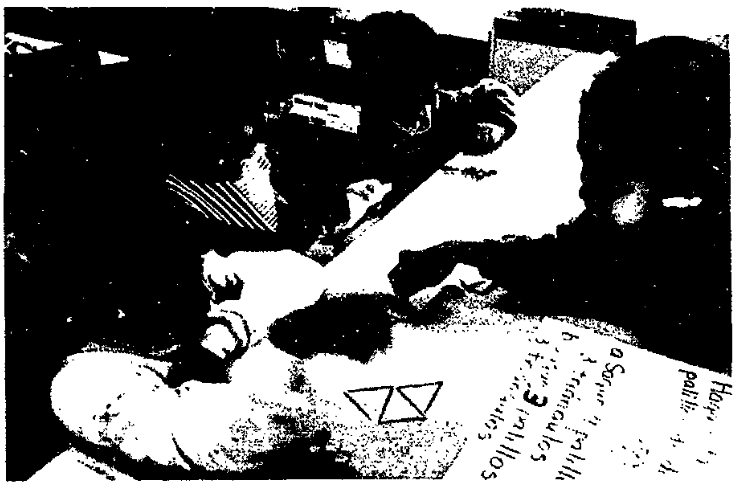
DOCUMENT RESUME

ED 356 664 FL 021 173

TITLE	Teaching Mathematics and Science in the Immersion Classroom. Teacher's Activity Manual.
INSTITUTION	Montgomery County Public Schools, Rockville, MD. Office of Instruction and Program Development.
SPONS AGENCY	Department of Education, Washington, DC.
PUB DATE	90
NOTE	84p.; For other manuals in this series, see FL 021 166-176.
AVAILABLE FROM	Foreign Language Coordinator, Division of Academic Skills, Montgomery County Public Schools, 850 Hungerford Drive, Rockville, MD 20850 ($25 for manual and videotape; prepaid).
PUB TYPE	Guides - Classroom Use - Instructional Materials (For Learner) (051) -- Audiovisual/Non-Print Materials (100)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	Caregiver Speech; Check Lists; Elementary Education; *FLES; *Immersion Programs; *Language Teachers; *Mathematics Instruction; *Science Instruction; Second Language Instruction; Teaching Guides; Teaching Methods; Videotape Recordings
IDENTIFIERS	*Content Area Teaching

ABSTRACT

The purpose of this manual, which accompanies a video program, is to provide general background information for foreign language teachers who are, or soon will be, teaching in total, partial, or two-way immersion classrooms. Part of a series of video programs, this manual highlights techniques, strategies, and special considerations that immersion teachers must think about as they plan for and teach mathematics and science to immersion students at the elementary school level. The manual and the video program have been designed to complement each other in a variety of ways. The video program has been divided into two sections and it is recommended that each section be viewed separately. The first section explores three principles for teaching math and science in the immersion classroom: actively involve students; integrate the teaching of language, math, and science; and adapt language and content instruction to students' background and life experiences. The second section presents three scenarios during which the viewer may identify the three principles from Part 1 in real classroom situations. Appended materials include math and science objectives, an immersion planning checklist, a checklist for evaluating an immersion lesson, and a discussion of caregiver speech. A background paper by Gilbert J. Cuevas is included. (Contains 22 references.) (VWL)



TEACHING MATHEMATICS AND SCIENCE IN THE IMMERSION CLASSROOM

Division of Academic Skills
Office of Instruction and Program Development
Montgomery County Public Schools
Rockville, Maryland

1990

EDRS

TEACHING MATHEMATICS AND SCIENCE IN THE IMMERSION CLASSROOM

TEACHER'S ACTIVITY MANUAL

Montgomery County Public Schools
Office of Instruction and Program Development
Division of Academic Skills
850 Hungerford Drive
Rockville, Maryland 20850-1747

Prepared by
Eileen B. Lorenz, Immersion Resource Teacher
Myriam Met, Foreign Language Coordinator

The Montgomery County Public Schools prohibits descrimination on the basis of race, color, national origin, marital status, religion, sex, age or handicap in employment or in any of its education programs and activities. Make inquiries or complaints concerning discrimination to the Department of Human Relations, Room 211, 850 Hungerford Drive, Rockville, MD 20850; telephone 301-279-3167.

The contents of the video program and manual were developed under a grant from the U.S. Department of Education. However, these contents do not necessarily represent the policy of the Department and readers should not assume endorsement of the content by the federal government.

TABLE OF CONTENTS

PREFACE

Video production

The production of this video program and manual was funded by a federal grant from the U.S. Department of Education, Title VI, International Research and Studies: Improving Foreign Language Methodology Through Immersion Teacher Training. This grant was developed and implemented by the Office of Instruction and Program Development, Division of Academic Skills, Foreign Languages, Montgomery County Public Schools, Rockville, Maryland, from July, 1989 to June 1990. The activities for this grant were carried out by Eileen Lorenz, immersion resource teacher and Myriam Met, foreign language coordinator.

The production of this program would not have been possible without the cooperation and support of the elementary immersion staff and students of the three Montgomery County Public Schools immersion programs: Oak View, Rock Creek Forest, and Rolling Terrace elementary schools. Montgomery County Public Schools television services staff members also made significant contributions.

Upon request, this manual and video program will be distributed to school districts and institutions of higher education to be used for nonprofit training workshops and research projects. Requests for these materials should be accompanied by a $25 check made payable to Montgomery County Public Schools. Requests should be addressed to:

Foreign Language Coordinator
Division of Academic Skills
Montgomery County Public Schools
850 Hungerford Drive
Rockville, Maryland 20850

INTRODUCTION

Purpose of the video program and manual

The purpose of the program and manual is to provide general background information for foreign language teachers who are, or will soon be, teaching in total, partial or two-way immersion classrooms. The seventh in a series of video programs, Teaching Mathematics and Science in the Immersion Classroom highlights techniques, strategies and special considerations that immersion teachers must think about as they plan for and teach mathematics and science to immersion students at the elementary school level.

How to use the video program and manual

The Teacher's Activity Manual and the video have been designed to complement one another and may be used in a variety of ways. The video program has been divided into two sections and it is recommended that each section be viewed separately. The first section explores three principles for teaching math and science in the immersion classroom: actively involve students; integrate the teaching of language, math and science; adapt language and content instruction to students' background and life experiences. The second section presents three scenarios during which the viewer may identify the three principles from Part I in real classroom situations. The viewer may first wish to read the articles found in the section, "Background Reading," and then view the video program and complete the related activities included in the manual. Or, the viewer may wish first to watch the video, read the articles and then complete the activities in the manual. Another option is several readings of the background materials, before and after viewing of the program.

INTRODUCTION - continued

The video and accompanying activity manual may be used effectively by either one teacher or by a group of teachers. Multiple viewings to review specific sections of the video provide opportunities to use the program to support a variety of objectives.

Previewing Activity

Before viewing the video program, take some time to reflect on the teaching of math and science. The two questions below may help you identify special considerations or challenges when teaching math and science in an immersion classroom. You will probably find it helpful to keep your responses to these two questions in mind as you view the video program. Once you've had an opportunity to think about how to respond to the questions, discuss your thoughts with a colleague, if possible.

I. What general considerations should all elementary teachers think about when teaching math and science? List them below.

II. What additional considerations should elementary foreign language immersion teachers should think about when teaching math and science? List them below.

PART I

THREE PRINCIPLES FOR TEACHING MATHEMATICS AND SCIENCE IN AN IMMERSION CLASSROOM

ACTIVITY 1

Principle 1: Actively Involve Students

The first principle for teaching math and science that is presented in the video program is that immersion teachers should actively involve students. Actively involving students in learning math and science can be achieved by using manipulative materials and hands-on activities.

Activities using manipulative materials in teaching math and science are indispensable at all levels in elementary foreign language immersion classrooms. As you, the teacher, demonstrate and explore a concept for the first time, the manipulatives that you use and the way that you use them support the meaning of what you are saying. Imagine trying to teach total or partial immersion first graders about objects that float and sink without being able to demonstrate. What a difficult task it would be to try to teach first grade immersion students the concept of subtraction without using manipulatives such as cuisinaire rods or unifix cubes!

Of course, drawing pictures on the chalkboard might show the float/sink or subtraction concepts pictorially. However, the motivational factors and the extensive contextual clues gained by using real objects cannot be ignored. "Plouf" as a descriptor in French of the sound made as an object hits the water, is not nearly as effective as hearing the word "plouf" as an object makes that sound when it hits the water. Students' predictions of whether the object will float or sink, verified immediately with real objects, makes the concept more meaningful and engaging than a picture drawn by the teacher.

ACTIVITY 1- continued

Principle 1: Actively Involve Students

Involving students in demonstrating a concept is highly motivating. Once students have had an opportunity to explore materials and possible interactions on their own, you could ask their assistance in recording guesses or predictions of outcomes of an investigation; or to place an item in a container of water to see if it floats or sinks. In addition, showing students how to use manipulatives as they learn and explore new concepts is an integral part of the learning process. It prepares them for the next step in the learning of math and science when they explore a concept independently using the same or similar materials.

Because students move in their concept development from the concrete to the representational to the abstract, all young children benefit from and need hands-on experiences to learn math and science concepts. But what about upper elementary (Grades 3 - 6) immersion students? Are manipulative materials needed to teach them math and science concepts?

Imagine teaching a Grade 6 science unit on energy. You're planning a lesson to teach the following performance objective: *Students will identify an inclined plan as a simple machine that requires less force to do work than simply lifting an object.* Compare two methods of approaching this objective. One teacher simply drew several diagrams of inclined planes on the board and explained their function as simple machines. Another teacher involved groups of students in constructing their own inclined planes. Students then compared the amount of effort needed to lift a heavy object to the top of the inclined plane with the effort needed to push the same object to the top of the inclined plane.

ACTIVITY 1- continued

Principle 1: Actively Involve Students

Which group of students do you think was more able to formulate their own definition of the term "simple machine"? Which group of students do you think could best explain how to use an inclined plane? Based on these two different approaches to the same lesson, which one would you opt for and why?

In Grade 5 mathematics students learn to demonstrate the meaning of decimal fractions. Using base ten block (3 types of blocks--100 square blocks, rods divided into 10 equal parts, and smaller blocks each equalling one-tenth of the hundred square blocks and rods) to physically represent decimal fractions will enable students to translate and manipulate parts of a whole into concrete objects from abstract symbols of numeric notation.

As you demonstrate and explore mathematical and scientific concepts with students, using manipulatives helps develop concepts, as well as promoting their immersion language development. Giving students a real example of the concept helps them understand what you're saying. When students use hands-on experiences to explore a concept, all learning channels are accessed--the auditory, visual, and kinesthetic/tactile. Students hear about, discuss, see, touch and use the manipulatives to explore the concept. They learn language and concepts from each other as well as from you!

Manipulatives provide students with readily available materials to ask questions about the concept being explored. For example, a student who does not have sufficient immersion language skills to ask a question about the amount of energy needed to lift a box compared with that needed

ACTIVITY 1- continued

Principle 1: Actively Involve Students

to push the box up the inclined plane, could show the teacher the two examples and ask, "How much,...difference?" Given the context of the lesson and the student's use of the materials at hand, the teacher would make a rich interpretation of what the student was trying to say. The teacher would rephrase the question, using the manipulatives to verify that she was interpreting the student's question correctly and then proceed to explore with the class ways to find the answer to the question. Because partial immersion students frequently have a higher degree of language comprehension than of expression, it is particularly important for teachers to use strategies that actively involve students with manipulative materials and hands-on experiences.

Using manipulative materials during hands-on experiences with immersion students must be carefully planned. Both the concept being explored and the language being used must be easy enough so that students understand, but challenging enough so that their language and concept learning is stretched. Of course, the activities also must be age-appropriate.

I. Manipulatives/Hands-on

Identify a math and/or science objective from the grade level that you are or soon will be teaching, or select one from those listed in Appendix A. As you plan the introductory phase of your lesson, think about the following points:

a) What manipulatives will you use to get the main concept of your lesson across to students?

ACTIVITY 1- continued

Principle 1: Actively Involve Students

b) What hands-on experiences will you plan for students' active involvement and exploration of the concept?

Keeping in mind special strategies you will need to include in your lessons because of students' level of language proficiency, plan in detail at least two hands-on experiences in which pairs or small groups of students can explore the concept. A planning sheet and checklist for evaluating the components of an immersion lesson are found in Appendices A and B.

II. If possible try out your lesson on colleagues who do not understand your immersion language. This will help you determine if the manipulatives and/or hands-on experiences you've selected give adequate support to understanding the concept and the immersion language.

Activity 2

Principle 2: Integrate Language, Math, and Science

In the immersion classroom, language instruction should not be separate from math and science instruction. Students' ability to understand concepts and develop skills is dependent on their skills in the immersion language. They must understand what the teacher is saying, process the concepts being explored, and be able to demonstrate--and eventually discuss and write about--what they have learned.

In the video program three strategies for integrating the teaching of language, math, and science are discussed. Integrating the teaching of language and content is promoted through the teacher's:

Using caregiver speech
Planning for content-obligatory and content-compatible language objectives
Engaging students in oral and written communication

Caregiver speech

Caregiver speech describes the way you modify your speech so that students understand what you are saying. The characteristics of caregiver speech are that you:

- speak more slowly and simply than in normal conversation
- focus on the here and now
- extend and elaborate on students' use of the immersion language

For a more indepth discussion of caregiver speech review the program from this series entitled "Second Language Acquisition in Children".

Activity 2 - continued

Principle 2: Integrate Language, Math, and Science

Content-obligatory/compatible language

As you plan math and science lessons, identify content objectives as well as language objectives. There are two kinds of language objectives to be considered: content-obligatory language and content-compatible language.

Content-obligatory language is that which is critical to students' understanding of the concept. Content-compatible language is that which is easily integrated into the content objectives of the lesson.

For example, during a Grade 1 science lesson where students will learn to classify objects by color and shape, the content-obligatory language will include: classify, the same as..., different from..., and the names of shapes (circle, square, triangle, and rectangle). The content -compatible language will be determined by the objects selected to be classified into the two categories and the colors of the objects selected for the lesson (red, yellow, blue, and green).

One teacher might decide to use wooden blocks to teach this objective while another may use other objects of the designated shapes, such as a round candy, a rectangular envelope. The content-compatible language objectives for the first teacher include vocabulary such as blocks and the colors of the blocks (red, white, etc.). The content-compatible language objectives for the second teacher include vocabulary such as candy, envelope, the colors of these objects and the names of other objects used to teach this objective. Adjective agreement is a content-compatible grammar objective for this science lesson.

Activity 2- continued

Principle 2: Integrate Language, Math, and Science

Oral and written communication

A third strategy for integrating the teaching of language, math, and science is using oral and written communication to increase students' understanding of content and improving language skills. Specialized or new language that is critical to achieving the math and science objectives is usually introduced by the teacher at the same time as the math or science concept.

During instruction, you, the teacher, serve as the language model. However hearing and understanding language is only the first step for students. Just as students cannot be expected to learn a concept merely by observing a teacher's demonstration, they cannot be expected to begin to master language only by listening to or reading it. And just as students need opportunities to "get their hands" on materials, perform meaningful tasks, and explore a concept themselves in order to learn it, they also must have opportunities to "get their hands on", use and practice the immersion language. Students' participation in whole class and small group discussion provides such opportunities for practice.

Pair work, small group, and cooperative group work should provide students with multiple opportunities to discuss and write about math and science activities. While teacher-student communication plays an important role in students' second language acquisition, there is not enough time during the school day for each student to practice language in this way.

Activity 2- continued

Principle 2: Integrate Language, Math, and Science

Furthermore, providing students with multiple opportunities to communicate in small groups allows them to practice language in a safe setting where all the eyes of the class are not upon them. Many students who are reluctant to speak during whole class discussions communicate more freely in smaller groups with their peers. Additionally, research shows that the give and take of ideas and the negotiation of meaning that takes place in small groups is beneficial to students' second language development (Long and Porter, 1985). Therefore, it is critical to students' second language development to have extensive opportunities to discuss math and science objectives as they work with peers.

As was mentioned during the discussion of Principle 1, partial immersion students frequently have a higher level of comprehension than their level of spoken and written language. Therefore, it is particularly important for partial immersion teachers to use caregiver speech, to plan for content-obligatory and content-compatible language, and to provide multiple opportunities for student practice of oral and written language to integrate the teaching of language, math, and science.

1. If possible, observe the introduction of either a math or science objective presented by an immersion colleague. Using the worksheet on the following page, note examples of caregiver speech you observe during the lesson. If you are unable to observe a colleague during the presentation phase of a lesson, review Appendix C which contains written examples of caregiver speech that a teacher might use during lessons in Part II of the video program for examples of caregiver speech.

Activity 2- continued

Principle 2: Integrate Language, Math, and Science

II. Return to the math or science lesson that you planned for Activity 1. Consider two ways of teaching this lesson--first, without caregiver speech and then with caregiver speech. What do you think would be the results of the lesson if no caregiver speech if used? What do you think would be the results using caregiver speech? Do you think that there would be a big difference between these two lessons? Why? Identify possible examples for each of the four categories of caregiver speech that might take place during this lesson. Using the examples noted in Appendix C as models, write an example of a teacher or teacher-student conversation for each category of caregiver speech that might take place during the lesson you've planned.

CAREGIVER SPEECH WORKSHEET

While observing an introductory immersion math or science lesson, note examples of caregiver speech that you observe in each of the categories listed below.

I. Teacher speaks more slowly and simply than in normal conversation. (Examples of this category of caregiver speech include emphasizing certain words, paraphrasing and defining by example.)

II. Teacher focuses on the here and now.

III. Teacher focuses on meaning over form.

IV. Teacher extends and elaborates on student's use of the immersion language.

Activity 2 - continued

Principle 2: Integrate Language, Math, and Science

III. Continue with the math or science objective that you selected to identify use of caregiver speech. Identify the content-obligatory and content-compatible language objectives for this objective. If possible, discuss these language objectives with a colleague.

IV. With the same math or science objective, and plan at least two student-centered pair or small group activities that will involve students in oral and written communication activities.

ACTIVITY 3

Principle 2: Integrate Language, Math, and Science

Teaching students problem-solving techniques combines two principles: 1) Integrating language, math, and science, and: 2) Actively involving students in learning of math and science.

Teaching students problem-solving techniques develops critical thinking skills as well as expanding students' use of language Students must be taught how to solve problems, a goal best achieved by actively engaging them in the solution of many problems. Many experienced teachers recommend teaching students a four-step problem solving process:

Understand the problem
Select a strategy for solving the problem
Solve the problem
Check the solution

Although the four steps refer specifically to problem-solving in math, the same four steps may be adapted to science.

Explore and observe
Ask a question, identify approaches to finding the answer and select one
Try the approach identified
Observe again

All the steps in the problem-solving or scientific investigation process involve spoken and written language. Some of the language will be specific to math or science and therefore may also be new to students. This language should not be learned in an isolated manner, as students are learning the mathematical or scientific concept and problem-solving process that the language expresses.

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

For example, a Grade 6 math objective states that *students will explore the relationships among the radius, diameter, and circumference of a circle.* Students will become familiar with and learn new vocabulary and expressions by identifying common circular objects in their environment and identifying and comparing their radii, diameters, and circumferences. Other vocabulary and expressions used during this lesson may not be specific to math; and it may be language students have generalized from other subjects or classroom experiences.

Whether the subject is math or science, understanding the problem is a critical factor in developing both language and critical thinking. Students must decide what information is important and what is irrelevant to decide how they will go about solving a problem or investigating a concept. If students don't understand the language used to present a problem or situation, they will be unable to go further.

Let's examine a Grade 4 problem about fractions to identify difficulties immersion students might encounter. Before attempting to solve the following problem, students would receive direct instruction about fractional parts and use manipulatives and diagrams to practice solving similar problems.

> *Margot has purchased sixteen plants to put in her garden. One-fourth of the plants are dahlias, one-eighth of the plants are marigolds, and five-eighths of the plants are impatiens. She also ordered six evergreen trees to place in front of her house for privacy. How many of each variety of plants will she plant?*

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

Imagine that you're a Grade 4 teacher. Think about difficulties students might have with vocabulary and expressions in this problem.

- What could you do to anticipate and thereby minimize these difficulties?
- Do you think that the irrelevant information about six evergreen trees would be immediately apparent to students?

When presented this problem, veteran partial immersion teachers identified the plant vocabulary as language with the most potential for causing students difficulty. Prior to independent problem solving, they suggested that students practice using this plant vocabulary along with illustrations from seed catalogues during small group problem-solving situations. Veteran immersion teachers also felt that partial immersion students would need frequent practice identifying irrelevant information in problem solving situations; problems with similar format were recommended for practice so that students could to recognize patterns and then generalize the patterns to new problems. Teachers were of the opinion that other difficulties with this problem would most likely stem from students': 1) Lack of understanding of fractions; or 2) Difficulty in selecting a strategy for solving the problem.

As students learn how to select a strategy for solving problems or organizing a scientific investigation, you will help them explore various possibilities for organizing and recording the information they have identified as important to the solution. In Grade 1 science, students

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

observe growing plants to learn that plants develop and grow in an orderly manner. Think about how many different ways you could help students record the development of plants during a month-long investigation. How could you integrate the use of manipulative materials, drawings, tables, charts, lists into this unit? What strategies could be incorporated into lessons to help students recognize patterns of growth? How could students learn to record information and data from their investigations independently?

As students solve problems or conduct investigations, they will learn how to identify (isolate) the steps or procedures they ollowed to arrive at their solution or the results of their investigation. They will learn how best to keep records of results or solutions. Students will learn to use pictures, numbers, words, phrases, sentences, and measurements of various kinds. Whether they record this information by writing or drawing, they are still learning the importance of noting procedures and observations.

Finally, students will learn the importance of checking the accuracy of their answer to a problem or examining the results of their investigation.

While all immersion teachers must be alert to students' understanding of language and concepts, the partial immersion teacher's task is particularly challenging. Because partial immersion students spend only half the school day surrounded by the immersion language, teachers must pay careful attention to their level of understanding and

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

provide them with multiple nonverbal and verbal opportunities to express what they have learned as well as to ask questions about the math problems to be solved or the scientific concepts to be explored. Veteran partial immersion teachers report that specific strategies are particularly effective when introducing new math and science concepts to their classes. Some of these strategies are described in the following paragraphs.

Partial immersion teachers use whole class instruction to introduce and familiarize students with language and procedures to be followed in solving a particular type of problem or in developing a scientific investigation. Problem situations or scientific procedures are frequently broken down into simple steps to keep students from feeling overwhelmed by the language and/or the complexity of the problem.

Partial immersion teachers incorporate many real objects and pictures into both math and science lessons. They also make these materials are available as students formulate and express their thoughts and pose questions. During whole class instruction, teachers provide many opportunities for students to practice solving many variations of a problem or to apply skills needed during a scientific investigation.

Once partial immersion students are familiar with a concept and the language they will need to understand and use, they may work independently in small groups or pairs. Peer support and interaction provides students with opportunities to practice and discuss the math or science concepts or skills to be learned. While students work in small groups, partial immersion teachers encourage and promote practice in the

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

problem using simpler language, often incorporating pictures to aid immersion language. Also, partial immersion teachers continuously monitor students' work and language development, making themselves available for students' questions and requests for assistance.

In instances where complicated language is used to express a problem or a scientific concept, partial immersion teachers rewrite the students' understanding. During assessment, partial immersion teachers must take into account students' limited language proficiency and give them nonverbal opportunities to demonstrate concepts they have learned.

I. Identify a science or math objective for your grade level or a grade level that you will be teaching. Using the Immersion Lesson Planning Sheet (Appendix B) and the Immersion Lesson Evaluation Sheet (Appendix C), plan a detailed lesson that includes all of the problem-solving process steps for a math problem, science investigation or a concept involving math and science.

II. Make a list of language that you think your students will use during the course of the school year to solve math problems or carry out science investigations. For example, in Grade 1 science units, students will most likely learn the following vocabulary and expressions:

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

guess/prediction, I observe, results, investigation, test
I think it (will float).
It is going to (float).
It (floats).
It didn't (float).

Students will use this vocabulary and these expressions during a science unit focusing on energy for the following objective: *Students will demonstrate that objects in motion are a result of a push or pull.* They will also use the same terminology during a unit on the changing universe where the objective is: *Students will identify that the position of shadows cast by objects in the sun change during the day.* Can you think of any other essential language for Grade students to use during science lessons over the course of the school year? If you do not teach Grade 1, note the language that would be essential during science units for the grade level you teach. Make a separate list of the language that is essential for math at the grade level you are or will be teaching.

II. If possible, discuss the language you have noted with colleagues who teach the same grade level. Compare your list of math and science language with a list compiled by those who teach other grade levels. What are the similarities and differences in the language components identified? Is it possible to identify a continuum of math and science language that begins at the primary level and becomes more extensive and sophisticated in upper elementary classes? Within your school,

ACTIVITY 3 - continued

Principle 2: Integrate Language, Math, and Science

you may want to consider making this math and science language part of your immersion reading and language arts scope and sequence.

Activity 4

Principle 3: Adapt Language and Content Instruction to Student Background and Life Experiences

Surveying students' background knowledge will make it easier for you to help them make connections between math and science learned in the classroom and their world outside the classroom. Students need to see that the skills and concepts they explore in the classroom are important and applicable in their everyday world. An important factor in helping you to make this connection successfully is knowing about students' background and experiences outside the school environment.

Like all students, immersion students have diverse backgrounds in language, math, and science. To determine where to begin instruction and how to make that instruction most meaningful, it is important to survey and evaluate students' background knowledge of the specific skills, concepts and language related to the concept you are about to teach. This will give you some of the information you need to compare what students already know with what they will need to learn. This survey can be accomplished by questioning and observing students one-to-one and in small and large groups. Asking students to make guesses or predictions, classify objects according to attributes, and brainstorming may serve as motivating techniques that encourage them to demonstrate and talk about what they already know.

For example, imagine that in a Grade 4 mathematics lessons students have learned to make change up to $5. Now, in Grade 5 you are about to introduce and teach an objective that states that *students will solve problems requiring making change for up to $10.* You survey

Activity 4 - continued

Principle 3: Adapt Language and Content Instruction to Student Background and Life Experiences

students' background knowledge about making change up to $5, demonstrating and involving student volunteers in making change for a variety of purchases from one to five dollars. Then you give small groups of students a sack of items with prices already noted. Each student "purchases" an item with a $5 bill. Another student in the group makes change for the purchase, using a "bank" of play money provided for each group.

Take a moment and think about opportunities during this introductory lesson to find out what students already know about making change and handling money. What questions, or experiences could you structure to elicit information about students already know?

The most obvious opportunities to formulate judgements about students' background knowledge would be based on their responses to questions and how well they make change during the review lesson activities. These interactions will indicate those in the class ready for the new math objective and those who need additional review. Students' language will help to identify their strengths and weaknesses and help you identify and plan language objectives.

Less obvious opportunities to survey students' background knowledge are their incidental comments about experiences handling money for errands, jobs, and weekly allowances. These comments, while not directly related to the math objective, may provide information about students' opportunities and experiences to handle money independently. Discussions

Activity 4 - continued

Principle 3: Adapt Language and Content Instruction to Student Background and Life Experiences

that link math and science objectives to everyday application in students' lives outside of the classroom are highly motivating and encourage students' spontaneous involvement. An additional benefit is that such comments and discussions encourage students to talk about topics that are indirectly related to the subject and frequently result in their learning and using new language that would not normally be part of their academic language repertoire.

Immersion teachers need to keep in mind the importance of helping students make connections between what they are learning in the classroom and their lives outside of school. We have just described the importance of surveying students' background knowledge before beginning to teach an objective. Once students have explored a concept, it is important for them to see links between classroom learning and their world outside of school. Although all or part of students' school day is conducted in a second language, the concepts they study are not language-bound and are easily transferable. An integral part of teaching a particular objective should be to help students to see the existence and application of the concept outside the school setting. Helping students make this connection is best achieved through the choice of activities you select for students' to explore and practice an objective. In science, for example, Grade 4 students, living in a land-locked city would see more immediate relevance in studying the pollution created in their city by

Activity 4 - continued

Principle 3: Adapt Language and Content Instruction to Student Background and Life Experiences

factories than they would in studying the pollution created by a major oil spill along the Alaskan coast.

I. Select a science objective from your grade level or from Appendix A. Use the Immersion Planning Sheet (Appendix B) and Checklist introductory math or science lesson. Be sure to list and describe in detail at least two activities to survey students' background knowledge about the content as well as their level of proficiency in the immersion language related to this objective.

II. Continuing with the same objective, list ways in which you could help students connect the concept being studied to their the world outside the classroom. You may want to consider some of the suggestions listed below. Connecting classroom learning with students' world outside the school environment:

- Students bring items from home to explore or investigate during math or science activities
- Students list examples of math or science concepts being investigated that they have observed in their home environment
- Students survey and discuss opinions and preferences of adults in home environment about math and science topics being explored (e.g., What do you think happens when....? Which item do you think is heavier....? Why do you think that....? How do you think I could.....?)
- Students search for news and magazine articles, film and other programs related to math and science topics being explored

APPENDICES

*Math Objectives

Students will:

Grade 1: Measure and record length using non-standard units and single-unit repetition with concrete models.
Estimate (and verify) lengths, weights, and capacity with non-standard units.

Grade 4: Identify horizontal, vertical, intersecting, parallel and perpendicular lines.
State the meaning of the parts of a fraction.

Grade 6: Distinguish among regular, non-regular, concave, and convex polygons.
Explore the relationships among the radius, diameter, and circumference of a circle.

*Science Objectives

Students will:

Grade 1: Identify seeds as things that grow.
Group objects according to weight.

Grade 4: Identify the origin of different kinds of pollution.
Distinguish between evaporation and condensation.

Grade 6: Explain that friction is a force that resists motion of matter.
Explain that the apparent brightness of stars is related to their size, distance, and temperature.

*These objectives are from the Montgomery County Public Schools Mathematics and Science Curriculum.

Appendix B

Immersion Lesson Planning Sheet

Objective/concept

Content-obligatory language

Vocabulary	Functions	Grammar

Content-compatible language

Vocabulary	Functions	Grammar

Activities (identify the following steps for each lesson)

1. Survey students' background knowledge (language and content)
2. Introduce new concept
3. Provide opportunities for student practice
4. Summarize lesson

Assessment

Materials needed

Follow-up activities

Appendix C

Checklist for Evaluating an Immersion Lesson

Planning

Are the math or science objectives clearly identified?

Are the language objectives clearly defined?

Do the objectives address both content and language?

What language skills are developed?

Is there integration of language skills with math and science learning?

Are the procedures sufficiently concrete for students to understand both language and concepts? (How do the planned activities help students acquire language and concepts?)

To what extent are the evaluation activities tied to or free from language?

Bold print indicates slower and/or emphatic speech for each of the characteristics of caregiver speech.

- Speaks more slowly and simply than in normal conversation.

Example: The teacher, while holding and describing a prism during a Grade 6 math lesson says, "Notice that the triangular prism has 5 **faces,** 9 **edges,** and 6 **vertices.** What did we say about **vertices**? They are the **points** where **three or more sides** come together."

- Focuses on the here and now.

Example: The teacher shows students the faces, edges and vertices on an actual triangular prism. Then in groups of 4, students examine a prism and identify the faces, edges, and vertices.

- Focuses on meaning over form.

The teacher posed the question, "Can you think of any items that have the same form and characteristics--5 faces, 9 edges and 6 vertices--as a triangular prism?". One student replies, "In Mrs. Vincent science class, we look light one of those." The teacher replies, "Ah, you looked at light with a triangular prism in Mrs. Vincent's science class?" The teacher has accepted the information the student communicated, and while she has rephrased the sentence correctly, she has not overtly drawn attention to the student's errors.

- Extends and elaborates on students' use of the immersion language.

Another student replies to the same question by saying, "The light in the ceiling in my dining room has those things hanging on it." The teacher gets the student to stretch his/her language by asking, "What things?" The student replies, "The triangular prisms." The teacher extends the student's reply and adds new information by saying, "Aha, you mean that the **chandelier** in your dining room is decorated with **triangular prisms**. So now we see that this geometric form has both a **scientific function** as well as a **decorative function**." The teacher also adds additional information to what the student has said.

BACKGROUND READING

Teaching/Learning Mathematics and Science in a Language Immersion Setting

Gilbert J. Cuevas
University of Miami, Coral Gables, FL

A sample classroom setting[a]

There are 26 children in this second grade class. The school is located in a ethnically diverse neighborhood of a large metropolitan area. The students have been participating in this Spanish immersion program since kindergarten. Their language skills are at a level which allows the children to carry out basic discussions in the target language. The teacher divided the class into three heterogeneous groups (by math achievement). While two of the groups work on activities with manipulatives, she is explaining to six students the concept of multiplication. Using concrete objects, she is having the students make representations of basic multiplication facts such as 2x3 and 4x5. The students use counters to make arrays for the given multiplication operations. The teacher then asks to explain their arrays. She asks questions such as -

"Cuantas filas horizontales tienes? Por que?" [*How many rows do you have? Why?"*]

"Cuantas filas verticales tienes? Por que?" [*How many columns do you have? Why?"*]

"Cuantas fichas hay en total?" [*How many chips are there in total?*]

At this point in the lesson emphasis is made on the development of oral language skills. After the students in this group feel comfortable with the ideas, the teacher carries out

[a] This example is based on a classroom the author observed.

the same lesson with another group until all of the students have been instructed.

While the small group instruction is taking place, the remainder of the students are involved in two different activities. One group is working with pattern blocks trying to determine how many blocks will fill a given figure. The students, working in pairs, will complete a table that asks them to note how many blocks of different shapes (i.e. triangles, squares, etc) will cover the assigned figures. The students are then asked to discuss or 'discover' any number patterns. The third group is conducting a small experiment on the weight of different objects. The students have been paired and given a set of common objects (book, toy, can, etc) and a scale. They are to weigh them and decide -
"Cual es el mas pesado? Por que?" [*Which is the heaviest?*]
"Cual es el mas liviano?" Por que?"[*Which is the lightest?*]
The activity also involves the solution of a problem situation - If the students are to mail any two objects to a friend, and there is a weight limitation, which two objects will they be able to send? By the end of the math/science class all of the students have had an opportunity to participate in all of the group activities.

A "moral" to the story

As we can see, the teacher in this classroom very effectively applied a number of teaching and learning principles to carry out the activities. The students were very involved in meaningful tasks; they were working with each other and verbally interacting. What are the principles which guided the teacher in the illustration to design the kinds of learning experiences provided for the students?

Although there is a lack of research which deals specifically with factors related to mathematics and science instruction in language immersion settings, answers to the above question can be found in what the research literature has to say about:

- the role of language in the learning of subject matter content,
- factors related to instructional effectiveness in mathematics and science education, and
- suggestions for the promotion of meaningful language development in immersion programs.

So I now turn the discussion to a review of the research literature concerning each of these areas. My objective is to provide suggestions for teaching math and science in language immersion programs.

Language and the learning of subject matter

In general, there has been quite a debate, which still continues, concerning the relationship of linguistic skills to cognitive processes. Some researchers, such as Piaget (1972), have stated that language reflects but does not determine cognitive development. Others, including Vigotsky (1962) have emphasized the interrelationship of thinking and language. The research evidence concerning the language-content relationship is still inconclusive, but appears to indicate that the development of concepts and skills in a subject matter has some inherent relation to language and to the development of linguistic skills (Cuevas, 1984).

From a general perspective, research studies suggest that the forms, functions, and uses of language can be best acquired and learned in context. Krashen (1982) has highlighted the importance of context to provide linguistic experiences to enhance the students' comprehension ("comprehensible input"). These experiences are available as part of the process of subject matter learning.

The research on the language/content relationship is more definitive if one examines specific aspects of the learning of math or science. Studies conducted in the area of both mathematical and scientific problem solving have found a high correlation between problem solving proficiency and the ability to read and comprehend written material (Aiken, 1967; Beardslee & Jerman, 1974; Caldwell & Goldin, 1979; Janvier,1980; Goldin, 1982). The first step in the problem solving process is to comprehend the problem (Polya, 1945). Understanding a given problem comprises the collection of information such as: what is the unknown?; what are the facts given?, and what are the conditions imposed?. This process also involves the processing of the information gathered: can a diagram/picture be drawn of the problem situation?; what mathematical operations might be required?; and are the underlying concepts known? Understanding of the problem is followed by the selection of a solution strategy, carrying out such a strategy (solving the problem), and finally checking the result (looking back).

Barnett (1984, p. 23) illustrates very effectively the language-content relationship within the process of reading/understanding a given problem through the analysis of two problem statements:

> Problem #1: *How much will Mary's puppy Spot weigh at the end of 1 year, if Spot weighs 2 pounds at birth and gains 3 pounds every 2 weeks?*
>
> Problem #2: *Mary's dog had a puppy which she named Spot. She weighed 2 pounds at birth. Mary observed that she gained 3 pounds every 2 weeks. At that rate, how many pounds will Spot weigh at the end of her first year?*

It is clear from the two examples that there are a number of linguistic differences between the problems. The second has more words and sentences. It also contains a number of pronouns which may affect the rate of information processing. The data in each problem is presented in a different order, with Problem #2 having the information necessary to solve the problem placed farther from that required for solution.

Barnett (1984) points out that there are linguistic variables which play a role in the process of problem solving. He states that:

> "...some types of syntax variables, such as those describing grammatical structures and syntax formats, may affect problem difficulty at the decoding stage, while other types of syntax variables, particularly those involving the sequencing of information and the positions of sentences and phrases, interact with a problem's underlying structure and therefore directly affect the ease or difficulty of processing the information contained in the problem statement (p.24).

Two comments may be derived from the above example: a suggestion for teaching practice, and a question. The immediate application of the illustration for teachers of immersion programs is to be sensitive to the textual structure of the materials given to students, whether they be problems or explanations. The question concerns the degree to which this relationship of language complexity to understanding can be generalized to other components of classroom interaction such as listening to teachers' directions, verbally explaining a scientific process or writing about a mathematical concept. Fortunately, as a result of the work of Krashen (1982), Wong-Fillmore (1985) and others, it can be concluded that teachers need to make adjustments and modifications in all language areas to help students process and understand the "messages" we send them in class. These modifications may involve speaking clearly and slowly, using concrete referents, and utilizing shorter sentences.

Another specific area in which language and learning have a close relationship is that of writing in the curriculum content areas. This research has been conducted mostly with first language learners, but the results have implications for second language students. Overall, the outcomes of studies indicate that writing in the curriculum content areas facilitates the students' thinking and communication skills. Another benefit is the increased understanding of subject matter (Resnik, 1987). In order to achieve these results the teacner must first provide opportunities for writing that are planned as part of the instructional process, and second, assist students in the development of writing skills in order to communicate clearly. Writing about mathematics or science can be a challenge in immersion settings due to the limited language skills some students may have. Writing tasks may be adjusted to the language proficiency level of students. For example, a writing assignment for students who are limited in the target language could be to list all of the words or phrases they can think of regarding a particular mathematics or science concept. A student in the fourth grade class wrote the following when she was given the term "multiplication": "hard", "homework", "not division", "makes big numbers", "fast addition". Writing tasks may range from the previous activity to the language proficiency level where a teacher can asks students to describe how they feel about mathematics or science, or to provide a self-report of what has been learned.

Studies concerning a language/thinking dimension of the learning of mathematics and science also shed light on the nature of the relationship between language and content. Gardner (1980) found that students in grades 7-10 enrolled in schools in Australia had difficulty with the connectives encountered in logical reasoning exercises in science. Mestre (1988) has concluded from his studies in language comprehension and mathematical problem solving that "language proficiency mediates cognitive functioning" (p.215). He hypothesizes the existence of four proficiencies: general language proficiency, proficiency in the technical language of the content area, proficiency with the grammar and usage of the language in the domain, and proficiency with the system of symbols used to communicate ideas in the content.

The picture that emerges from the research conducted dealing with the role of language in the learning of content matter is much clearer than it was a decade ago. The exact nature of the relationship is still not fully explained, but from the existing studies we may conclude that -

- There are language skills that play an important part in the achievement of subject matter, such as reading in problem solving, writing to facilitate thinking, knowledge of vocabulary to deal with concepts, and familiarity with the symbols of the discipline and forms of the language used to express ideas.
- At a "deeper level" we may perceive language as a mediator for thinking in the academic domain. Whether thinking is prerequisite to language development, or the other way around remains to be answered. The important lesson to remember is that language is a vehicle for learning. Students need to be able to use language in dealing with subject matter.
- It makes very little sense to separate language learning and use from learning about mathematics and science. Language must be viewed as a medium of learning and as an integral part of the classroom activities.

Given these conclusions about the role of language in the learning of content, we now move to explore research in the content areas. What does research have to say to the practitioner concerning instructional practices? What curriculum and teaching trends can be derived from such research? First, these questions will be addressed in the context of mathematics, and second with respect to science education.

Instruction and learning in mathematics: Implications from research

There is a strong movement in mathematics education circles to change the perception most people have of mathematics: that of a difficult discipline governed by the memorization and rote application of rules. The "new" image of mathematics promoted has been described as:

"...a diverse discipline that deals with data, measurement, and observations from science; inference, deduction, and proof; and with mathematical models of natural phenomena, of human behavior and of social systems (National Research Council, 1989, p.31)."

This global view of the discipline has also been transferred to calls for revision of curriculum and teaching. According to this orientation, teaching must be directed to help students "construct" their own mathematical understanding. This can be accomplished by giving students opportunities to 'examine,' 'represent,' 'transform,' 'solve.', 'apply,' 'prove,' and 'communicate' the ideas, principles and concepts of the domain. Mathematics educators suggest that these opportunities be made available through working in groups, engaging in discussions, making presentations, and allowing students to take charge of their own learning (National Research Council, 1989).

At the elementary school level, the curriculum which facilitates this view of mathematics and teaching has been conceptualized as follows:

"Elementary school mathematics should reinforce a child's natural curiosity about patterns. Children must be encouraged to perceive mathematics in the world around them. Shapes, numbers, chance - the foundations of geometry, arithmetic, probability - will emerge from carefully guided observation. Science study will lead naturally to mathematics, following the paradigm of data, deduction, and observation (National Research Council, 1989, p. 48)."

The reader may wonder at this point what the foundations are of such a drastic change in the way mathematics is taught and learned. Is it common sense? Good experienced teachers have been observed using many of the proposed methods. Is there a research basis which supports this view of teaching and learning mathematics? As you have probably guessed, these are not the wild ideas and dreams of mathematicians and math educators. There is a body of research that points in this direction.

Mathematics education in the '80's has been strongly influenced by a "cognitive science" view of learning. Cognitive scientists are interested in "how the mind works" (Schoenfeld, 1987). Their studies examine "...the representation of knowledge, language processing, image processing, question answering, inference, problem solving..." (Cognitive Science, 1977, p.1). The goal is to develop models of the process through which students achieve understanding. A number of studies have focused upon this process. Brophy and Good (1986) report that learning is facilitated by having teachers relate new material in a structured way to what the students already know. Also, learning is enhanced by providing meaningful, constructive feedback to students at regular intervals.

Research has also shown that students have the ability to informally conceptualize concepts and operations. Studies on addition and subtraction have shown that elementary school children can develop their own informal counting and modeling strategies to successfully solve simple addition and subtraction word problems (Carpenter, Hiebert & Moser, 1983; Carpenter & Moser, 1982). This knowledge can be used by teachers to help students develop a meaningful understanding of mathematics concepts and skills (Peterson, 1988). The use of manipulative or concrete materials plays an important role in helping children explore and refine mathematical concept development and understanding. In a comprehensive review of the effects of manipulative materials in math instruction, Sowell (1989) reports that the use of concrete materials has a positive effect on achievement and attitudes toward mathematics under the following conditions: first, the materials must be used on a long-term basis (for a school year or more); and second, teachers need to be knowledgeable about their use. Concrete materials provide a way for students to connect their understandings of real objects and their own experiences to mathematical concepts. The use of concrete materials in problem solving also helps students understand the settings and conditions given in the problem. Students can construct a representation of the problem and use the manipulatives to experiment with possible solution strategies. From a language perspective, the use of concrete materials has been found to have constructive effects on the development of communication skills. These materials provide children with a basis for explaining, relating, verbally exploring, discussing, and providing justification for processes used.

In addition to concrete materials there are other "tools" which can be used by children to explore and acquire mathematical knowledge. Computers and calculators provide opportunities not only for practice, but for exploration, conjecturing, testing (as in testing hypotheses), and retrieving information. While research in the area of educational uses of computers and calculators in mathematics is sorely needed, there are a number of pr mises which can be made concerning their instructional value and limitations:

- computers and calculators are tools that simplify, but do not accomplish, the tasks at hand; they play the same role that word processing does for writers,
- the availability of calculators does not eliminate the need for students to learn computational procedures; deciding when to use a calculator and how to use it are the important skills children need to master, and
- the availability of computers and calculators has expanded students' capabilities of performing calculations; contrary to the fears of many educators (Schofield and Verban, 1988).

Studies into the efficacy of computers on language skills have shown positive results (Ragosta et al., 1982), although the effects have been small. In ESL, students and instructors have given favorable reports of the benefits of computer use to learning. Overall, the studies have been informal and there is a need for more research in this area.

Student' input to the learning/teaching process has been found to be another aspect of meaningful learning. A number of investigations have found that children's ability to express their self-diagnosed mathematical strengths and weaknesses is an important predictor of their mathematical achievement (Peterson, Swing, Braverman & Buss, 1982; Peterson & Swing, 1982). This self-reporting can be nurtured and refined by addressing the language skills needed to write or verbalize descriptions of processes used or diagnostic evaluations of the work performed. As mentioned earlier, self-reporting of learning may present a challenge to immersion students with limited language proficiency. A reporting mode must be found so the student can use the language skills he/she has. There are a number of strategies which may be utilized here (Stenmark, 1989):

- representing a problem setting using diagrams or models,

- using symbols to communicate operations,
- graphicaly representating the students' perceived progress in the class,
- displaying photographs of student projects,
- generating video or computer examples of student work,
- recording dictated report from students,
- developing student journals, and
- writing a mathematical or scientific biography.

The above list is not an exhaustive one; but regardless of the approach selected care must be exercised to provide a activities which closely address the language proficiency level of the student.

Another aspect of the study of mathematical learning processes deals with the ways in which students are organized in the classroom. One particular mode of organization is that of cooperative learning groups. Cooperative learning involves groups of two to six students in tasks that require cooperation and positive interdependence among individuals in each group (Slavin, 1983). Working in such groups increases each student's opportunity to interact with materials and other students while learning. Opportunities to speak, speculate, question, explain and clarify their thinking are increased from large group activities. Some outcomes of these interactions are the development and improvement of communication skills as well as gains in understanding of the content.

So we see there is research evidence to support the "new view" of mathematics teaching and learning. This does not imply that further research is not needed. As a matter of fact, research on all of the different aspects of this orientation must be conducted on an on-going basis. In summary, this revision of the way in which math is taught and learned reflects:

- A conceptual orientation.
- The active involvement of children in doing mathematics.
- Emphasis on the communication of mathematical ideas and processes.
- Emphasis upon the development of children's mathematical thinking and reasoning abilities.
- Emphasis upon the application of mathematics.
- The appropriate and ongoing use of calculators and computers.

The National Council of Teachers of Mathematics (NCTM) has translated this revision of the way mathematics has been traditionally taught into specific curriculum and instructional recommendations. The Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) describes:

> "...what students need to know, how students are to achieve the identified curricular goals, what teachers are to do to help students develop their mathematical knowledge, and the context in which learning and teaching occur." (Standards, 1989, p.1).

The resulting curriculum, at the elementary school level, reflects four "views" of mathematics instruction and nine content strands. According to the Standards, mathematics teaching should emphasize:

1. Problem Solving. This is recommended as the central focus of the mathematics curriculum. Problem solving activities should be integrated into the total program not as a separate component, but as a context in which concepts and skills can be learned (Standards, p.23).

2. Communication. This is an area where the development of language skills and understanding of content come together. Communication in the classroom plays an important role in helping children construct connections between their informal, intuitive notions and the abstract language and symbolism of mathematics.

Communication also plays a role in assisting students make important connections among physical, pictorial, graphic, symbolic, verbal, and mental representations of mathematical ideas (Standards, p.26).

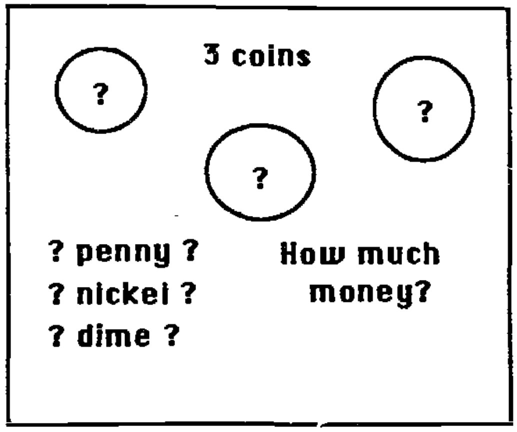
3. *Reasoning*. An important objective of math instruction is to develop in children the belief that they have the power to do mathematics and that they have control over their own successes and failures. Children need to know that mathematics is not just memorization of rules and procedures, and that in the math classroom there needs to be respect for others' ideas. It is important in this environment for students to know and be able to justify their thinking (Standards, p.29).

4. Connections to the students' daily lives, other disciplines, topics within mathematics, and conceptual and procedural knowledge. The primary goal here is to help children see how mathematical ideas are interrelated and how mathematics is used both in and out of school.

These four emphases may be illustrated in a lesson which integrates each view in an immersion environment.

Class setting: The teacher has been working on the value of coins and operations with money. At the beginning of this particular class the children are shown a poster with the names and values of the appropriate coins in the target language for penny, nickel and dime. The names are reviewed, and language structures such as: How much?; I have ___ coins; I have ___cents,and (#coins) gives me ___ cents are presented and reinforced.

Problem: A picture is shown of three coins



Reasoning: The students are asked to compute how much money different combinations of coins will produce more than 45 cents. Play coins are provided as manipulatives and the children are also given the following chart to record the results.

Pennies	Nickels	Dimes	Total
0	0	3	30
?	?	?	?
?	?	?	?

The students must decide which of the coin combinations result in more than 45 cents. The basic reasoning strategy emphasized is trial and error.

Communication: Depending on the language proficiency levels of the students, the teacher may ask them to give orally (or write) one combination which gives the desired outcome. This is written on a class chart on the chalkboard. For students with appropriate language skills, the teacher may ask questions such as:

- How did you find out the right combinations of coins?

- Explain to a classmate how to get the results.

Connections to daily life and other knowledge: Students have an opportunity to bring together computational and thinking skills as well as the language needed to experiment, relate, and describe the processes and results of the problem. Handling of money is a skill required of all of us and one in which many children have difficulties. The lesson provides opportunities for the children to learn and reinforce these skills.

The Standards also recommend a broadening of the content covered in the curriculum. At the elementary school level this implies including topics which traditionally have not been studied as well as de-emphasizing ones which have historically received significant attention. A list of these topics has been appended for your information and for use in planning math activities in the language immersion program.

Trends in science education: A perspective for immersion teachers

The teaching and learning of science is being influenced by the same conceptual and theoretical orientation which is changing mathematics instruction. Renewed emphasis is being placed upon the development of concepts and relationships through the processes of observation, identification, description, experimental investigation, and explanation of natural occurrences.[b] The instructional focus is upon active involvement of students in learning, just as it is in mathematics.

Kessler and Quinn (1987), in their discussion of the role of language in learning science, describe the 'language of science' as one in which:

---

[b] Historically this is how the teaching of science has been emphasized. This has been referred as an inquiry approach to science education. Unfortunately, a textbook-oriented approach has been the norm in most classrooms(Kessler and Quinn, 1987).

- abstract concepts are logically developed and connected through a variety of linguistic devices such as repetition of key words, use of paraphrases, and logical connectors (e.g. because, however, for example, consequently).
- the linguistic elements are used in hypothesis testing and argumentation. The ability to raise questions about a problem, promulgate hypotheses and design experiments to test such hypotheses are dependent upon these language features.
- knowledge of vocabulary is closely related to the ability to communicate content. Science contains a specialized vocabulary which is used to label and describe concepts and processes; in order to effectively express themselves in science, students must have some command of the terminology.

Mohan (1986) provides examples of science lessons which illustrate the above characteristics of the role of language in science teaching and learning. Two of the lessons are summarized in the following section.

Lesson #1: Classification

Setting: The students are asked to describe the contents of their lunch boxes (Note: it is assumed the immersion students have the necessary language skills). The teachers helps those who may not have sufficient language proficiency.

Task #1: Observation and measurement

As the students describe their lunches, the teacher writes the information on a table which contains each of the children's names and the amount of food they have (e.g. Peter - 1 apple, 2 slices of bread, etc.). After the table is completed, the teacher guides the students in the classification of the foods found into basic food categories: milk, vegetables, meat and fish, fruit, bread and cereals, and others.

Task #2: Classification and labelling:

Based on the results of the previous activity another table is produced cooperatively by the students and the teacher which shows a class profile of the **types** of foods children bring to lunch. The results of such a table might show 4 students having vegetables; ten having items in the bread and cereal category, and 6 having meats. The object of the classification is for the students to group items into classes/concepts based on class attributes and/or properties.

Language and the tasks: Activities such as the one here will probably elicit a large amount of oral behavior from the students. Mohan (1986, p. 99) provides an analysis of the language which might result as related to the accompanying cognitive processes. For example, during the task of observing, describing and measuring, the students might use pointer words (*this / that*), verbs of class membership (*be*), verbs of possession (*have*), possessives (*his*), amount or quantity (*some / two / half*), unit nouns (*piece / lump*), and nouns of measure (*a pound of / a pint of*). To classify the foods into groups the students might use species nouns (*fruits / vegetables*), and classification words (*include / put under / be*).

Lesson #2: An experiment on nutrition

Setting: The students have been assigned to feed two mice; one who is to receive a balanced diet; the other, a sugar/soft drink diet.

Task #1: Observation

During a period of a week the students record the appearance and level of energy of the mice. The results are placed on a chart which relates the conditions (balanced/'junk' diet) to the effects (good appearance/high energy vs. poor appearance/low energy).

Task #2: Determination of cause and effect

The teacher relates the idea of "conditions" to the concept of "cause" (a poor diet 'causes' low energy levels). The students make generalizations about the effects of a good vs. a poor diet on the appearance and activity levels of the mice.

Language and the tasks: Based on the above lesson Mohan (p. 83) summarizes four components of the inferential processes and the language structures students may use for each.

1. Inferring conditions from effects: There are a number of language structures the students may use to infer results from the diets. These include: structures indicating attitudes to perceived reality (*I know / doubt / believe / assume / think*), and elements which indicate cause/reason (*is due to / the result of / because of*).

2. Predicting effect of conditions: Generalizations involving predictions involve *must / ought to / should / I bet and probably / maybe / it is likely.*

3. Formulating hypotheses about conditions and effects: Such hypotheses may be formulated as follows: *Eating sugar makes a mouse unhealthy. If the mouse does not eat sugar, then he stays healthy*. Language in this case includes structures to express condition and contrast (*if / unless / in that case*), and hypothetical meaning (*were, would*)

4. Generalizing about a given cause-effect relationship: *If we do not give the animals a balanced diet, the health of all animals will not be good. For example, the mouse that drank the sugar drink was not active*. Students may use a number of linguistic elements to express this form of inference - words of general or inclusive meaning (*all, every everyone, none, never*), summary and generalization words (*in short, for example*).

One can see from the above lesson and analysis the relationship between thinking processes and language. While there is yet much to be studied concerning the language of science and how language is used in the science classroom, there are a number of premises which can be derived from the literature to guide immersion teachers in the planning and implementation of science instructional activities. First, let's examine what research says about how children acquire ideas in science. According to Osborne and Freyberg (1985), children:

- develop meanings for many words used in science teaching and views of the world which relate to ideas taught in science; this is accomplished from an early age and before any learning of formal science;
- hold strongly to ideas about science matters; many times these ideas are significantly different from the views held by scientists and teachers, and
- appear to have an internal logical structure which holds their scientific ideas together; these ideas are often uninfluenced by science teaching.

In order to address these characteristics of children acquisition of scientific knowledge, Osborne and Freyberg (1985), based on a review of the research literature, recommend that teachers help students:

- investigate things and explore ideas. This can be accomplished through cooperative learning groups, individually, or by carefully planned and structured large group activities;
- ask useful and productive questions. Studies reported by these authors indicate that student interest in a problem is related to the kinds of questions asked about the problem;
- broaden their experience of nature and technology, and
- become interested in the explanations of others about how and why things behave the way they do, and how those explanations have been acquired.

These general suggestions need not be confined to science teaching. Any subject area in the elementary school curriculum can address them. For example, in language arts, reading and writing about the nature and the world that surrounds the students can help develop and/or reinforce these experiences. In mathematics, giving explanations of procedures used to solve a problem, describing a geometric figure or numerical patterns in mathematics also contribute to these goals.

Based on the current theories which explain how children learn science, Raper and Stringer (1987) suggest a framework for conceptualizing how scientific content relates to the skills, attitudes and concepts children must learn. Figure 1 shows the conceptual framework.

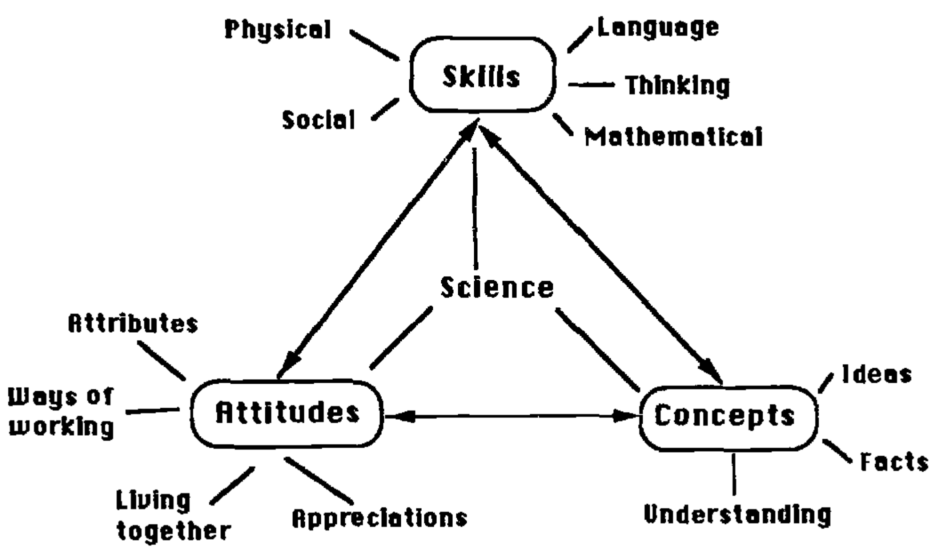


Figure 1. Conceptual framework for learning science (Raper & Stringer, 1985, p.11)

How can this orientation to teaching science be implemented in the classroom? Osborne and Freyberg (1986) recommend a teaching model for generative learning based on a constructivist view of learning. Under this orientation[c] ,the teacher moves from a preliminary stage in which he/she has an opportunity to determine the childrens' views about the problem or concept , to an application phase in which students, having internalized concepts and processes, proceed to discuss the findings and relate the solutions and strategies to other problems. Table 1 presents the full model suggested by Osborne and Freyberg (p.109-110).

Phase	Teacher Activity	Pupil Activity
Preliminary	•Ascertains pupils' views; classifies these views; seeks scientific views; identifies historical views; considers evidence which led to abandoning old views	•Completes activities, designed to pin-point existing ideas
Focus	•Establishes a context. •Provides motivating experiences.	•Becomes familiar with the materials used to explore the concept.
	•Joins in, asks open-ended personally oriented questions.	•Thinks about what is happening, asks questions related to the concept.
	•Interprets student responses	•Decides and describes what he/she knows about the events, using class and home inputs.
	•Interprets and elucidates pupils' views	•Clarifies own view on the concept. Presents own view to (a) group, or (b) class, through discussion and display.

[c] This model is based upon the same theoretical assumptions as the curriculum framework used in mathematics education.

Challenge	In large or small groups: •Facilitates exchange of views. •Ensures that all views are considered. •Keeps discussion open.	•Considers the view of (a) another pupil, (b) all other pupils in class seeking merits and defects.
	•Suggests demonstrative procedures, if necessary.	•Tests the validity of views by seeking evidence.
	•Presents evidence from the scientist's viewpoint.	•Compares the scientists' view with their own (or the class's).
	•Accepts the tentative nature of pupils' reaction to the new view (if different from their own).	
Application	•Contrives problems which are most simply solved using the accepted scientific view.	
	•Assists pupils to clarify the new view, asking that it be used in describing all solutions.	•Solves practical problems using the concept as a basis.
	•Ensures students can describe (orally or written) solutions to problems.	•Presents solutions to the small group or class. •Discusses and debates the merits of solutions; critically evaluates these solutions.
	•Helps in solving advanced problems; suggests places where help might be sought	•Suggests further problems arising from the solutions presented.

The preliminary phase of the model encompasses a number of preparatory activities both teachers and students need to address. Since children bring in a number of ideas concerning natural phenomena and their causes, the teacher must appraise what these are. In addition, the teacher must have a comprehension of the "big picture" which involves the concepts to be presented in the lesson in order to (a) determine how the childrens' conceptions differ from established science, and (b) relate these scientific ideas to the childrens' conceptual framework. This initial assessment of children's concepts can be informally accomplished through activities in which the students can explore the ideas to be presented in a non-threatening way. It is at this stage that the teacher may provide information concerning the topics to be explored or discussed. The children can demonstrate what they think the concepts are by means of games or discussion. The choice for immersion teachers will depend, in part, on the level of target language proficiency the students have. For students who are extremely limited in the target language this stage should comprise instruction in the language needed to describe observations and ideas. These skills may include production of terms in context (this is a vegetable), imitations of models, spelling, writing of known elements from dictation). For students with sufficient proficiency a general question presented with appropriate realia may be posed. For example, in a lesson on electricity, the students can be asked - "Is there electric current in a car battery?" (the students are shown different types of electrical devices, and pictures of vehicles). The teacher can assess whether the students know that batteries store electrical energy (correct idea) or have some other idea of what the role of a battery is in providing electricity.

In the focus phase the children's attention is directed to particular phenomena. For example, (to continue with the illustration about electricity), the students are given a lamp, wires and a 1.5 volt battery. Pupils suggest and learn ways of testing whether or not the lamp is defective or whether the cell has expired. The teacher encourages students to think through questioning about the problem, and helps them interpret their responses.

Students present their own views and conclusions about the activity during the challenge phase. Differing views held or results obtained by members of the class are sought, displayed and discussed. Teacher guidance of the discussion here is critical. During this phase, for the example given earlier, students would clarify their own views about electricity, learn about the views of other students and the teacher. Opportunities are given for students to reconsider their views (and change them if necessary) in light of the evidence presented.

In the application phase, student-generated procedures and generalizations, and the scientific view are compared. Students are asked to report on their findings. Writing skills are important at this stage; the students should be able to describe and conjecture about what they have done and seen.

A lesson on the properties of floating/sinking objects follows in order to illustrate some of the activities an immersion teacher may carry out in a series of lessons which follow Osborne and Freyberg's model.

Phase	Lesson: Sinking and Floating Objects
	Objectives: Children will- (a) make observations of objects which sink or float in water; (b) hypothesize the properties which make some objects 'floaters' and others 'sinkers', and (c) test these hypotheses. Note: It is assumed that the students have mastery of a basic vocabulary so simple classroom/household objects can be named and described.

Preliminary	The teacher shows the students some objects: sponge, chalk, Ping-Pong ball, stones, cups, nails. The teacher asks them to name the objects (review?), describe them. At this point the necessary vocabulary and language structures needed to describe the objects may have to be taught. Using a pail of water, the teacher selects an object and asks the students to predict whether the object will float or sink. This is the object of the <u>preliminary phase</u>: to assess pupil's knowledge and language skills. Some students might have this knowledge, but not possess the language proficiency to express their views. The teacher at this stage must address the language skills.
Focus	The students are divided into small groups. Each group is given a pail of water and a set of objects. The students are to test each object and record on a sheet provided whether the object sinks or floats. The students are also asked to conjecture why does the object sink or float. The teacher asks each group to share/display the results. Objects are classified as 'sinkers' or 'floaters'. The description or properties of the objects are reviewed.
Challenge	The teacher directs the students to the identification of the general properties of floating and sinking objects. These properties (from the previous activity) may be written on sentence strips. The students place the strips in the appropriate category ('floater' or 'sinker'). If the level of language proficiency permits, the students may challenge the validity of some of the classification or give reasons for placing certain properties in a specific category.
Application	Extension activities are given to students. These may include: • Build a boat that can carry two/three/sinkers. Describe each boat. •Draw a boat that can keep a lion/bear/elephant afloat. Describe each boat.

<u>Summary</u>

The research literature in science education indicates that if children are to receive instruction which will help them become scientifically literate, teachers must provide:

•numerous opportunities to explore objects and the environment freely,

•opportunities to share findings and discoveries,

63

- a learning environment that helps children solve problems by thinking critically and creatively, and
- an integrated approach that builds skills in mathematics, social studies and language arts (Zeitler &Barufaldi, 1988).

Generalizations for language immersion programs

We return at this point to the setting described at the beginning of this paper. The question was posed, what principles guided the teacher to conduct the kinds of learning experiences she provided to the students. The teacher used a number of instructional strategies and activities designed to involve children actively in their learning. The previous sections have provided a survey of the research and teaching principles underlying exemplary instructional practices in mathematics and science at the elementary school level. There are two general implications for language immersion programs concerning the teaching of mathematics and science:

1. The theories and models which guide mathematics and science education in 'regular' programs must be followed in language immersion programs, and
2. These content teaching principles must be integrated with the standards which guide language teaching and learning.

Figure 2 illustrates the relationship between these two components of a content/language immersion lesson (or curriculum).

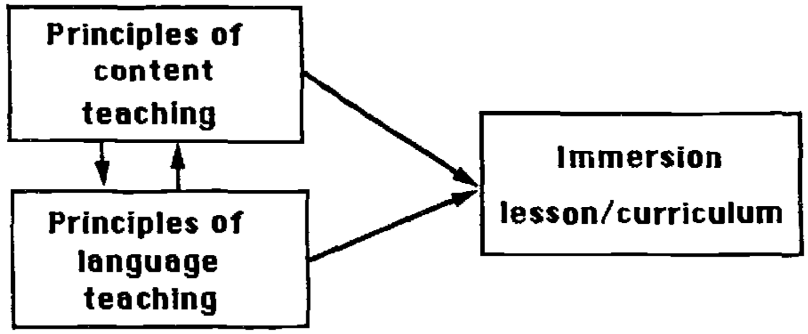


Figure 2: Content/Language Integration Framework

There is a high degree of agreement between the principles that govern meaningful learning in language and subject matter. Both areas have a common set of premises as the foundation for their instructional principles. These premises include:

1. Instruction must be conceptually oriented

Instructional experiences should emphasize the development of understanding mathematics and science. They should also assist children relate knowledge to the learning of skills by establishing relationships between the conceptual and the procedural aspects of the tasks. This premise is compatible with Krashen's "comprehensible input" hypothesis of language development

2. Instruction must actively involve children in doing science and mathematics

Young children are active individuals who construct, modify, and integrate ideas by interacting with the physical world, materials and other children. Verbs such as explore, justify, represent, solve, construct, discuss, use, investigate, describe, develop, and predict are used to convey this active physical and mental involvement of children in learning mathematical and scientific content. There is a need to make use of physical materials to foster the learning of abstract ideas. Active participation in learning will facilitate the negotiation of language meaning as students interact with each other and with the environment. Active involvement in learning will also provide students with a variety of opportunities for language output.

3. Instruction must emphasize the development of children's thinking and reasoning abilities.

There is a need to instill in students a sense of confidence in their ability to think and communicate math and science, to solve problems, to demonstrate flexibility in working with mathematical and scientific ideas and problems, to make appropriate decisions in selecting strategies and settings, to detect familiar structures in unfamiliar settings, to detect patterns, and to analyze data.

4. Instruction must emphasize the application of mathematics and science

If children are to view these two content areas as practical, and useful subjects; they must understand that it can be applied to a wide variety of real world problems and phenomena.

And the final premise provides an explicit bridge between the the teaching of content and the development of language skills in children -

5. Instruction must include the language skills necessary for children to understand and to interpret math and science content and to communicate proficiently in class.

This is one of the primary aims of immersion programs. It is also one of the goals of the revised standards for math and science teaching.

To accomplish the integration of language and content development a number of specific suggestions can be offered given the discussion of the research in these areas. The framework that follows is offered to assist teachers of language immersion programs in "orchestrating" the teaching of language and content. It combines skill areas in language - listening comprehension, speaking, reading and writing with content strands:

A - Concepts B - Procedural learning[d]

C - Applications D - Problem Solving

The objective of the framework is to "remind" teachers of the need to focus on language as well as content[e].

A Framework for Integrating Communication Activities in Mathematics and Science

	Skills	Content Strands: Concepts	Procedural Learning	Applications	Problem Solving
Verbal	Listening				
	Reading				
	Speaking				
	Writing				
Non-Verbal	Building Models/Using Manipulatives				
	Drawing Diagrams				

[d] procedural learning includes the mastery of algorithms (steps necessary to solve an operation) in math as well as rules for dealing with scientific investigations.

[e] Sorry, I know that as immersion teachers language development is foremost in your minds, but I am just reinforcing it, just in case one "gets lost" teaching content.

In addition there are a number of other specific instructional suggestions which facilitate the integration of language and content learning:

1. Be familiar with each student's level of target language proficiency. There is a need to design activities which require language skills the students can reasonably handle. For example, in the opening illustration, the teacher made an attempt to gear the questions and direct classroom interactions at a level the students could handle.
2. Spend at least part of each lesson reviewing previously studied words, phrases and symbols related to the lesson for the day.

According to Saville-Troike (1984), knowledge of vocabulary and symbols is the most important aspect of second language competence for learning academic content through that language. Be "creative" in how vocabulary is reviewed and presented. Use concrete objects, diagrams and pictures to accomplish this. It is important to remember that vocabulary and symbols should be presented and reviewed through the content and not in isolation.

3. Present and discuss the meanings of the words, phrases and symbols in the context of each new lesson.

Identify vocabulary, language functions, and grammatical structures which are content-obligatory as well as content compatible. Addressing these language elements in a meaningful context will help students carry out discussions in which they will have to agree, disagree, describe, express opinions, and give directions .

4. Encourage students to describe processes and concepts; let the students talk about mathematics and science; place emphasis on the communication of meaning.

Learning experiences must be planned which have "built-in" opportunities for students to share their opinions and results. This where the functional aspects of language come into play. For example, in the initial classroom illustration, the following was recorded as the teacher asked student what 'times' was:

Student: *Like four sets of five is twenty.*

Teacher: *So what's another word for times then?*

Student: [After thinking a bit] *Lots*

Teacher: *Show me four lots of five.*

Student: [Draws four circles with five dots each] *...and it equals twenty.*

5. Use manipulatives and pictures to accomplish #3 and #4.

There is sufficient evidence in the literature concerning the effectiveness of the use of concrete materials in learning both subject matter and language. It is not enough to have these objects present during lessons, but also they need to be available to students for them to use in any class activity.

6. Utilize computers and calculators whenever possible.

The thoughtful use of technology can improve the quality of classroom activities and the quality of children's learning. Computers and calculators can also serve as another vehicle for language development.

Mathematics and science comprise writing systems which are complex, rule-governed, and full of symbols whose manipulations form part of the mathematician's and scientist's art. These characteristics are also reflected in the oral language used to communicate mathematical and scientific thought. As a result mathematics and science instruction involves in part the teaching of language. It is partly due to the successful integration of content and language instruction that an immersion program can develop into a place where learning can be a growing and interesting experience for children.

SUMMARY OF CHANGES IN CONTENT AND EMPHASIS IN K-4 MATHEMATICS

INCREASED ATTENTION

NUMBER
- Number sense
- Place-value concepts
- Meaning of fractions and decimals
- Estimation of quantities

OPERATIONS AND COMPUTATION
- Meaning of operations
- Operation sense
- Mental computation
- Estimation and the reasonableness of answers
- Selection of an appropriate computational method
- Use of calculators for complex computation
- Thinking strategies for basic facts

GEOMETRY AND MEASUREMENT
- Properties of geometric figures
- Geometric relationships
- Spatial sense
- Process of measuring
- Concepts related to units of measurement
- Actual measuring
- Estimation of measurements
- Use of measurements and geometry ideas throughout the curriculum

PROBABILITY AND STATISTICS
- Collection and organization of data
- Exploration of chance

PATTERNS AND RELATIONSHIPS
- Pattern recognition and description
- Use of variables to express relationships

PROBLEM SOLVING
- Word problems with a variety of structures
- Use of everyday problems
- Applications
- Study of patterns and relationships
- Problematically-solving strategies

INSTRUCTIONAL PRACTICES
- Use of manipulative materials
- Cooperative work
- Discussion of mathematics
- Questioning
- Justification of thinking
- Writing about mathematics
- Problem-solving approach to instruction
- Content integration
- Use of calculators and computers

DECREASED ATTENTION

NUMBER
- Early attention to reading, writing, and ordering numbers symbolically

OPERATIONS AND COMPUTATION
- Complex paper-and-pencil computations
- Isolated treatment of paper-and-pencil computations
- Addition and subtraction without renaming
- Isolated treatment of division facts
- Long division
- Long division without remainders
- Paper-and-pencil fraction computation
- Use of rounding to estimate

GEOMETRY AND MEASUREMENT
- Primary focus on naming geometric figures
- Memorization of equivalencies between units of measurement

PROBLEM SOLVING
- Use of clue words to determine which operation to use

INSTRUCTIONAL PRACTICES

- Rote practice
- Rote memorization of rules
- One answer and one method
- Use of worksheets
- Written practice
- Teaching by telling

National Council of Teachers of Mathematics, Curriculum and Evaluation Standards for School Mathematics. Reston, VA: March 1989, pp. 20-21.

References

Aiken, L.R. (1967). Language factors in learning mathematics. Mathematics Education Reports. Columbus, Ohio. (ED 068 340).

Barnett, J. (1984). The study of syntax variables. In G. A. Goldin & C.E. McClintock (eds.), Task variables in mathematical problem solving (pp. 23-69). Philadelphia: The Franklin Institute Press.

Bearddslee, E., & Jerman, M. Structural, linguistic, and topic variables in verbal and computational problems in elementary mathematics. A paper presented a the AERA annual meeting, Chicago, 1974.

Brophy, J.E., & Good, T.L. (1986). Teacher behavior and student achievement. In M. Wittrock (ed.), Handbook of research on teaching, (3rd ed., pp.328-375). New York: Macmillan.

Caldwell, J., & Goldin, G.A. (1979). Variables affecting word problem difficulty in school mathematics. Journal for Research in Mathematics Education, 10, 323-336.

Carpenter, T.P.; Hiebert, J., & Moser, J.M. (1983). The effect of instruction on chidren's solutions fo addition and subtraction problems. Educational Studies in Mathematics, 14, 56-72.

Carpenter, T.P., & Moser, J.M. (1982). The acquisition of addition and subtraction concepts. In R. Lesh & M. Landau (eds.), The acquisition of mathematical concepts and processes (pp. 7-14). New York: Academic Press.

Cuevas, G. (1984). Mathematics learning in English as a second language. Journal for Research in Mathematics Education, 15,134-144.

Gardner, P.L. (1980). The identification of specific difficulties with logical connectives in science among secondary school students. Journal of Research in Science Teaching, 17, 223-229.

Goldin, G.A. (1982). Mathematical language and problem solving. Visible Language, 16, 221-238.

Janvier, C. (1980). Translation processes in mathematics education. In R. Karplus (ed.), Proceedings of the VIth PME Conference. University of California, Berkeley.

Kessler, C., & Quinn, M.E. (1987). ESL and science learning. In J. Crandall (ed.), ESL through content-area instruction. Englewood Cliffs, NJ: Prentice Hall Regents.

Krashen, S. (1982). Principles and practice in second language acquisition. Oxford: Pergamon Press.

Mestre, J. (1988). The role of language and comprehension in mathematics and problem solving. In R.R. Cocking & J. Mestre (eds.), Linguistic and Cultural influences on learning mathematics (pp.201-220). Hillsdale, NJ: Lawrence Earlbaum Associates, Publishers.

National Council of Teachers of Mathematics (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: The Council.

National Research Council (1989). Everybody Counts: A Report to the Nation on the future of mathematics education. Washington, DC: National Academy Press.

Osborne, R., & Freyberg, P. (1985). Learning in science. Auckland, NZ: Heinemann.

Peterson, P.L. (1988). Teaching higher-order thinking in mathematics: The challenge for the next decade. In D.A. Grows; T.J. Cooney, & Jones,

D. (eds), Perspectives on research on effective mathematics teaching (pp. 2-26). , & Moser, J.M. (1983). Hillsdale, NJ: Lawrence Earlbaum Associates, Publishers.

Peterson, P.L.; Swing, S.R.; Braverman, M.T., & Buss, R. (1982). Students' aptitudes and their reports of cognitive processes during direct instruction. Journal of Educational Psychology, 74, 535-547.

Peterson, P.L., & Swing, S.R. (1982). Beyond time on task: Students' reports on their thought processes during classroom instruction. Elementary School Journal, 82, 481-491.

Piaget, J. (1972). Problems of Equilibration. In C. Nadine, J. Gallagher, R. Humphrey (eds.), Piaget and Inhelder on Equilibration. Philadelphia: Jean Piaget Society.

Ragosta, M.; Holland. P., & Jamieson, D. (1982). Computer-assisted instruction and compensatory education: The ETS/LAUSD Study. Washington, DC: U.S. Department of Education, ED 222 169.

Raper, G., & Stringer, J. (1987). Encouraging primary science. London: Cassell Publishers Limited.

Resnik, L. B. (1987). Education and learning to think. Committee on Mathematics, Science, and Technology Education, commission on Behavioral and Social Sciences and Education. National Research Council, Washington, DC: National Academy Press.

Saville-Troike, M.(1984). What really matters in second language learning for academic achievement. TESOL Quarterly, 18, 199-219.

Schoenfeld, A.H. (1987). Cognitive science and mathematics education: An overview. In A.H. Schoenfeld (ed.), Cognitive science and mathematics education (pp. 1-32). Hillsdale, NJ: Lawrence Earlbaum Associates, Publishers.

Schofield, J.W., & Verban, D. (1988). Computer usage in the teaching of mathematics: Issues that need answers. In D.A. Grows; T.J. Cooney, & Jones, D. (eds), Perspectives on research on effective mathematics teaching (pp. 2-26). , & Moser, J.M. (1983). Hillsdale, NJ: Lawrence Earlbaum Associates, Publishers.

Slavin, R.E. (1983). Cooperative learning. New York: Longman.

Sowell, E.J. (1989). Effects of manipulative materials in mathematics instruction. Journal for Research in Mathematics Education, 20, 498-505.

Vigotsky, L.S. (1962). Thought and Language. Cambridge, MA: MIT Press.

Wong-Fillmore, L. (1985). When does teacher talk work as input? In S. Gass & C. Madden (eds.), Input in second language acquisition (pp. 17-50). New York: Newbury House Publishers.

Zeitler, W.R., & Barufaldi, J.P. (1988). Elementary school science: A perspective for teachers. New York: Longman.

EDRS

BIBLIOGRAPHY

IMMERSION BIBLIOGRAPHY

California State Department of Education, Bilingual Education Office. Studies on Immersion Education: A Collection for United States Educators. Los Angeles, CA: California State University, Evaluation, Dissemination, and Assessment Center, 1984.

Cummins, Dr. James. Bilingualism and Special Education: Issues in Assessment and Pedagogy. Clevedon, England: Multilingual Matters, 1984.

Curtain, Helena A., and Carol Ann Pesola. Languages and Children--Making the Match. Reading, MA: Addison-Wesley Pub. Co., 1988.

Genesee, Dr. Fred. "Second Language Learning through immersion: A Review of U.S. Programs." Review of Educational Research 55 no. 4 (Winter 1985): 541-61 .

________. Learning Through Two Languages. Rowley, MA: Newbury House, 1987.

Kagan, Spencer. Cooperative Learning Resources for Teachers. Riverside, CA: University of California, 1987.

Krashen, Stephen. Second Language Acquisition and Second Language Learning. Oxford, England: Pergamon Press, 1981.

Lapkin, Sharon, Merrill Swain, and Valerie Argue. French Immersion: The Trial Balloon that Flew. The Ontario Institute for Studies in Education and Canadian Parents for French, 1983.

Lambert, Wallace E., and G. Richard Tucker. Bilingual Education of Children. The St. Lambert Experiment. Rowley, MA: Newbury House, 1972.

Long, Michael H., and Patricia A. Porter. "Group Work, Interlanguage Talk, and Second Language Acquisition." TESOL Quarterly 19, no. 2 (1985): 207-227.

Met, Myriam, Helena Anderson, Evelyn Brega, and Nancy Rhodes. "Elementary School Foreign Language: Key Links in the Chain of Learning." In Foreign Languages: Key Links in the Chain of Learning, ed. Robert G. Mead, 10-24. Middlebury, VT: Northeast Conference on the Teaching of Foreign Languages, 1983.

Met, Myriam. "Decisions! Decisions! Decisions! Foreign Language in the Elementary School." Foreign Language Annals 18, no. 6 (1985): 469-473.

________. "Twenty Questions: The Most Commonly Asked Questions About Starting an Immersion Program." Foreign Language Annals 20, no. 4 (1987): 311-315.

Montgomery County Public Schools. Instructional Guide: Elementary and Pre-Algebra Mathematics, Grades K-6. Rockville, MD: 1989.

National Council of Teachers of Mathematics. Curriculum Standards for School Mathematics. Reston, VA: National Council of Teachers of Mathematics, March, 1989.

Saville-Trocke, Muriel. "Dilingual Discourse: The Negotiation of Meaning Without a Common Code." Linguistics, 25 (1987), 81-100.

Schinke-Llano, Linda. Foreign Language in the Elementary School: State of the Art. Washington, D.C.: Center for Applied Linguistics, 1986.

Snow, Marguerite Ann. Immersion Teacher Handbook. Los Angeles, CA: Center for Language Education and Research, University of California, 1987.

Swain, Merrill and Sharon Lapkin. Evaluating Bilingual Education: A Canadian Case Study. Clevedon, England: Multilingual Matters, 1985.

________. "Immersion French in Secondary Schools: 'The goods' and 'The bads'." Contact, 1986.

Weber, Sandra and Claudia Tardif. "What Did She Say? Meaning In a Second Language Classroom" Faculté Saint-Jean, University of Alberta. Paper presented at the April 1987 meeting of the American Educational Research Association, Washington, D.C.

Wells, Gordon. The Meaning Makers: Children Learning Language and Using Language to Learn. Ontario Institute for Studies in Education. Portsmouth, NH: Heineman, 1986.