DOCUMENT RESUME

ED 376 720 FL 022 587

AUTHOR Spanos, George; And Others
TITLE Communicative Math and Science Teaching: An Instructional Guide.
INSTITUTION Center for Applied Linguistics, Washington, D.C.
SPONS AGENCY Carnegie Corp. of New York, N.Y.
PUB DATE 90
NOTE 11p.; Funding also provided by the Xerox Foundation.
AVAILABLE FROM Center for Applied Linguistics, 1118 22nd Street, N.W., Washington, DC 20037 ($50, videotape and guide).
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Classroom Communication; Classroom Techniques; *Communicative Competence (Languages); Cultural Context; Elementary Secondary Education; English (Second Language); Instructional Materials; *Interdisciplinary Approach; Language Role; Language Usage; *Mathematics Instruction; *Science Instruction; Second Language Instruction; Teacher Education; Videotape Recordings; Vocabulary Development

ABSTRACT

The guide is intended for teacher trainers providing pre- and in-service programs for mathematics, science, and language teachers, and designed to accompany a 34-minute videotape recording of the same title (not included here), to help teachers integrate language learning and academic mastery in math and science. The video was created for a teacher training program for schools with high proportions of ethnic- and linguistic-minority students, but has been effective with native-English-speaking students who have difficulty with the specialized languages of math and science. It is consistent with guidelines of major math and science teaching associations. The video illustrates ways in which language, math, and science teachers can promote classroom discourse characterized by inquiry, problem-solving, clarification and justification of ideas, and teacher-student interaction. It uses a documentary approach, with examples from elementary, middle, and high schools nationwide. The guide describes the videotape and provides suggestions for pre- and post-viewing discussions. Post-viewing discussions are based on specific ideas presented in the video, focusing on: (1) linguistic and cultural factors in math and science education, (2) techniques for increasing classroom communication, and (3) need for interdisciplinary cooperation. A list of related contacts and a brief bibliography are appended. (MSE)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 376 720

The Center for Applied Linguistics

COMMUNICATIVE MATH AND SCIENCE TEACHING

An Instructional Guide
Prepared by George Spanos

with assistance from:

Donna Christian, JoAnn Crandall, Nancy Rhodes, Deborah Short, and G. Richard Tucker of the Center for Applied Linguistics, and Joseph Keyerleber of The Media Group.

The videotape "Communicative Math and Science Teaching" was produced and directed by

Joseph Keyerleber

and supported by grants from
the Carnegie Corporation of New York
and the Xerox Foundation.

A project of the
Center for Applied Linguistics
1118 22nd Street, NW
Washington, DC 20037
(202) 429-9292

In collaboration with
The Media Group
1118 22nd Street, NW
Washington, DC 20037
(202) 833-4461

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

CAL

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)"

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it

Minor changes have been made to improve reproduction quality

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

FL022587

© 1990 CAL

BEST COPY AVAILABLE

Introduction to the Guide

This guide is intended for teacher trainers who provide pre- and in-service programs to mathematics, science and language teachers. The participants in training programs may be exclusively teachers of one of these subjects, but CAL staff have found the most effective format to include a collaborative, interdisciplinary audience.

About "Communicative Math and Science Teaching"

The video, "Communicative Math and Science Teaching," aims to help teachers integrate language learning and academic mastery in math and science.

The video project, funded by the Carnegie Corporation of New York and the Xerox Foundation, has been a key component in a training program developed primarily for schools with high percentages of ethnic and linguistic minority students. It has also been effective in schools with native English-speaking students who have difficulty with the specialized languages of mathematics and science. It is consistent with recent guidelines of the National Council of Teachers of Mathematics (NCTM), the Mathematical Sciences Education Board (MSEB), the National Science Teachers Association (NSTA) and the American Association for the Advancement of Science (AAAS) which recommend the implementation of communicative teaching techniques, materials, curricula, and assessment instruments for all students.

In its *Curriculum and Evaluation Standards for School Mathematics*, NCTM (1989a) recommends that students learn to communicate mathematically. This recommendation is elaborated upon in the NCTM *Professional Standards for Teaching Mathematics* (1989b):

> The discourse of a classroom–its activity and talk–is central to what students learn about mathematics as a domain of human inquiry with characteristic ways of knowing.
>
> The discourse is shaped by the tasks in which students engage and the nature of the learning environment; it also influences them.
>
> Students must talk, with one another as well as in response to the teacher. The teacher's role is to initiate and orchestrate this kind of discourse and to use it skillfully to foster student learning.

In order to promote discourse, NCTM (1989b) recommends that teachers encourage and accept the use of such linguistic devices as metaphors, analogies, stories, written hypotheses, oral presentations, and dramatizations. Furthermore, teachers should pose questions that provoke and challenge students' thinking, ask students to clarify and justify their ideas, and monitor students' participation in discussions. Finally, mathematics teachers should promote classroom discourse so that students initiate problems and questions, make conjectures, and respond to and question their teacher and one another.

The 34-minute video illustrates ways in which language, math, and science teachers can address these recommendations. The themes and programs presented in the video evolved from a survey and conference sponsored by CAL in 1988, which focused upon the needs of limited English proficient students in math and science classes, and from innovative approaches to teaching observed by project staff since 1984. The teachers, classes, and programs chosen for the video represent a broad spectrum of program types and grade levels from several national locations:

The International High School at LaGuardia Community College (Queens, NY)
The Bronx High School of Science (Bronx, NY)
The Lawrence Hall of Science (Berkeley, CA)
McKinley Elementary School (San Francisco, CA)
Marina Middle School (San Francisco, CA)
The San Francisco Science Collaborative (San Francisco, CA)
The Exploratorium (San Francisco, CA)
The Science at the Core Program (San Francisco, CA)
Francisco Middle School (San Francisco, CA)
Sidney Lanier Intermediate School (Fairfax, VA)

The video program uses a documentary approach in real classroom settings where teachers are utilizing teaching techniques and materials which emphasize:

- cooperative learning,
- peer tutoring,
- the use of games and realia,
- sensitivity to individual learning requirements,
- patience and encouragement in the development of language skills, and
- cooperative teaching.

Commentary in the program is based on interviews with teachers, students, school administrators, and experts in the fields of mathematics and science education.

Introducing the Video

The video is, for the most part, self-explanatory; however, the facilitator should preview the video prior to group presentations in order to become familiar with its content.

During a training session, it is not necessary to spend a great deal of time introducing the video. However, because the notion of using a communicative approach in mathematics or science classes may be novel or controversial to some educators, it is recommended that the group spend a few minutes discussing the rationale and central concepts of the approach. If the presenter is unfamiliar with the rationale and concepts involved, the resources listed in the *Contacts* and the *Further Reading and Resources* sections below will be helpful.

A pre-viewing discussion with the audience will be helpful in a training situation. Any of the following questions might be posed by the facilitator to stimulate the discussion:

How can math and science teachers help students of limited English proficiency succeed in their classes?

How can teachers of English as a second language collaborate with math and science teachers to improve the learning opportunities of their students?

What is communicative teaching? How does it differ from other kinds of teaching?

Why should math or science be taught in a communicative fashion?

Would communicative teaching be viable in your school or district? Is it currently being used in your school or district? If so, please describe the program.

What are some of the characteristics of mathematics and science language that make a communicative approach necessary and desirable?

What types of students are best served by communicative teaching? (answer can be in terms of ethnicity, socioeconomic background, grade level, age)

Are you aware of any recommendations on the part of math or science organizations which pertain to the need for communicative teaching?

What kinds of techniques/textbooks/materials/curricula can be used to increase communication in math and science classrooms?

What specific roles can language teachers play in planning and implementing communicative math and science teaching?

Are there any roadblocks to communicative teaching in your program? Can you think of ways that these roadblocks can be overcome?

There are several ways to present the video. One option is to play the video straight through without pausing for discussion. If time permits, however, the presenter should prepare the group for a post-viewing discussion. One technique for conducting a postviewing discussion is the pair-and-share method. Each participant is asked to write down two or three techniques viewed that they could use in class, or several general questions or comments about the video, during the presentation and to share them with a partner at the conclusion of the video. After 3-5 minutes of paired discussion, the facilitator opens up the floor to general discussion. A variation would be to distribute questions, such as those listed in the following sections below, to the participants before the video is shown. When the video is over, the participants may be divided into pairs or groups of 3-4 to consider the questions and report back to the main group. Another option is to play the video in segments, such as each class scene—either on a first or second showing—and discuss the segments in turn as a group.

Post-viewing Discussion

Three topics are particularly conducive to discussion following the video presentation:

I) linguistic and cultural factors in mathematics and science education,
II) techniques for increasing communication in mathematics and science classes, and
III) the need for interdisciplinary cooperation.

The post-viewing discussion can be used to build upon the pre-viewing questions indicated in the section above. It is useful to divide the teachers into pairs or small groups to discuss the questions or parts of questions. Depending on the subjects and grade levels represented by the participants, it might also be useful to form groups homogeneously according to grade level, subject matter, school, school district, job description, etc. However, in some cases, it is better to form heterogeneous groups in order to insure discussion from a variety of points of view. An ideal group, therefore, might include a math teacher, a science teacher, a language arts teacher, and an administrator.

I. Linguistic and Cultural Factors in Math and Science Education

In the segment from Felicita Santiago's class, Felicita asserts that "math is a language." The same might be said for the various sciences and social sciences (*i.e.*, chemistry, physics, astronomy, sociology, psychology, etc. are languages). Linguists refer to such languages as "linguistic registers," or varieties of language used by certain individuals, on specific occasions, for special purposes. These registers may be divided into the following linguistic categories. (Examples from the registers of mathematics and science are provided.)

Syntax: the formal grammatical patterns which exist in language registers, *e.g.*, the frequent use of passive voice in scientific prose and mathematical definitions;

Semantics: the meanings of words and the things or concepts that words refer to, *e.g.*, the special meaning of words like *variable*, *function*, and *constant*;

Pragmatics: the influence of context on language meaning and use, *e.g.*, in sales tax problems, students bring different levels of knowledge to the problem-solving situation which reflect their experiences in the marketplace and influence their ability to solve related word problems.

The notion of linguistic registers is accepted by many math, science, and language educators, particularly those working with students from diverse cultural backgrounds. Students who are learning mathematics or science in their second language are handicapped not only by their lack of general English language skills, but also by the difficulty of learning complex concepts in an unfamiliar language. The latter point also holds true for many native speakers of English, *i.e.*, the languages of math and science pose a barrier to academic success. [See Spanos et al. (1988) and Spanos and Crandall (1990) for discussions of the features of the mathematics and science registers. See Cocking & Mestre, eds. (1988) for articles pertaining to the roles of language and culture in mathematics learning. See Pimm (1988) for an interesting analysis of the notion that mathematics is a language.]

QUESTIONS:

What are some of the difficult features of the languages of mathematics and science which are evident in the various segments of the video? (For example, vocabulary items such as *whorl* in the segment from Bonnie Coffey-Smith's class; sentence structures such as "to form the contrapositive we..." in Judy Engel's class; or the attempt by David Hirschy to contextualize Newton's Third Law.) Are any of these features problematic for native speakers of English as well as for non-native speakers?

What examples from your own experience as a teacher or student of math or science support the notion that math and science are languages? (It is interesting to note that many people joke that math and science are foreign languages, citing the often arcane vocabulary and formalized linguistic patterns in textbooks and lectures.)

What cultural factors are evident in either the video or in your own classes that would affect the learning of mathematics or science? (For example, in the video there are several instances of group work. Do some students prefer to solve problems collectively as opposed to independently?)

Is it necessary for teachers to insist that students use only English in class? (For example, in David Hirschy's class, the students doing the pendulum experiment are using Spanish. Is this acceptable? Why or why not?)

How would you assess a student's proficiency in the language of mathematics or science? (For example, in the pendulum experiment in David Hirschy's class, the student is not readily able to explain Newton's Third Law in English. Does this mean that he does not understand what is going on? Is it a problem of science proficiency, language proficiency, or both?)

Should students be expected to use standard English at all times in their math and science classes? (For example, in David Hirschy's class, Giovanna asks: "How come nothing happened with the paper?" instead of "Why didn't anything happen to the paper?")

II. Techniques for Increasing Communication in Math and Science Classes

David Hirschy asserts: "Students learn English when they learn it in a context that is meaningful to them...They need to use English; they need to talk about the experiences with one another; and in the process of using the language, they just simply learn it automatically."

This statement has implications for both language arts classes and for math and science classes. On the one hand, students can improve their English ability through the learning of mathematical and scientific concepts presented in a contextualized manner. On the other hand, they can learn mathematical and scientific concepts more readily if they are presented in a manner appropriate to their linguistic abilities. Thus, math, science, and language arts teachers need to utilize techniques which provide contextualized opportunities for student discourse. Many of these techniques are modeled by the teachers in the video. They include:

- questioning and explaining,
- use of key vocabulary,
- allowing sufficient time for answers,
- reporting observations,
- focused questioning,
- discovery learning,
- vocabulary games,
- using native language and English,
- use of teaching interns,
- developing thinking skills,
- cooperative learning,
- students questioning students.

QUESTIONS:

What are some of the techniques used by teachers in the video to provide meaningful contexts for language and content learning? Would any of these techniques work/not work in your class? (For example, investigating and describing fingerprint patterns provides a context for content learning and language development.)

Do you use any of these techniques in your class? Do you use any other techniques which you would like to share? (It is often the case that teachers will have received training in cooperative learning, in the use of learning style strategies, and/or in classroom management techniques. Trainers will want to draw upon the teachers' expertise in the discussion.)

Are there any drawbacks to using these techniques in your classroom? How can these drawbacks be overcome? Are they really drawbacks? (For example, Gloria Allen's class frequently breaks into cooperative groups. Some teachers favored the language learning opportunities that group work affords while others are concerned about the sometimes unpredictable results of cooperative learning. Still others believe that techniques such as group work take up an inordinate amount of class time.)

How is Gloria Allen's policy, "Ask three before me," effective?

Judy Engel states that critical thinking is a major factor in education. Can you locate instances in the video where the students are engaging in critical thinking? (For example, in the "Fingerprinting" exercise in Bonnie Coffey-Smith's class, the students use inferencing skills to decide whether or not the accountant took the money from the safe.) What methods for inducing critical thinking do you use in your class? How do these methods relate to a communicative approach?

Both Judy Engel and Felicita Santiago express the need for teachers to take risks. Why? Is it also important for students to take risks? Why? How can teachers develop supportive classroom environments so students are willing to take risks?

Felicita Santiago expresses the importance of the process of learning. What does she mean by this? Do you think that the learning process is as important as the products of learning? More important?

What aspects of the scientific method are modeled in the scene from Bonnie Coffey-Smith's class? Is the scientific method useful in a communicative approach? Are there other instances of the scientific method shown in the video?

III. The Need for Interdisciplinary Cooperation

At the beginning of the video, Eric Nadelstern talks about the need for students to develop language skills within the context of content area studies. Interdisciplinary cooperation is absolutely necessary if math and science are to be taught in a manner which is sensitive to the linguistic needs of students. Whereas the language teachers are familiar with techniques for increasing linguistic proficiency such as cooperative learning and academic writing activities, the math and science teachers know which concepts need to be mastered, how they should be taught, and the order in which they should be taught. Thus, it is essential for teachers to pool their expertise and receive administrative support in order to insure that the subject matter is taught in both a linguistically-sensitive and content-appropriate manner.

QUESTIONS:

The teachers in the video are adept at integrating language and content instruction. Can you identify specific examples of good language teaching in the video? Good mathematics or science teaching? Good integrated teaching? Is it possible to separate good language teaching and good content teaching? (For this question, you might wish to have different groups focus on different segments of the video.)

Which mathematics and science topics can be included in language classes? What kinds of language activities can be included in math or science classes? How can language and content teachers support each other?

Does your school or institution have an in-service program which offers opportunities for interdisciplinary cooperation? If so, please elaborate.

What role might the school principal, curriculum supervisors, or community leaders play in facilitating an interdisciplinary program in your school district?

Trouble Shooting

Some viewers may find difficulties with some of the assertions and behaviors found in the video. There is no way to predict how the viewers will react, but some common concerns and questions, along with possible replies, follow:

1) There is no time in the math/science curriculum for time-consuming activities such as cooperative learning, journal writing, hands-on experiments.

Possible reply: These activities are not a waste of time! They are essential to both language learning and content mastery. Moreover, major mathematics and science associations and educators are recommending the use of activities which increase communication in the classroom.

2) There is no time in the language classroom for the inclusion of math and science topics.

Possible reply: Make time! One of the best ways to inspire motivation and cooperation in a language classroom is through the use of topics which are interesting, engaging, and relevant to other classes in the school curriculum.

3) Bonnie Coffey-Smith uses the word *criminalist* when she meant to say *criminologist*.

Reply: No, she was correct. A *criminalist* is an expert in the use of scientific methods for solving crimes. A *criminologist* is a person who is an expert in the sociological aspects of crime.

4) What game are the math students playing in Felicita Santiago's classroom?

Reply: It's an adaptation of Scrabble. Each team has individual cardboard squares with letters of the alphabet on them. As the teacher reads the clue, they spell out the answer with their letters.

5) Why does the student teach the same lesson to David Hirschy's class?

Reply: She is teaching the same lesson to a different class. As an intern for a trimester, she sits in David Hirschy's morning classes and teaches his afternoon class. She also helps prepare the labs and assignments. It is worth noting, too, that David Hirshey only gives a "lecture" on new subject matter once a week. The rest of the time is spent on labs and other student-centered activities.

6) How does David Hirschy's sign-in process work?

Reply: His class is set up into several (4 or 5) different work stations. To complete a science unit each student must complete the tasks, or lab experiments, at these stations. Every day students enter class and sign up for their work station at the same time they take their own attendance. Some stations require several class periods to complete.

7) I'd like to try this, but there are no communicative materials available for classroom use.

Reply: It is true that many commercial materials are not yet available, but fortunately publishers are working to change that in light of the recent NCTM recommendations. Some materials have been developed though, such as *English Skills for Algebra* (Crandall, et al., 1989), *Science for Language Learners* (Fathman & Quinn, 1989), and the *Pre-Algebra Lexicon* (Hayden & Cuevas, 1990).

8) I wouldn't expect to find limited English proficient students at the Bronx High School of Science.

Reply: You're right. Although several language minority students in Judy Engel's class were limited English proficient at one time in their schooling, they are no longer. CAL wanted to include that scene to show that the communicative approach is also very effective in mainstream classes. Incidentally, the International High School student population is 100% limited English proficient. In order to enroll, students must have been in the US for less than four years and have scored on the *bottom* third of the Language Assessment Battery (LAB) test.

Contacts

For information pertaining to mathematics and science education and the use of communication strategies in math and science classrooms, you may contact the following institutions and organizations:

National Council of Teachers of Mathematics
1906 Association Drive, Reston, VA 22091
703-620-9840

National Science Teachers Association
808 Connecticut Ave., NW, Washington, DC 20006
202-328-5800

The National Research Council
Mathematical Sciences Education Board
818 Connecticut Ave., NW, Suite 500
Washington, DC 20006 202-334-3294

The Center for Applied Linguistics
1118 22nd St., NW, Washington, DC 20037
202-429-9292

American Association for the Advancement of Science
1333 H St., NW, Washington, DC 20005
202-326-6666

The Educational Development Center
55 Chapel St., Newton, MA 02160
617-969-7100

Triangle Coalition for Science & Technology Education
5112 Berwyn Rd., 3rd floor
College Park, MD 20740 301-220-0874

The Lawrence Hall of Science
Univ. of California, Berkeley, CA 94720
415-642-5133

The Exploratorium
3601 Lyon St., San Francisco, CA 94123
415-561-0360

The San Francisco Science Collaborative
2550-25th Ave., San Francisco, CA 94116
415-731-6309

Further Reading and Resources

American Association for the Advancement of Science. (1989). *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology.* Washington, DC: AAAS.

Cocking, R.R. & Mestre, J.P. (eds). (1988). *Linguistic and Cultural Influences on Learning Mathematics.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Connolly, P., & Vilardi, T. (eds.). (1989). *Writing to Learn Mathematics and Science.* New York : Teachers College Press.

Crandall, J. (ed.) (1987). *ESL Through Content Area Instruction: Mathematics, Science, and Social Studies.* Englewood Cliffs, NJ: Prentice Hall Regents.

Crandall, J., et al. (1989). *English Skills for Algebra: Math-Language Activities for Algebra Students. Book I: Tutor Book and Resource Materials. Book II: Student Workbook.* Englewood Cliffs, NJ: Prentice Hall Regents.

Cuevas, G. (1984). Mathematical Learning in English as a Second Language. *Journal for Research in Mathematics Education* 15, 134-144.

Fathman, A.K. & Quinn, M.E. (1989). *Science for Language Learners.* Englewood Cliffs, NJ: Prentice Hall Regents.

Hayden, D. & Cuevas, G. (1990). *The Pre-Algebra Lexicon*. D. Short & G. Spanos (eds.). Washington, DC: Center for Applied Linguistics. [Project funded by the Carnegie Corporation of New York, Grant No. B 5003.]

Miami-Dade Community College. (1990). *Preparing Teachers to Integrate Math and Language Instruction*. Video project funded by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education, Grant No. G008730483.

National Council of Teachers of Mathematics. (1989a). *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: NCTM.

National Council of Teachers of Mathematics. (1989b). *Professional Standards for Teaching Mathematics: Working Draft*. Reston, VA: NCTM.

National Research Council. (1989). *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*. Washington, DC: National Academy Press.

Pimm, D. (1988). *Speaking Mathematically: Communication in Mathematics Classrooms*. London & New York: Routledge & Kegan Paul.

Short, D.J., Crandall, J.A., & Christian, D. (1989). *How to Integrate Language and Content Instruction: A Training Manual*. Los Angeles: Center for Language Education and Research, UCLA. [ERIC ED 305824.]

Short, D.J. & Spanos, G. (1989). Teaching Mathematics to Limited English Proficient Students. *ERIC Digest*. Washington, DC: ERIC CLL/Center for Applied Linguistics. [ERIC ED 317086].

Spanos, G. (1990). On the Integration of Language and Content Instruction. *Annual Review of Applied Linguistics X*. New York: Cambridge University Press.

Spanos. G., & Crandall, J. (1990) Language and Problem-Solving: Some Examples from Math and Science. In A. Padilla, H. Fairchild, & C. Valadez (eds.), *Bilingual Education: Issues and Strategies* (pp.157-170). Newbury Park, CA: Sage Publications.

Spanos, G., et al. (1988). Linguistic features of mathematical problem solving. In R.R. Cocking & J.P. Mestre (eds.), *Linguistic and Cultural Influences on Learning Mathematics*. (pp. 221-240). Hillsdale, NJ: Lawrence Erlbaum Associates.

Production of this guide was supported by a grant from the Carnegie Corporation of New York.