Teaching science: meeting the academic needs of culturally and linguistically diverse students.

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In this article, we discuss ways for teachers to address the academic needs of students who are culturally and linguistically diverse (i.e., have a language background other than English) in inclusive classrooms through the modification of science instruction. We provide an example of a lesson plan showing specific suggestions and offer multiple strategies for modifying science instruction to promote "science for all."

Today, schools across the country are working to deliver an appropriate and effective curriculum for all students as indicated by the enactment of Goals 2000: Educate American Act of 1994. Various professional organizations have responded to this concern by calling for curriculum changes and by developing curriculum standards for all children. In the case of science, the 1996 standards developed by the National Research Council (NRC) assume the participation of all students (American Association for the Advancement Of Science, 1993). These standards require science teachers to create an accessible environment that actively involves all students--including students who are culturally and linguistically diverse (CLD) and those with a disability--in the learning of science process skills (e.g., observing, communicating, and applying information in a variety of formats [AIMS Education Foundation, 1986]). This is important because these students have been underserved. Research data have indicated that CLD students perform poorly in academic areas when compared to their mainstreamed peers (e.g., Snyder, 1995).

Many CLD students are at risk for school failure (Gonzales, Brusca-Vega, & Yawkey, 1997; Snyder, 1995; Stephens & Price, 1992). They also often come from families with lower incomes and less formal education. As a result, these students may not have the experiences or the social and/or academic preskills necessary to succeed in schools, and they are more likely to be identified as having a disability (Collier, 1998; Gonzales et al., 1997; Westby, Dezale, Fradd, & Lee, 1999).

The first step in promoting scientific literacy for CLD students is recognizing the possible reasons they may struggle to perform well in science. The second step is using this knowledge to make appropriate modifications to science instruction. In this article, we address the academic needs of CLD students (with or without disabilities) in inclusive classrooms through the modification of science instruction. We provide an example of a science lesson plan (see the Appendix) with specific suggestions and strategies for modifying instruction to promote science for all.

The Problem

Given the growing diversity within the school-age population, expecting teachers to include all students poses numerous challenges. One of these challenges is the multiple learning requirements of science classrooms. Science performance is influenced by science knowledge and vocabulary, the use of cognitive strategies, and sociocultural influences (Akatugba & Wallace, 1999; Lee &

Fradd, 1998; Lee, Fradd, & Sutman, 1995), and CLD students (i.e., learners from non-English language backgrounds) often have limited language and empirical knowledge (Westby & Velasquez, 2000), may have a disability (Baca & Cervantes, 1998), and come from different "socio patterns of organizations"--different socioeconomic backgrounds and different social rules (Rakow & Bermudez, 1993; Tharp, 1997). A second challenge is that teachers are not prepared to teach science to learners who are CLD (Barba, 1993; Rakow & Bermudez, 1993; Yates & Ortiz, 1998).

The equity and excellence principles upon which the National Science Education Standards were developed require educators to promote scientific literacy, which involves "knowing" science (vocabulary and knowledge), "doing" science (inquiry and process), "talking" science (discourse and communication), exploring attitudes and values about science, and achieving a scientific "worldview" (identify ways of learning science that are different from the way one learns about other bodies of knowledge; Lee & Fradd, 1998). Teachers must create lessons and use teaching strategic that address the students' knowing, doing, and talking about science (Westby, 1997; Westby & Velasquez, 2000).

Science instruction provides many benefits to all students but particularly for CLD learners. Science offers a context for language development; increases the development of scientific process skills such as communicating, infering, and applying; and helps students to better understand their world (Lee & Fradd, 1998; Mastropieri & Scruggs, 1992; Watson & Houtz, 1998; Westby, 1997, 1998). Hands-on science lessons, which are usually considered beneficial to students with language difficulties, can pose significant challenges to CLD students, however, if these lessons are not well planned, because of differences in language, sociocultural experiences, and past learning experiences (Akatugba & Wallace, 1999; Au & Kawakami, 1994; Lee & Fradd, 1998; Lee et al., 1995; Westby et al., 1999; Westby & Velasquez, 2000). For example, students may not have the background knowledge to understand certain scientific concepts (e.g., properties of earth materials), the sociocultural learning skills to participate in activity-based lessons (e.g., working with a partner in an experiment), and the language skills to understand and communicate scientific concepts (e.g., volcanoes and earthquakes can cause dramatic changes to the earth's surface). In short, meeting the standards generally is more cognitively demanding for students with limited English proficiency than for students whose first language is English (Akatugba & Wallace; Lee et al., 1995; McKeon, 1994).

To meet the needs of diverse students, educators need to do the following:

1. They must recognize what is required in learning tasks such as vocabulary knowledge (e.g., crust), the ability to make inferences (e.g., If the earth has grass, trees, etc., then the earth is a living planet), and the ability to work independently.

2. They also should know their students' strengths and weaknesses (e.g., completion of tasks, reading decoding skills).

3. Once these tasks are accomplished, the educator must determine the reason for the mismatch between a student's abilities and the task requirements of the lesson (e.g., pragmatic knowledge of class activities participation; Au & Kawakami, 1994; Collier, 1998; Echevarria, Vogt, & Short, 2000; Friend & Bursuck, 1999; Lee & Fradd, 1998; Westby et al., 1999). For example, some of the students who are required to work independently on a hands-on assignment (see the Appendix) have been socialized to be told what to do and to value rote memorization (Cheng, 1991; Collier,

1998; Trueba, Cheng, & Ima, 1993). This mismatch will probably prevent these students from participating successfully in the science lesson (Barba, 1993; Lee & Fradd, 1998; Westby et al., 1999).

Possible Reasons CLD Students Struggle

According to Baca and Cervantes (1998), the student who is culturally and linguistically diverse has to acquire a second language and a second culture. Acquiring a second language is an arduous and slow process that involves learning different ways of thinking, interacting, and communicating. This process is composed of linguistic, cognitive, social, and emotional tasks. Students may experience memory slippage, feelings of inadequacy, and fatigue, among many other stress-related behaviors that are considered normal side effects of second language acquisition and acculturation (Baca & Cervantes; Berry, 1976; Collier, 1985; Padilla, 1980). These psychological side effects occur along with life's daily challenges, all of which can place the CLD student at risk for poor academic performance (Collier, 1998).

Second language acquisition is influenced by a variety of factors--singly and collectively--including the student's age when he or she arrived in the new culture, his or her level of first language development, and the type of instruction and the opportunities afforded to him or her to use language in contextualized and decontextualized instructional situations. Cummins (1984, 1989, 1994) explained that the development of conversational language or basic interpersonal communication skills (BICS) in a second language can take approximately 2 years, while development of academic language or cognitive/academic language proficiency skills (CALP) can take as much as 5 to 7 years. Acquiring a second language thus is similar to acquiring a first language: It takes time and requires rich learning environments (e.g., access to good language models, opportunities to engage in conversations).

Language and culture are interrelated because language is a tool for communication but also a system that represents how one thinks, perceives, and behaves (Stewart & Bennett, 1991). As noted previously, learning a second language thus also means acquiring a second culture (Jiang, 2000). Culture influences people's behavior, language function, and language use (Hall, 1976; Rivera & Rogers-Adkinson, 1997). For example, some students come from cultures that tend to value being part of a group and are less bound to the monochronic (i.e., one thing at a time) concept of time. Individuals from other cultures may learn by observing rather than by being told the steps of a task. They often use topic-associated language, and communication is usually symmetrical (i.e., individuals assist one another in carrying on the conversation; Hall). Teachers need to be aware of these possible differences when planning science instruction for CLD students.

As we have suggested, culturally and linguistically diverse students are at risk of performing poorly in science because they usually lack the linguistic, the cognitive, the social, and the emotional behaviors required by science learning (Lee & Fradd, 1998; Lee et al., 1995; Westby et al., 1999). Because the behavior, culture, and language of CLD students are usually different from those involved in the task requirements (Akatugba & Wallace, 1999; Au & Kawakami, 1994; Lee et al.; Westby & Velasquez, 2000), these students often have difficulty completing science projects. For example, some scientific tasks require the use of a "one-step-at-a-time" procedure; the CLD student may be used to engaging in multiple steps at the same time (Hall, 1976; Lee et al.). This discrepancy places him or her at a disadvantage and can negatively influence overall performance.

Teachers thus need to identify the discrepancy between task demands and student ability and then modify to their lesson plans accordingly. By understanding the process of acquiring a second language and a second culture and the cognitive, linguistic, emotional, and social demands involved in the process, science teachers can incorporate instructional conditions that attend to the students' needs (Collier, 1998; Luft, Bragg, & Peters, 1999; Westby et al., 1999). Doing so often also provides the educator with insight regarding how he or she teaches (Blair & Jones, 1998; Collier, 1998; Echevarria et al., 2000).

Planning Science Lessons

Given the number of factors that influence the learning of CLD students, teachers must carefully select the science concepts to be taught. By using what is known as the Planning Pyramid (Schumm, Vaughn, & Leavell, 1994), science teachers can consider the needs of CLD students and the need of the rest of their students. Science teachers can select and organize concepts according to the different degrees of learning (i.e., information essential for all students to learn, information that most students should learn, and information that a few students have an interest in learning; see Figure 1). The degrees of learning are at the foundation of the Planning Pyramid, and they are based on the assumption that all students are able to learn although not all students will learn all the information presented in a lesson. Equal access to information is provided to all students, but the presentation of information is varied according to a student's needs.

Figure 1. Planning pyramid

What some students will learn

* Changes the Earth went through over millions of years.

* Forces that cause changes in the Earth.

* Different types of fossils and precious minerals that can be found by a geologist.

* Ways man can mine rocks without disturbing the Earth.

What most students will learn

* Describe at least 1 way to mine rocks without hurting the Earth.

* Fossils are found in the Earth's crust

-- Crust is constantly changing, and it has layers.

-- Earth layers: crust, mantle, outer and inner core

What ALL students should learn

* Earth has layers.

* Outer layer (crust) is where we live.

* Most of the Earth's crust is covered with land and water.

* There is more water than dry land.

* There are rocks under us.

To provide equal information access for all students, science teachers must specifically plan contextualized and decontextualized instructional activities that are cognitively demanding and undemanding for each lesson (Rupp, 1992). The example lesson plan shown in the Appendix depicts the Quadrant of Task Demand (Cummins, 1984; see Figure 2). According to Cummins (1984), tasks can be cognitively demanding (i.e., require active thinking) or cognitively undemanding (i.e., are done without thinking, automatically). For each student, the level of difficulty and the cognitive demand may vary. Cognitively demanding and undemanding tasks can be context-embedded or context-reduced. Context-embedded tasks are contextualized through the use of objects, body movements, pictures, and hands-on materials to assist students in understanding the language used in the science task--for example, making a model of the earth or doing a laboratory experiment. In contrast, context-reduced tasks are dependent on language only to convey meaning for a science concept--for example, reading about the layers of the earth. Figure 2 shows planned activities for the task demands in each quadrant.

One misconception many educators may have about contextualized instruction is that it requires lowering academic standards. Science teachers can use numerous instructional strategies to differentiate instruction without "watering down" the curriculum (Boudah, Lenz, Bulgren, Schumaker, & Deshler, 2000). Contextualization means drawing from students' personal experiences and building on their prior knowledge to teach the new scientific concept. Teachers can "group individualize" the process by structuring questions that encourage each student to think about his or her own personal experience as it relates to the topic or content to be learned (e.g., "Think of a time when you or someone you know ..." "What part of the earth are you from?") and/or by providing common experiences to all students (e.g., books, videos, and field trips; see the Appendix). All students, not just CLD students, can benefit from contextualization. For example, contexualization includes designing instructional tasks so that students can understand more complex concepts through instructional conversation by questioning, restating, praising, encouraging, and demonstrating the concepts to be learned (see examples in the Appendix).

The use of contextulized instruction provides CLD students the support they need for understanding the lesson by visually representing the information through experiments, pictures, graphic organizers, and charts (see the Appendix). Contextualization allows teachers to (a) consider their students' language proficiency levels of vocabulary control and (b) highlight specific text information. This type of instruction interrelates content across subject areas through the development of thematic units, making learning more meaningful through linkages across different types of learning activities (Echevarria & Graves, 1998; Zehler, 1994). It also includes having students work in pairs and in small groups; devising classroom interactions between the teacher and the students; and maintaining a balance among teacher-directed, individual, and small-group activities (Diaz-Rico & Weed, 1995). All or some of these instructional strategies can be used to differentiate instruction, and they will benefit all students (see the Appendix).

Choosing Instructional Strategies

In view of the needs of CLD students, the science teacher might make use of thematic units (i.e., the planning and organization of instruction where each discipline/subject is interrelated; see Figure 3). These units facilitate the linguistic and cognitive demands of learning science in a second language by allowing CLD students to build on previously learned vocabulary and concepts (Myers & Boothe, 2000; Zehler, 1994). The teacher must also use instructional conversation with the purpose of integrating students' cultural and linguistic resources to construct scientific learning (Cummins, 1986; Franquis & Reyes, 1998). Students' background knowledge must be assessed (e.g., "What do you know about the earth?") and activated (e.g., "What part of the earth are you from? Tell me if there are trees where you live"). This will help the teacher determine the extent of a student's existing knowledge (Echevarria et al., 2000; Reiss, 2001). The teacher builds on new knowledge by connecting the new information to students' prior knowledge (e.g., "If where we live we have trees, weeds, flowers, and grass, then we live on the earth's crust"; Diaz-Rico & Weed, 1995; Echevarria & Graves, 1998; Lee et al., 1995; Saunders, O'Brien, Lennon, & McLean, 1998). All students can remember relevant information better than irrelevant information, and using thematic units and activating prior knowledge can make learning more meaningful (Bos & Vaughn, 1998; Echevarria & Graves; Mastropieri & Scruggs, 2000; Roberts & Kellough, 2000). This is especially true for the CLD students (Lee & Fradd, 1998; Lee et al.; Westby et al., 1999).

Figure 3. Thematic unit.

Our Changing World

Physical Education

* Students move like planets--relate how body changes as does the Earth

Social Studies

* Climates

* Growing crops in different areas of the world

Math

* Weigh precious minerals

* Story problems: buying and selling precious minerals

* # population in other countries

Music

* We Are the World

Technology

* Web sites

* CD: Magic School Bus

* Wordprocessing

Art

* Make volcano

* Create pet rock

Reading

* Magic School Bus

* Keepers of the Earth

* Multicultural literature

Language Arts

* Volcano-shaped word search

* Writing stories

Analogies and examples that are culturally relevant may also be used to help students understand scientific concepts (Barba, 1993; Lee & Fradd, 1998; Rakow & Bermudez, 1993). According to Pressley and Woloshyn (1995), analogies show the similarities between a new concept and a familiar concept, making the new concept more meaningful to the student. Analogies can assist in diminishing the cognitive and linguistic requirements of the task. For example, students may better understand the concept of layers of the earth if the teacher uses the analogy of egg with its shell, white, and yolk (see the Appendix).

The science teacher should model the thinking process involved in science processing skills (e.g., comparing and inferring) and use scaffolding techniques to encourage students to know science, talk science, and do science (e.g., "What can happen to the surface of the earth while mining minerals?" "I found fossils while mining for minerals"; Anstrom, 1998; Westby et al., 1999; Westby & Velaquez, 2000). The teacher should also demonstrate scientific concepts and processing skills step by step. Several researchers have successfully used modeling and "think aloud" strategies with different types of learners (Chamot, 1993; Chamot & O'Malley, 1987; Echevarria et al., 2000; Klinger & Vaughn, 2000; Meichenbaum, 1977; O'Malley & Chamot, 1990; Padron, 1992; Pressley & Woloshyn, 1995; Schumaker & Deshler, 1992). Cognitive modeling and demonstration are especially beneficial for CLD students because these strategies facilitate understanding by providing concrete, step-by-step procedures that lessen the cognitive, linguistic, and social requirements of the task (Anstrom; Echevarria & Graves, 1998). Westby et al. noted that teachers may have to reduce the cognitive and linguistic demands of the curriculum or its presentation, or they may have to facilitate the development of cognitive and linguistic skills needed to learn science.

The science teacher may consider using graphic organizers, which--along with visual materials--are key to instruction and materials adaptation (Anstrom, 1998; Echevarria & Graves, 1998; Saunders et al., 1998). These instructional aides help organize concepts, structure discussions, and visually represent important concepts and vocabulary (see the Appendix; Boudah et al., 2000; Echevarria et al., 2000; Guastello, Beasley, & Sinatra, 2000; Mastropieri & Scruggs, 2000; Zehler, 1994). By matching these tools to specific teaching/learning tasks, the teacher can meet the cognitive and linguistic needs of CLD students.

The organization of discourse is crucial for students who are learning a second language. Science teachers need to embed language in meaningful contexts (e.g., hands-on experiments, demonstrations) and allow students to learn from each other in collaborative situations to make the communicative task easier for the second-language learner. For example, the teacher needs to monitor and modify teacher talk (i.e., use paraphrases, repetition, and visuals; down crucial vocabulary; place emphasis on important concepts; and clearly articulate words and sentences; Diaz-Rico & Weed, 1995). The teacher should plan instruction so that complex information is understandable to the CLD student but the curriculum is not watered down. Incorporating the previously mentioned instructional strategies makes it possible for teachers to do this.

Adapting to the sociocultural backgrounds of CLD students involves organizing the classroom by establishing routines and patterns of participation so students know what to do next when the teacher is not directly instructing (Hoover & Collier, 1998; Westby et al., 1999). Having a predictable environment will help students focus on understanding the concepts and learning the skills rather than on procedures or forms of social engagement, thus reducing the social demands of the task (Simich-Dudgeon, McCreedy, & Schleppegrell, 1988). An explicit agenda and explicit teaching will address social, emotional, cognitive, and linguistic demands involved in learning a second language/second culture (Echevarria & Graves, 1998; Echevarria et al., 2000).

Many CLD students struggle to perform academically because their linguistic, cultural, and social needs are unrecognized or misunderstood (Kea & Utley, 1998). Part of understanding and accommodating these differences involves making explicit rules for classroom behavior and creating a predictable and accepting environment in order to reduce the demands of learning a second language/ second culture. Science teachers who recognize these students' learning needs incorporate active student participation in small cooperative activities and allow "nonstandard" appropriate interactions among students and the teacher (Rueda, Ruiz, & Figueroa, 1995). Other helpful strategies include scheduling breaks within the lesson so students' cognitive skills will not be exhausted, providing linguistic cues to help students with the organization of the lesson, and not forcing reluctant students to speak (see the Appendix). Educators who know about second-language and second-culture acquisition processes are more able to choose effective instructional practices for CLD students with and without disabilities (see Table 1).

Final Thoughts

Given the number of diverse students in today's classrooms, educators should expect to encounter a number of students with disabilities who are from culturally and linguistically diverse backgrounds. According to the U.S. Department of Education (1998), 5% of the students with disabilities in inner-city schools speak English as a second language. It has also been documented that many CLD students come from low socioeconomic backgrounds and that poverty places students at risk for disabilities and school failure (U.S. Department of Education). Students who are bilingual and have a disability need programming that addresses both second-language acquisition and the disability.

Several of the instructional strategies and modifications recommended for teaching CLD students are based on research findings regarding second-language acquisition, bilingual education, special education, cognitive strategy, and effective teaching. For this reason, many of the instructional strategies, modifications, and adaptations described in this article could also benefit students with mild and moderate disabilities. The literature has indicated that explicit instruction, cognitive strategies, demonstrations, hands-on activities, graphic organizers, thematic units, and activation of background knowledge have also been successfully used with students with disabilities (Boudah et al., 2000; Houtz & Watson, in press; Mastropieri & Scruggs, 2000; Watson & Houtz, 1998). Science teachers must be aware, however, that the nature of these students' problems is different, even though they can benefit from similar strategies. Many of these instructional strategies address the difficulty students with disabilities encounter in using language; processing, organizing, and retrieving information; and obtaining and using strategies. The most effective teachers are able to effectively include students with disabilities and students from diverse backgrounds (Mastropieri & Scruggs, 2000) by identifying instructional strategies and tools that emphasize learning for all students.

Figure 2. Quadrant of task(s) demand.

	Cognitively Undemanding	Cognitively Demanding
Context Embedded	* Globe activity * Look at Earth cake and talk about what we see (trees, grass, etc.)	* Earth cake activity: Make inferences usin scientific language * Write on learning logs using scientifi language * Listen to the story and work with CD-ROM * Go on a rock-hunting field trip around your area
Context Reduced	* Describe where you come from using familiar language * Describe the Earth around your house (trees, grass, etc.) * Compare/contrast Earth and your body * Fill in concept maps/organizers * Make vocabulary flash cards * Draw diagram and/or make a	* Answer chapter questions * Create a new planet and show its layers * Describe the Earth's layers to someone else

model of the Earth's layers and label them (* depending on language)

Table 1. Summary of Interventions

Student need	Strategies and tools
Cognitive and linguistic needs	Planning Pyramid Contextualized instruction * Thematic units * Activation of prior knowledge * Analogies * Cognitive modeling & scaffolding * Demonstration * Graphic organizers * Hands-on activities * Modified classroom * Discourse * Balance between individual and small-group activities Schedule breaks within lessons
Sociocultural needs	Modeling/demonstration Predictable environment * Routines * Patterns of participation * Explicit agenda

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Silvana M. R. Watson, PhD, is an assistant professor of special education at Old Dominion University. Her current research interests include curriculum and instruction for students with disabilities and for students who are culturally and linguistically diverse and modification of science instruction for students with mild/moderate disabilities and for students who are culturally and linguistically diverse. Lynne E. Houtz, PhD, is director of elementary education at Creighton University. Her scholarly interests focus on improvement of teaching and learning of science, math, and technology. Address: Silvana M. R. Watson, Child Study Center, Room 109, Old Dominion University, Norfolk, VA 23529-013 9; e-mail: swatson@odu.edu