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ABSTRACT

This document examines the education of secondary level English language learners within mainstream science classes. It provides teachers and teacher educators with an understanding of how mainstream science instruction can be designed and implemented to enhance academic achievement for these students. Research for this report included an extensive search of various databases and World Wide Web sites; analysis of the national content standards documents for science and three other core areas; site visits to a suburban high school that used a team teaching approach to working with English language learners enrolled in mainstream classes; and personal interviews with education faculty at George Washington University who are responsible for preparing preservice teachers for secondary level mainstream instruction. After an introduction, the first section discusses National Science Education Standards and the English language learner, focusing on: involving students in scientific inquiry; advocating for a less is more curriculum; teaching the language of science; making oral and written language comprehensible; teaching problem solving and learning strategies; using appropriate assessment; and using a three-tiered approach to science instruction for English language learners. The second section discusses the preparation of mainstream teachers to work with English language learner students. (Contains 38 references.) (SM)

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Preparing Secondary Education Teachers to Work with English Language Learners:

SCIENCE

Kris Anstrom

with contributions from Sharon Lynch, Ph.D.
Patricia DiCerbo, Editor

Center for the Study of Language and Education
The George Washington University
Washington, DC

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Overview

This document is number two of a series of four reports prepared under contract by the National Clearinghouse for Bilingual Education (NCBE) in response to Task Order number D0003 for the U.S. Department of Education, Office of Bilingual Education and Minority Languages Affairs (OBEMLA). In accordance with the task order requirements, this report integrates findings from research pertaining to content area instruction of English language learners. Three key questions outlined in the task order are addressed:

- What does the relevant literature pertaining to content area instruction of linguistically and culturally diverse learners (LCDLs) contribute to the theory and practice of standards for LCDLs?
- What does the relevant literature pertaining to content area instruction of LCDLs contribute to the theory and practice of measures of achievement, proficiency, and/or academic literacy for LCDLs?
- What does the relevant literature pertaining to content area instruction of LCDLs contribute to the field of promising practices in content area instruction for LCDLs?

The focus of this second report is on the education of secondary-level English language learners within mainstream science classes. The intent of this document is to give teachers and teacher educators a better understanding of how mainstream science instruction can be designed and implemented to enhance academic achievement for these students.

Research for the report included an extensive search of the NCBE bibliographic database, the ERIC bibliographic database and various World Wide Web sites for information regarding effective curriculum and instruction, content standards, student assessment, teacher training and education.

In addition, the national content standards documents for science (*National Science Education Standards*) and three other core areas (language arts, math, social studies) were analyzed to determine whether their theoretical bases were consistent with what educational research tells us is effective practice for English language learners.

Information was also collected through site visits[1] to a suburban high school that had implemented a team teaching approach for working with English language learners

1. Site visits were conducted in May 1997.

enrolled in mainstream classrooms. Vignettes from the visit lend context to the discussion of exemplary instructional and curricular models.

Finally, personal interviews were held with education faculty at The George Washington University (GW) in Washington, DC who are responsible for preparing pre-service teachers for mainstream instruction at the secondary level. Dr. Sharon Lynch of GW provided valuable insights into current issues related to science education; her comments are interwoven throughout the report.

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 (Cornell, 1995) 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,[2] it is critical to adequately prepare mainstream teachers for meeting the diverse needs of this group.

Adequate teacher preparation has become even more important with the advent of national education goals and guidelines. Most academic fields at the national level, including science, mathematics, history, and English language arts, have issued content or curriculum standards for their respective areas. These core standards are expected to assist state and local initiatives in developing their own set of guidelines, and have already influenced activity at these levels to a significant degree (Chris Green & Solis, 1997).

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,

2. Annual reports from State Education Agencies indicate that K-12 enrollment figures for limited English proficient students increased by almost 45% from the 1990-1991 to 1994-95 school years (Macias & Kelly, 1996).

Vignette

I. A Collaborative Approach to Teaching Sheltered Biology

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.

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.

Ensuring that ELLs have equal access to challenging academic content depends, to a large extent, on the existence of skilled teachers who are trained in the use of effective educational practices for these students. In planning sound educational programs for ELLs then, it is important to consider not just the implications of content standards for these students, but also the teacher behaviors and instructional approaches that will help make language and content accessible. The following section discusses these issues within the context of secondary science instruction, including the characteristics of a sound curriculum and fair and meaningful assessment. A concluding section describes the key components of an effective mainstream teacher preparation program.

National Science Education Standards and the English Language Learner

According to Dr. Sharon Lynch, science education professor at The George Washington University, science at the secondary level has traditionally been taught for the twenty percent of students who were college bound. Truly effective science teaching, in contrast, 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:

National science education standards provide insight into more effective science learning for English language learners.

> 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

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 needs to be taken that information is not watered down. Dr. Lynch describes, for example, a lesson on Egyptian tombs in which students were allowed to select from a list of very different projects. While one group of students wrote an editorial about scientists raiding an Egyptian tomb, another group made clay models of an Egyptian tomb. It is questionable, in this case, whether both groups were learning the same theoretical concepts. To be effective, each menu choice needs to 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,

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

or summarizing the current research on cloning (S. Lynch, personal communication, March 1997).

Advocate For a Less is More Curriculum

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 students can develop a deeper understanding of how science works. This idea of spending more time on learning fewer concepts is one of the main points of the Third International Mathematics and Science Study (TIMSS). In comparing science and mathematics education in the U.S. with that in other peer countries, TIMSS researchers criticize the U.S. for its "splintered vision" — emphasizing familiarity with many topics rather than concentrated attention to a few. Authors of the TIMSS study note that curricula in this country fail to focus on fundamental goals, or link content together. A result of this splintered approach to teaching and learning is that students grasp pieces but not the whole (Schmidt et al., 1996).

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

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. 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.

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, e.g., "Living things need nutrients" than the

Vignette

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)

passive voice, e.g., "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 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).

Teach Problem Solving and Learning Strategies

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.

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

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). 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

Vignette

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).

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).

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).

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), 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, e.g., 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; and
- 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, a student's academic achievement is likely to be underestimated.

A Three-Tiered Approach to Science Instruction for ELLs

The following method for teaching science to English language learners allows students the time and guidance they need to explore new principles and theories, and takes into account their prior knowledge of a given topic. Since the focus is on scientific inquiry, alternative assessment techniques are easily incorporated.

By exploring a smaller number of science concepts in different ways, English language learners have the opportunity to learn important content in-depth and acquire necessary language skills.

To examine a particular concept, the teacher leads students through three different inquiry activities: a guided demonstration, an organized group inquiry, and open-ended individual study. This sequencing allows students to progress naturally through stages of language learning: observing to solving, listening to speaking, and interacting to initiating (Fathman et al., 1992).

During the demonstration stage, the teacher introduces new science concepts and raises questions or problems to solve. Activities are designed to stimulate student initiative, interest, and different approaches to problem solving. Ideally, the demonstration phase gives ELLs the opportunity to listen and observe before having to produce any language (Fathman et al., 1992).

The group inquiry phase lets the ELL students use new language and further explore science concepts. Heterogeneous grouping is useful during this stage since it encourages interaction between English language learners and native speakers. By communicating with native speakers in academic contexts, second language learners have access to language unavailable in traditional teacher-directed settings (August & Pease-Alvarez, 1996). In addition, heterogeneous groups allow students the flexibility to participate in different ways, depending on their English proficiency level. For example, a student with limited writing ability might create a simple chart illustrating the group's finding while a more proficient student records the results of an investigation in paragraph form (Fathman et al., 1992).

After the group activity, students explore a science concept independently, often outside of the classroom. Students at all levels of English proficiency can conduct individual investigations, although they will vary in their ability to communicate their findings in English (Fathman et al., 1992). Student-directed formats such as "science talk" allow students of even limited English proficiency to share their experiences. In science talk, students gather in a circle to discuss their investigations; students develop the discussion topics, guide the discussion, analyze their results and determine further questions to explore (Minicucci, 1996). The science talk approach could be adapted to any mainstream science classroom where ELLS are present.

Preparing Mainstream Teachers to Work with ELL Students

Perhaps the most important link in effective mainstream instruction of ELL students is the mainstream teacher. Since both research and logic suggest that teachers who receive appropriate training are more likely to create supportive instructional environments than those without such preparation, defining and implementing appropriate training are critical to ELL achievement (Castaneda, 1993; among others).

Teacher education is the key to improving mainstream instruction of ELL students.

An integral component of any teacher education program is the quality of its field experiences. Education programs designed to train teachers to work with ELL students must provide them with practical experiences that allow them to not only observe effective teachers, but also to practice teaching in multilingual environments, and to reflect with their peers and collaborating teachers on their developing skills and cultural competencies. Moreover, all aspects of the education program, including field experiences and coursework, have to involve preservice teachers in the kinds of active, student-oriented approaches described here. Specifically, findings from the research argue for instilling in our future teachers:

- a repertoire of methods and skills for adapting instruction to the needs of ELL students;
- alternative strategies for assessing ELL student progress;

- ways to incorporate differences in cognitive and learning style into classroom instruction;

- proficiency in assessing instructional materials for comprehensibility and cultural content as well as for educational merit;

- an understanding of cultural differences; and

- an awareness of the contributions of linguistically and culturally diverse peoples to the content areas (Chisholm, 1994; Sakash & Rodriguez-Brown, 1995; among others).

Conclusion

Successfully reforming the way in which science is taught in our middle schools and high schools requires a rather substantial shift in the way in which science educators are taught in our colleges and universities. It is essential that teacher education programs begin to reflect the fact that today's students comprise a broad mix of cultures and languages. The goal of the new science standards — quality science education for all students — will only be met if all teachers have the knowledge and understanding necessary to educate an increasingly multicultural student population. Teacher education programs serious about meeting this challenge will go beyond the addition of one or two courses in culture or linguistics and develop a comprehensive curriculum that instills in our future teachers an appreciation of diversity, and the capacity to address both the academic and linguistic needs of their students.

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