Chapter 7 At-a-Glance

Chapter 7 is the fourth of four subject-specific chapters that will address ways in which you can help your ELLs meet the standards that are an increasing factor in measuring the success of teaching and learning. Middle and high school teachers, as you know, are primarily focused on their subject areas, and these chapters are designed to supplement the more general information presented in Chapter 3. Also, for a much more detailed discussion of assessment strategies and resources, please refer to Chapter 8, "Assessment and Evaluation: How Can We Be Fair and Demanding?"

Some highlights of Chapter 7 include:

- Involving students in scientific inquiry
- Teaching the language of science
- Using experiments to teach scientific discourse
- Demonstrating learning strategies in science
- Using appropriate assessment

The bulk of this chapter is adapted from "Preparing Secondary Education Teachers to Work with English Language Learners: Science," by Kris Anstrom, with contributions from Sharon Lynch and Patricia DiCerbo (1998). The project was funded by the U.S. Department of Education, Office of Bilingual Education and Minority Language Affairs. The paper in its entirety is available at the National Clearinghouse for Bilingual Education at the George Washington University website at www.ncbe.gwu.ed.

Because worldviews are shared belief systems in children's sociocultural environments, the scientific worldview presents a challenging "border crossing" for diverse students.

—W. W. Cobern

CHAPTER 7: Making Science Comprehensible to the English Language Learner

Introduction

Vignette I depicts what has become a common scenario in American classrooms, ELLs in mainstream settings. Not so common, though, is the kind of “sheltered” instructional approach shown here. More often, responsibility for teaching English language learners is up to mainstream teachers who have had little or no preparation in working with these students (McKeon, 1994). Teachers without the necessary training—and who identify themselves as content specialists rather than language teachers—may feel resentful or apprehensive of their ELL students (Constantino, 1994). Since the number of ELLs enrolled in our nation’s schools shows little sign of abating, it is critical to adequately prepare mainstream teachers for meeting the diverse needs of this group.

One of the issues state and local education agencies have struggled with in developing standards is the extent to which linguistically and culturally diverse learners should be expected to meet the standards they have set. In mainstream American classrooms, native speakers, for whom English is nearly automatic, can focus primarily on the cognitive tasks of an academic assignment. The student who is in the process of learning English, though, must focus on both the cognitive and the linguistic—learning new information, procedures, and related tasks—while also learning new vocabulary, structures, and academic discourse (McKeon, 1994). Moreover, at the secondary level, ELL students only have “a window of a few years” to acquire the language ability necessary for successful academic work (Whitten, Lathrop, Hays, & Longo, 1995). Thus, setting rigorous academic standards does not guarantee that all students will have the opportunity to achieve them.

I. A Collaborative Approach to Teaching Sheltered Biology

(See Chapter 2, page 28 for more information on ESL–Mainstream Collaboration.)

Here is an example of a lesson that is "team taught" by a mainstream and an ESL teacher:

As the bell signals the beginning of the second block period, 30 sophomore biology students take their seats at seven tables spaced evenly around the classroom. Interspersed among the students are ten who have relocated to this large, suburban high school from such places as Ghana, Liberia, Bangladesh, Vietnam, Korea, Pakistan, and El Salvador. At first glance, it is difficult to separate the native English speakers from the students who are learning to speak English (ELLs). Two teachers, a biology teacher and an English as a second language (ESL) teacher, conduct the class. The biology teacher introduces the content, in this case a lab experiment on measuring lung capacity, while the ESL teacher assists by clarifying certain points, writing key expressions on the board, or by circulating and quietly checking with individual students.

The biology instructor introduces the lab, which consists of blowing up a balloon and measuring its width in order to determine differing lung capacities. She uses exaggerated gestures and breathing motions to illustrate, simultaneously relating her actions to key terms she has written on the board. She speaks somewhat more slowly than usual and enunciates her words carefully. To explain the lab assignment, she designates individual students to read and demonstrate the different steps. When an ELL student is called upon to read, the ESL teacher assists by helping with pronunciation. Part of the lab involves using mathematical formulas, which have been written on the board. The ESL teacher adds the formula for determining averages and gives an example to clarify. The biology teacher illustrates the amount of residual volume in the lungs by holding up a glass beaker so the class can visualize the approximate amounts for men and women.

After the teachers finish explaining the lab procedures, students work with partners at their lab tables. For the most part, ELL students are paired with native English speakers. The classroom is noisy with the sounds of blowing up balloons and chattering back and forth among the students. Both teachers circulate throughout the room, answering questions and checking student work. The ESL teacher, who is working intensively with two students near the front of the class, pulls one student to the board to help him with a mathematical formula. She first questions him to find out what he knows, then supplies the needed information. Finally, she has him apply his own measurements to the formula. Later, she models ways for a native speaker to help her ELL partner without actually doing the calculations for her. Throughout the lesson, the focus is on understanding the lab and completing it within the hour and a half time period. Some of the ELL students will meet later with the ESL teacher to work on questions relating to the lab; a block of time has been set aside toward the end of the day for such individualized instruction.

National Science Education Standards and the English Language Learner

Truly effective science teaching encourages all students to learn science, to develop scientific habits of mind, and to become scientifically literate (S. Lynch, personal communication, March 1997). The National Science Education Standards define scientific literacy in the following manner:

> *Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it* (National Research Council, 1996).

Meeting the goal of a scientifically literate population requires a radical departure from traditional science teaching strategies—strategies that emphasize the acquisition of specific facts and procedures and stress the idea that scientists work according to a narrowly conceived, logical "scientific method." Rather, the national science standards advocate a broader approach to scientific inquiry that includes: (1) the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work and (2) the methods students use to develop an understanding of scientific ideas. Scientific inquiry involves students in observing phenomena, asking questions, referring to written and other source material to determine what is already known, proposing solutions, planning experiments, and predicting and communicating outcomes. Authors of the science standards view inquiry as the primary means of understanding science (National Research Council, 1996).

Involve Students in Scientific Inquiry

Effective science education for English language learners makes use of a variety of venues through which a student can learn a particular science concept.

The restructuring of science education to incorporate more opportunities for investigating science concepts corresponds to what is known about effective education for English language learners. Inquiry techniques, such as data collection and reporting, allow ELLs to use language in a purposeful and meaningful way. Interviewing a botanist, for example, not only enhances their understanding of plant science, but also encourages the use of written and oral language as students go through the process of developing an interview guide, asking questions, and recording answers.

Giving students a "menu" or choice of projects to complete is another way to strengthen their comprehension of difficult science material. By providing a combination of highly contextualized, less cognitively demanding assignments and more abstract, less contextualized tasks, students with different learning styles will have equal access to the curriculum (Rupp, 1992). However, when using a menu approach, care must be taken that information is not watered down. To be effective, each menu choice should be tied to a central objective; if the goal is to have students understand the basic properties of a cell, the list of projects might include drawing and labeling a cell diagram, preparing an oral report on the structure and function of a cell, or summarizing the current research on cloning (S. Lynch, personal communication, March 1997).

Advocate for a Less-Is-More Curriculum

Science curriculum development involves the careful organization of concepts to form connections and patterns across the discipline.

Involving students as active participants in the process of scientific inquiry often requires more time than traditional teaching methods. A key focus of the national science standards is to reduce the number of concepts that must be taught so that students can develop a deeper understanding of how science works.

Educators of English language learners (e.g., Chamot, 1993) suggest developing a more narrowly focused curriculum that includes major principles and unanswered questions rather than an accumulation of random bits of knowledge. Those who design science curriculum are advised to use a unit organizer or conceptual map that lays out a picture of the big ideas in a unit and how they are connected to one another (S. Lynch, personal communication, March 1997). Dr. Lynch explains,

What can happen in science is, for example, if a teacher is doing a unit on sound, [s]he may look through the textbook and choose a series of experiments and other activities, and then perhaps [s]he brings in [a] guitar and from all of this creates a set of experiences. I call this the 'beads on a string' technique of teaching—all the activities are sort of related to sound. If a student is from a typical middle class background, you can give them a string of experiences, and they'll come out the other end learning something. However, kids that come from other cultures need to have more explicit instruction. Consequently, a unit organizer can be helpful for teachers to understand how you structure activities and tie them together, making connections and patterns. (S. Lynch, personal communication, March 1997)

Teach the Language of Science

The national science standards underscore the idea that students who have learned to follow scientific practices and to assimilate scientific theories must also learn to communicate their understanding and findings to others (National Research Council, 1996). An essential aspect of instruction designed to achieve these standards is actively engaging students in scientific discussion by encouraging students to ask questions, propose answers, make predictions, and evaluate evidence. Facility with science terminology and the discourse patterns common to science is necessary if students are to engage in the level of discussion essential to scientific inquiry.

Research suggests that the kind of advanced reasoning used in scientific communication is dependent on the acquisition of specific linguistic structures of argumentation, including logical connectors and specialized vocabulary (e.g., Kessler et al., 1992). English language learners who have not yet acquired the linguistic structures necessary to scientific discourse may fall behind in both scientific reasoning and understanding.

Giving ELLs more opportunities for using the language of science can make science content more accessible by encouraging linguistic and cognitive development. Cognitively, patterns drawing on comparing and contrasting events, making cause and effect connections, and problem solving require higher-order thinking than the patterns of time order and list structure. Observing similarities and differences, noting cause and effect relationships, understanding the problem, and hypothesizing or offering a solution are thinking processes basic to scientific inquiry. The ability to engage in the thinking processes underlying science discourse patterns indicates high levels of both cognitive and linguistic functioning. This interlocking of cognitive and language development is central to second language learning in the context of science. One idea is for mainstream science teachers to identify linguistic structures or discourse patterns associated with a particular topic and then incorporate appropriate language learning activities into their science lessons. Kessler et al. (1992) describe a sample lesson (Vignette II) which combines a unit on electricity with the discourse function of agreeing and disagreeing.

II. Using Experiments to Teach Scientific Discourse

The teacher (and/or student) first models an experiment using balloons to demonstrate electrical attraction and resistance. The teacher (and/or student) also models expressions commonly used in scientific discourse for agreeing and disagreeing, along with associated linguistic structures. Students may then conduct their own experiments, carefully record their results, and share information about their observations orally or in writing (Kessler et al., 1992).

Make Oral and Written Language Comprehensible

Mainstream science teachers can make scientific language more comprehensible to their ELL students by modifying the way they speak. For example, it is often easier for ELLs to understand the active voice, for example, "Living things need nutrients" than the passive voice, "Nutrients are needed by living things." Limiting the number of new terms, paraphrasing or repeating difficult concepts, and using visual or real referents are other ways to make "teacher talk" more comprehensible to the English language learner.

Mainstream teachers can make science comprehensible to their English language learners by adding contextual and visual information to lessons and texts.

Asking questions is another effective strategy. Questions of varied linguistic and cognitive complexity are useful in encouraging critical thinking and finding out what students know. Moreover, teacher questioning in the science classroom serves as a model for student questioning and supports the development of inquiry skills.

Focusing on what is right about a student's response rather than what is wrong is also important. For instance, in answer to the teacher's question, "What are some foods that contain protein?" an English language learner might respond, "Some food are eggs, milks, meats." Instead of overtly correcting the student, the teacher can model correct language indirectly by stating, "Yes, some foods that contain protein are eggs, milk, and meat" (Fathman et al., 1992).

Making science information accessible to English language learners often requires modifying written materials. For the most part, teachers can modify written text in the same way that they adjust their speech: by limiting the number of new vocabulary words, simplifying grammatical structures, and using the active voice. Clear organization and the use of guideposts, such as "first" and "next" to indicate sequence and "but" to indicate contrast, are other ways to help ELLs access meaning from written works.

Bringing scientific texts within reach of the ELL student, though, is more than simplifying vocabulary and reorganizing sentences. Some materials may require more context or background information in order to make sense to ELL students. Research suggests (Short, 1992; among others) that teachers need to consider students' proficiency level(s), prior knowledge of the topic, and the text itself, when adapting written materials.

Successful adaptation includes adding contextual and visual information such as charts, graphs, outlines, and pictures. A flowchart, for example, can convey a scientific process to students more rapidly than several paragraphs of text filled with complex structures and difficult vocabulary. Timelines and charts are useful in developing higher-order thinking skills such as sequencing and comparison/contrast. All of these visual formats emphasize essential points and reduce extraneous information (Short, 1992). (See "Adapting Materials" Chapter 3, page 63.)

Teach Problem Solving and Learning Strategies

Help English language learners acquire strategies that facilitate both second language acquisition and knowledge acquisition.

The approaches described above—developing a manageable curriculum, applying the inquiry process, making language comprehensible—are all critical in helping ELLs reach the national standards for science. Equally important is to teach them the specific strategies they need to facilitate both second language acquisition and knowledge acquisition (August & Pease-Alvarez, 1996). An essential task for teachers is to show students strategies that work and then to provide opportunities for them to practice using their strategies in pursuing academic learning (Padron & Waxman, 1993). Vignette III illustrates how one teacher incorporated the explicit use of problem solving and learning strategies into a series of science experiments.

An approach to teaching learning strategies that was developed specifically for English language learners is the Cognitive Academic Language Learning Approach (CALLA) (Chamot & O'Malley, 1994). (See "Learning Strategies Across the Curriculum" Chapter 3, page 74.) The CALLA helps students use their prior content knowledge as a tool in acquiring new knowledge and has been successful in improving student learning in science as well as in other academic subjects. One of the premises of the CALLA is that students come to science classes with naive theories of heat, energy, and other concepts that are either inconsistent or incompatible with current scientific knowledge. If lessons designed to teach new concepts do not account for this existing knowledge, it is highly likely that students will ignore or misinterpret what is taught. This tendency is even more likely to occur when instruction is given in a language students are still learning (Gelman, 1995). Introducing new concepts through brainstorming or discussion sessions can highlight student misperceptions about science and help students understand that intuitive knowledge may not always be relied upon in science (Chamot, 1994; S. Lynch, personal communication, March 1997).

III. Demonstrating Learning Strategies in Science

The instructor returned all of the student worksheets (he had been keeping the students' work in individual student portfolios) and asked them to complete checklists and evaluation forms that covered four experiments. When they were finished, he conducted individual interviews with each student asking them to refer to their portfolios to clarify the checklists and evaluation forms. The interviews focused upon student perceptions of their learning both in terms of what they had learned and what they had learned how to do. The instructor was able to introduce learning strategy terminology by simply asking questions such as: "What resources did you use?" "What can you infer from this experiment?" and "What words or information did you have to pay attention to [in order] to do the experiment?" This provided a vehicle for the instructor to integrate learning strategy instruction with content and language learning rather than isolating the learning strategy instruction and making it an end in itself (Spanos, 1993).

Teachers can also use "think-aloud" or "scaffolding" techniques to coach their students in appropriate problem-solving strategies (Chamot, 1993). After completing an experiment or research study, for example, teachers can "scaffold the reasoning process" by taking a sample of data and saying, "Well, I can see that as this [variable] is decreasing, this [variable] is increasing. What might that mean?" to guide the students from raw data, to wondering how the data fit together, to hypothesizing (S. Lynch, personal communication, March 1997).

Developing the Scientific World View

Science is a way of knowing that "distinguishes itself from other ways of knowing and from other bodies of knowledge" (National Research Council, 1996). The nature of science in the standards documents is defined according to a traditional seeking to understand how the world works (i.e. describe, explain, predict, and control natural phenomena). National Science Education Standards (NRC, 1996) clarifies the scientific world view as opposed to alternative views: "Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific."

Although the distinction between the scientific world view and alternative views may be relatively straightforward to educated Westerners, children's world views involve a complex interaction of personal beliefs and scientific understanding (Loving, 1997). In addition, different cultural groups hold diverse and sometimes opposing views about the social and natural world (Cobern, 1991). Some groups tend to have mechanistic, instrumental views that seek to explain or control natural phenomena, whereas others express alternative views in which personal, social, and supernatural forces interact with natural phenomena. For example, in explaining the cause of a major hurricane they had personally experienced, mainstream students often interpreted the phenomenon as a natural event, whereas culturally diverse students expressed world views in which people and society (e.g., social ills of crime and violence), nature, and supernatural forces (e.g., God and devils) were all responsible (Lee, 1996). Because world views are shared belief systems in children's sociocultural environments, the scientific world view presents a challenging "border crossing" for diverse students.

The emphasis on inquiry poses challenges for many ESL students. Students from oral language traditions may have difficulty using language functions such as reflecting, predicting, inferencing, and hypothesizing (Casteel & Isom, 1994). Because of limited formal schooling and/or the oral language traditions in the home, newly arrived students may experience difficulties with scientific inquiry in school because they have not been encouraged to ask questions or devise plans for investigation on their own. Students from cultures that respect authority may be receptive to teachers telling and directing them, rather than making an effort to inquire, explore, and seek alternative ways.

Instructional Strategies for Science Teachers

1. Give practice in reading cause and effect relationships and the language signals that show them. For example, “if” and result clauses, conditional statements, and action-reaction expressions.
2. Teach the many forms of graphs used in science. Have students draw them, label their parts, and interpret them.
3. Use real materials, objects, and apparatus to demonstrate concepts or principles. Accompany demonstrations with simple language followed by written charts that summarize each step.
4. Teach the steps to problem solving, and provide the vocabulary to identify each step. The steps are as follows:

   a) Identify the problem
   b) Define or delimit the problem
   c) Gather data
   d) Sift data
   e) Suggest theories or make hypothesis
   f) Draw conclusions

   Give practice in both skills of problem solving and the language which explains the process.
5. Develop the skill of finding facts and noting details by asking students to list all the information in a given paragraph.
6. Ask students to keep written records of scientific events, for example, a chronicle of space flights, a diary of the Sealab experiments, a progress report of plant growth.
7. Point out words that have special meanings in science and other meanings in different contexts. Such words are “test” meaning *prove* and “test” meaning *trial*.
8. Help students to acquire a vocabulary of expressions that provide clues to likenesses and differences. Science reading demands the ability to distinguish small details that may denote important similarities and differences. Word lists may include the following: same, alike, congruent, duplicate, resemble, agree, parallel, copy, match, double, affinity, alien, atypical, diverse, disparate, unlike, unrelated, etc. Use in spoken context, find in written material, and use in science lessons.
9. Provide selections that include several causes and effects. Help students identify causes, find their effects, and relate them to one another. For example,
   “A careless camper who does not put out his campfire and acres of valuable timber burned; or, a year of little or no rain and poor crops, dry wells, and a shortage of irrigation water.

Excerpted from Teaching Reading to Non-English Speakers *by E. Thonis*

Use Appropriate Assessment

More and more often, school districts committed to meeting the needs of diverse learners are combining hands-on, student-focused instruction with hands-on, student-focused assessment—assessment that requires students to perform authentic academic tasks similar to those originally used to teach the material. *The Guide to Performance Assessment for Linguistically Diverse Students* (Navarrete & Gustkee, 1996, available online at www.ncbe.gwu.edu), for one, asks local schools and districts to use alternative assessment tasks to measure student progress, such as student work on a science exhibit or lab report. The *Guide* also advocates assessment procedures that match classroom instructional practices and add context to assessment tasks, such as cooperative small groups, individual conferences, visual prompts, and assessment in the language of instruction. In addition, the following techniques are suggested:

- Allow extra time to complete or respond to assessment tasks.
- Permit students to use dictionaries or word lists.
- Simplify directions in English or paraphrase in the student's native language.

Many of the attributes of effective assessment listed in the *Guide* are reflected in the findings of August and Pease-Alvarez (1996). Their study of instructional services for English language learners indicates that a good assessment plan uses a diversity of standard and alternative measures that are adapted to individual needs and educational experiences. Using a variety of measures—such as observation checklists, interview guides, criterion-referenced tests, and portfolios—provides a more complete picture of a student's proficiency and progress.

Like the *Guide,* August and Pease-Alvarez also suggest using the student's native language to facilitate assessment of content knowledge, particularly when students have learned a particular concept or skill in that language. Without such assessment, they argue that a student's academic achievement is likely to be underestimated.

Insect-Eating Plants Matrix

	Venus Fly Trap	Pitcher Plant	Sundew
Location	Costal marshes, N and S America	Various parts of U.S.–bogs/marshes	No description
General Appearance	Small, 12 leaves in circle on ground, stem with blossoms	Author does not describe	Very small, size of button/pincushion
Catch/Lure Mechanism	Outer ends of leaves hinged w/spines on edges; secretes sweet liquid	Horn-shaped leaves; glands secrete sweet material	Red leaves like spoons covered with hairs like flypaper
Catch/Lure Process	Insect presses trigger hairs Red center of leaf secretes liquid Hinge closes/traps bug Digestive juice dissolves bug	Insects go for material Get caught in neck hairs Struggle/slip Drug makes bug unconscious	Bug sticks on hairs Struggle/get stuck Hairs bend to pin bug Digested–how?

Notes:

- The matrix format makes it visually clear how many things are being compared and how many categories of information are discussed by the author.
- It is also evident at a glance what information is missing; for example, the author does not really describe the general appearance of the pitcher plant, nor is it clear how the sundew plant digests the insects.
- Parallel information to be analyzed is physically adjacent in the various cells and rows, facilitating analysis. In this particular matrix, it is likely that the reader might have drawn different conclusions about the similarities and differences among the plants had the information been diagrammed in a semantic map because the relevant information would not have been parallel and easy to read.

Excerpted from Teaching Reading as Thinking (Facilitator's Manual), *Alexandria, VA: ASCD and NCREL, 1986*

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