in analyzing statistical information, preparing reports, evaluating financial offers, and recognizing unsubstantiated claims.

Communication

Communication is an important part of science for all students. It is especially important for students from non-English language backgrounds. When students work on tasks involving science or technology, they apply concepts and procedures regardless of their backgrounds. However, the ways they interact and communicate and the ways they interpret and present ideas may differ across languages and cultures (Cazden, 1988; Heath, 1983; Lee & Fradd, 1996b). In situations involving participants from diverse backgrounds, students from non-English language backgrounds need to learn ways of interacting and communicating across culturally diverse settings. If these communication skills are developed, such students can modify and accommodate their communication to meet the needs of a variety of audiences in a range of contexts.

Habits of Mind

Science involves more than understanding a body of knowledge or engaging in inquiry process. Science promotes habits of mind, including certain values, attitudes, and worldviews. Scientific habits of mind generally reflect the norms of the western society in which modern science has evolved, such as critical and independent thinking, tolerance of ambiguity or uncertainty, skepticism, empirical verification, arguments based on evidence and logic, and questioning rather than deference to authority (AAAS, 1989, 1993; NRC, 1996, 2000). These values and attitudes may be incongruent with the norms of cultures that favor cooperation, consensus building, social and emotional support, and acceptance of the authority of teachers and elders (Aikenhead, 1996; Atwater, 1994; Cobern & Aikenhead, 1998; Lee, 1999b; McKinley et al., 1992).

Because science promotes fundamental ways of thinking in the science community and the mainstream, the cultivation of scientific habits of mind may be one of the most important contributions that learning science offers these students. By recognizing and appreciating a variety of ways of

explaining events, students realize the importance of cultural and linguistic diversity in ways of knowing and talking.

In summary, ELL's bring their own cultural and linguistic experiences to the learning process. Through instruction, they learn science knowledge, inquiry, and habits of mind. They also learn to communicate and interact according to the norms and traditions of the mainstream. Through these experiences, ELL's make sense of natural and social phenomena from diverse points of view, solve problems in alternative ways, and communicate ideas and results using multiple formats.

The Current Status of Science Instruction and Assessment for ELL's

Although science learning is demanding for most students, it is particularly challenging for students learning English. In addition to learning academic knowledge, ELL's need to develop English proficiency and ways of communicating and interacting in the mainstream. ELL's with limited literacy or little schooling in their home countries also need to develop general literacy. Because of these multiple requirements, ELL's are more vulnerable to discontinuities that occur when policies and practices fail to meet their learning needs.

The Current Status of Science Instruction for ELL's

In states implementing statewide assessments in literacy and mathematics but not in science, the pressure for accountability overshadows elementary students' access to and learning opportunities in science. Schools serving ELL's and students in inner-city schools are pressed to ensure students' basic achievement in literacy and mathematics. Given the primary educational goal in literacy and mathematics accompanied by accountability pressure, school administrators require that teachers focus on these subjects at the expense of other subjects including science. Significant portions of ELL's attend inner-

city schools, and they often have limited exposure and access to science both at home and at school (Fradd & Lee, 1995).

In elementary schools across the nation, literacy and mathematics take up most of the instructional time, with little left during the school day for other subjects. The U.S. Department of Education reported that most elementary schools allocate over two hours to literacy (reading and writing) instruction daily (National Center for Education Statistics, 1997). One hour is given to mathematics instruction, and another hour is divided between social studies and science. To engage in any meaningful science lesson, 30 minutes is insufficient — students can barely complete a hands-on science activity, leaving little time for setting up the activity beforehand or discussing the results afterwards. In addition, science is usually scheduled in the afternoon when special school activities tend to occur. As a result of both planned policies and inadvertent practices, the instructional time available for science is greatly limited.

Although state statutes require that all elementary students, both English proficient and ELL's, have equivalent content instruction, ELL's may be removed from their classrooms during time periods allocated for content learning to receive instruction for English language development (Fleischman & Hopstock, 1993; Thomas & Collier, 2001). Although ELL's should have science instruction, such learning opportunities are not always possible or feasible under these schedules. Thus, ELL's may not be exposed to science until they become "English proficient." Once ELL's are assessed and determined to be English proficient, they receive science instruction in English in regular classrooms. Even those students who appear fluent in English often require assistance in learning the academic language of science (Scarcella, 2003). Use of students' home language can help them understand science concepts and communicate ideas. Unfortunately, in an effort to promote English language development, policies

sometimes prohibit teachers and students from using languages other than English, even in classrooms where teachers and students share the same languages.

In secondary schools, ELL's enroll in regular classes for content area instruction, including science. Because secondary science teachers are often not skilled to work with ELL's, even with the best of intentions, they may not meet ELL's learning needs. Some secondary science teachers may even resent having ELL's placed in their classrooms, believing that these students should master English first in order to learn science in regular classrooms. ESL or ESOL teachers may also fail to provide appropriate instruction because of their lack of science knowledge. As a result, ELL's may be physically present in science courses, but may not receive meaningful input or opportunities to learn science (Rumberger & Gándara, 2000).

Science instruction depends greatly on the availability and appropriateness of instructional materials. Science supplies and equipment are often insufficient, although "teachers should not be expected to supply the essential supplies of teaching" (NRC, 2000, p. 139). Even when supplies are available in the school building, these may not be easily accessible to individual teachers. Science books and materials in languages other than English are also limited. Most science instruction is done in English with regular science textbooks. The vocabulary in such textbooks is generally language-intensive and difficult to understand, even for English proficient students. In fact, science textbooks often have more vocabulary words than those in foreign language textbooks. Without the support of instructional materials and with an overemphasis on technical language, content instruction is difficult for both ELL's and their teachers (Scarcella, 2003).

The Current Status of Science Assessment for ELL's

Assessment policies and practices exist at national, state, district, and classroom levels. Assessment at each level has a variety of purposes, data collection methods, decision-making requirements, and use of results. Regardless of these differences, assessments should be aligned with science content standards in terms of promoting excellence while being fair to all students.

National Assessment of Educational Progress [NAEP] at the U.S. Department of Education has been the only national-level assessment in various subjects, including science, since its inception in 1969. The most recent NAEP science assessments in 1996 and 1999 significantly incorporated science content standards (Campbell, Hombo, & Mazzeo, 2000; National Assessment of Governing Board, 1994, 1996; Sullivan, Reese, & Mazzeo, 1997).

These assessments used short answer items, extended response items, and performance measures, in addition to multiple-choice items. The reports provided student achievement data for a national sample at grades 4, 8, and 12. The reports also provided group comparisons in terms of ethnicity, gender, and other demographic variables. Generally, Hispanic, Black, and American Indian students had lower average performance than White and Asian/Pacific Islander students at all three grades. The 1996 and 1999 science assessments included limited English proficient students and students with disabilities and offered an array of accommodations for these students (Campbell et al., 2000; Sullivan et al., 1997).

Standards-based reform has been active and strong across the nation. Although most states administer assessments in literacy and mathematics, many do not implement science assessments (American Federation of Teachers, 2001). With no statewide assessment or accountability in science, even school districts that once had comprehensive science assessments tend to eliminate them. In these

states and districts, science assessment is expected locally. Thus, public means to hold the states, districts, or schools accountable for science instruction is lacking.

Teachers are in the position of assessing their students' science performance on a daily basis. To assess ELL's learning progress and achievement in science, teachers need to differentiate students' English language proficiency, literacy development, and science performance. Teachers also need a solid understanding of science content. In addition, they need a sound knowledge of concepts related to assessment, such as validity, reliability, utility, and practicality. Unfortunately, teachers often lack knowledge in these multiple areas (NRC, 2001; Shaw, 1997). Because of such difficulties, science assessment for ELL's may often be conducted inadequately.

Effective Science Instruction and Assessment for ELL's

Science content standards require higher-level thinking and complex abilities of all students. Compared to the traditional notion of knowing science facts and vocabulary, the current view expects students to think, reason, investigate, communicate, and solve problems. Efforts need to be made to ensure that all students have access to and learning opportunities in science.

Effective Science Instruction for ELL's

In any learning situation, students bring their previous experiences and prior knowledge related to the topic of study. ELL's bring with them their own ways of looking at the world, which may not be compatible with the nature of science or the way science is generally taught. On the other hand, ELL's may bring cultural and linguistic resources that can promote science learning as well as general literacy and English language proficiency (see Lee, 2002 for literature review).

States have established policies and practices to meet the learning needs of ELL's through both regular and special instructional programs. In states and school districts with high proportions of ELL's,

education policies require regular teachers to be prepared for effective instruction. These policies apply to almost all elementary teachers in self-contained classrooms and a large number of secondary teachers in content areas, including science. To work with ELL's, regular teachers need to understand the students' languages and cultures in social and academic contexts (August & Hakuta, 1997). They also need to understand how to incorporate the students' linguistic and cultural experiences with academic content, such as science (Lee & Fradd, 1998). For example, teachers may relate science content and process to: (a) students' lives at home and in the community; (b) cultural artifacts, culturally relevant examples, and community resources, and (c) students' culturally-based communication and interaction patterns (Barba, 1993; see Lee, 2002 for literature review).

As regular teachers are learning more about how to work with ELL's, ESL or ESOL teachers can be prepared to collaborate with regular teachers. Because of the urgency for students to acquire English language proficiency, ESL or ESOL programs tend to focus on literacy at the expense of other subjects. Although ELL's may develop general literacy and social language, they fail to learn the more complex academic language of science (Cummins, 1984, 1986; Scarcella, 2003). Thus, ESL or ESOL teachers can work with regular teachers to promote academic language in science, while developing English language proficiency and general literacy simultaneously. As a result of such instruction, when ELL's are exited from ESL or ESOL programs, they will have an understanding of science equal to that of their English-speaking peers. Collaborating and planning instruction will increase learning opportunities for ELL's as their content area objectives are presented in multiple ways (e.g., thematic units), specifically with the support that ESL or ESOL teachers are trained to provide. At the same time, ELL's English vocabulary will grow stronger as they are supported while learning new concepts in their second language.

Hands-on science provides natural settings for students to use literacy and mathematics. Because communication and computation are integral in science, science can be part of literacy and mathematics instruction. By integrating academic content across subjects, teachers can help students see meaningful connections and relevance among various subjects. An integrated approach is especially important for ELL's with limited access to science instruction and limited opportunities to experience the relevance of science in everyday life (Amaral et al., 2002; Casteel & Isom, 1994; Fradd et al., 2002; Hampton & Rodriguez, 2001; Stoddart et al., 2002).

Science instruction requires adequate supplies and equipment. Although science equipment is often expensive, supplies do not have to be costly or sophisticated. In fact, everyday, household items may be more meaningful and relevant for students, as well as more affordable and easier to maintain than expensive equipment. Nevertheless, an adequate budget is required for science materials. These supplies need to be stored and organized for easy access and use. Some science materials are available in multiple languages. The increasing availability of technology in multiple languages means that school districts can consider science as an area for multiple language learning. Even when few or no commercial materials in multiple languages are available, districts can assist by developing lists of terms and phrases in students' home languages to facilitate communication and comprehension of key science concepts.

Effective Science Assessment for ELL's

Traditional assessments generally focus on basic knowledge and skills in multiple-choice formats. In contrast, science content standards require different kinds of assessments to measure higher-level thinking and complex abilities. Policies and practices to promote assessments aligned with the standards are needed in the context of current assessment reform.

For those states that do not have science assessment systems, science could be part of statewide assessments for literacy and mathematics. For example, prompts for writing assessments or passages to assess reading comprehension could be related to science topics. Similarly, mathematics assessments could use examples of hands-on science activities with mathematics applications. For those states that have science assessments focusing on coverage of science content, policies and practices may not promote the reform-based science in standards documents. Yet, science instruction can be comprehensive in order to promote meaningful learning that also ensures content coverage.

District and school support for effective assessment practices is critically important, especially in those states with no statewide science assessments. To establish accountability in science, districts and schools could require science grades on report cards to be based on students' performance in the classroom. Using science content standards as the criteria, assessments and grades could reflect the extent to which students have reached these standards.

District and school policies could allow accommodations to meet ELL's needs in science assessments. Such accommodations include flexible time restrictions, availability of dictionaries in both home languages and English, use of assessment materials in home languages, and use of multiple measures. In addition, students could have opportunities to become familiar with assessment procedures and test-taking strategies.

An important aspect of classroom assessment includes the use of meaningful and relevant topics, tasks, and activities. Teachers may employ assessment practices for ELL's, which may serve to benefit all students. First, using two separate scoring criteria, teachers may assess ELL's for science learning and English language proficiency separately. This assessment practice enables teachers to identify strengths and weaknesses of ELL's in both science content and English language. Such scoring rubrics

in elementary science instruction are available (Fradd & Lee, 2000; García, Bravo, Dickey, Chun, & Sun-Irminger, 2002).

Second, teachers may assess ELL's in their home languages as well as in English. Allowing students to communicate science knowledge in their home languages promotes both general literacy and academic learning which, in turn, promotes English language proficiency. The emphasis on English language proficiency should not overshadow the importance of general literacy and academic learning. Achievement in these three areas can develop simultaneously (Scarcella, 2003; Thomas & Collier, 2001).

Finally, teachers may promote the use of multiple representational formats, keeping in mind that the goal is move students toward established literacy standards. Those who cannot write in either home language or English can express ideas in drawings or through oral communication. For example, a newly arrived Haitian elementary student, who had developed very limited literacy and little schooling, had difficulty even holding a pencil. When he was asked to explain why a boat made of clay would float or sink, he became intently involved, gave explanations in terms of the air in the boat, and related this task to his perilous journey to the U.S. on a boat. Not only did the oral assessment allow him to demonstrate his knowledge of the topic, it made science come alive for him.

Conclusions

Despite efforts to ensure that all students receive equivalent content instruction and fair assessment, opportunities to learn science may be more limited for ELL's than for English proficient students. In addition, educational policies and practices may reduce opportunities for meaningful science instruction. Educators at various levels of the educational system should make efforts to provide resources and opportunities that meet the learning needs of all students, including ELL's. With

innovative and creative planning, much more can be done without overburdening the current system. In providing quality science instruction for all students, the education system should prepare students to become educated citizens and to participate effectively in a multilingual and multicultural society.

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