AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
BATCH 61

1. SUBJECT CLASSIFICATION
A. PRIMARY
TEMPORARY
B. SECONDARY

2. TITLE AND SUBTITLE
The Nicaragua radio mathematics project

3. AUTHOR(S)
Searle,Barbara; Suppes,Patrick; Friend,Jamesine

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	67p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Stanford

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

9. ABSTRACT

(EDUCATION R&D)
Research was carried out on the teaching of primary mathematics by radio in one population center in Nicaragua. The project site is about 30 kilometers southeast of Managua; favorable factors include proximity to Managua, the presence of a compact and relatively large population in and around the town of Masaya, and an energetic school inspector who welcomed change and who took an active role in its promotion. The operation of the project, its objectives, and the school setting are described; the curriculum structure, the radio lessons used, and the research and testing aspects of the project are also given. The stated research aims of the experiment are related to educational achievement, to the economics of radio as a technology of instruction, and to the applicability of the results to other settings. When this report was written, teachers were responding well to the program, and great care had been taken to assure that the children experienced success in their first exposure to radio lessons. Experience to that point confirmed the belief that it is possible and practical to produce attractive radio lessons in primary school mathematics.

10. CONTROL NUMBER
PN-AAD-833

11. PRICE OF DOCUMENT

12. DESCRIPTORS

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/CM/ta-C-73-40 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

THE NICARAGUA RADIO MATHEMATICS PROJECT

Barbara Searle, Patrick Suppes and Jamesine Friend*

Among the various technologies of instruction now being used around the world, ranging from programmed instruction booklets to color television and computers, radio emerges as one of the most economical. Although radio instruction has been used in various parts of the world for over 40 years it has been little studied. In a recent survey of experimental and empirical studies of the effectiveness of teaching by radio, Jamison, Suppes and Wells (1974) found few in which radio carried the major burden of instruction, and none that examined the relation of curriculum structure to student achievement.

The study reported here, now in the early stages of implementation, uses radio to teach mathematics to primary-grade school children in Nicaragua. Extensive collection of student response data and a precisely defined model for curriculum development make possible the type of study of radio instruction that has heretofore been absent from the research literature. In July, 1973, the Agency for International Development (AID) contracted with the Institute for Mathematical Studies in the Social Sciences at Stanford University to carry out a two-stage project. During the first stage, which occupied the first funding year, we visited developing countries whose governments expressed an interest in teaching mathematics by radio, and selected from among them a suitable project site. During the second stage of the

---

*This work is supported by the Education and Human Resources Division within the Technical Assistance Bureau of the United States Agency for International Development.

project we are developing and evaluating the radio instruction system.

Nicaragua was selected as the project site from among 12 prospective countries: four in Asia, two in Africa, and six in Latin America. In making the choice, we eliminated from consideration those countries in which primary-grade students are not taught in their native language, and those countries that are already using radio instructional systems, and we gave favorable consideration to countries that agreed to support the project with local facilities and personnel. The site visits and country selection process are described fully in Searle (1974).

As of this writing, the project is completing its first year of operations in Nicaragua. Since the beginning of the school year in mid-February, 1975, we have been pilot testing first-grade lessons. In the first section of this paper we describe the operation of the project, its objectives, and the school setting in which we are working. We then consider the preparation of the radio lessons and describe the research aspects of the project. We conclude with an informal assessment of the status of the project today.

1. The Project

1.1 The Nature of a Day's Lesson

The Radio Mathematics Project assumes responsibility for all of the mathematics instruction children receive. A daily lesson consists of a twenty-minute radio presentation, followed by approximately twenty minutes of teacher-directed activities, for which instructions are contained in a project-developed teachers' guide. No textbooks are

used and printed material is limited to a one-page worksheet for each child each day. All instruction, including the radio lesson, is given in Spanish.

Before the broadcast portion of the lesson the teacher gives each child a worksheet, on which the child writes his name and student number, a task which most first-graders can learn to do adequately. Then the broadcast lesson is turned on. During each lesson two main characters join with one or two subordinate characters to sing, play, and talk mathematics, usually inviting the children to join in. The children are asked to respond orally, physically, and in writing, and they do so 40 to 50 times during each twenty-minute lesson.

Sometimes children handle concrete materials during the broadcast--for example, counting or grouping small objects. Dialogue between radio characters introduces new mathematical material and children are asked to respond orally. In later lessons, the same exercises are repeated and the children respond individually on their worksheets.

After the radio transmission, the teacher continues the lesson, following the directions given in the teacher's guide. Usually children continue working on the worksheet during this portion of the lesson. During the experimental phase of the project, worksheets are collected and returned to the project office for analysis.

1.2 The Objectives of the Project

The development and testing of curriculum materials for each grade level is being carried out in two phases. During Phase A lessons are presented in a small number of classrooms using tape recorders, and evaluation efforts are concentrated on improving the quality and

effectiveness of lessons. During Phase B lessons are broadcast to a larger number of classrooms, and the evaluation is directed toward a comparison of the effectiveness of the radio instructional system with traditional instruction.

The research aims of the project can be broadly characterized as related to educational achievement, to the economics of radio as a technology of instruction, and to the generalizability of the results to other settings. Among the educational questions of concern are: Can mathematics be taught effectively using radio as the primary source of instruction? How are achievement gains related to student characteristics? How does achievement of students learning by radio compare with learning in the conventional classroom? How does the instructional program affect student and teacher attitudes towards mathematics, towards school, towards learning by radio? Do attendance and dropout patterns change when radio instruction is introduced in the classroom? Does the failure rate attributable to mathematics change? Does performance in other school subjects change? As we chart the successes and failures of the instructional system we want to search for causes, to investigate how the components of the system are related to its effects.

The economic aspects of the instructional system are of great concern. We want to know: What are the development costs of the program? What are the operational costs? Can the cost of implementing the system in a different setting be estimated? What are the economic consequences of using radio in the classroom? Is the rate of flow of students through the school system, and hence the per-pupil cost of education, affected? What is the cost of each of the components of the system and how is that cost related to its effectiveness? How much teacher training is necessary

to maintain an effective level of instruction? How much supplementary material must be prepared for students? How much supervision will teachers need in order to use the radio in the classroom?

Our interest in generalizability requires first that we describe each component of the instructional program and the methods of its design and validation. We will ask: What types of data analysis prove useful during lesson development? Can we identify variables that characterize successful radio lessons? We must also explore in detail our relationship with the Nicaraguan educational system at the Ministry level and at the local school level. Have we successfully established the project as an integral part of the educational establishment? Have we successfully trained counterparts for Stanford personnel? Is operation of the project included in the Ministry budget? What kind of reception has the project received? How do local supervisors and teachers view the use of radio in the classroom? And finally, how should the project document the organizational requirements for implementation so that another group can put the instructional materials to use in a different setting?

We should also mention some interesting and important questions that our research effort is not designed to answer. We do not intend to investigate ways of changing the mathematics curriculum; rather, we see our task as implementing the established guidelines using teaching methods specifically designed for radio. There is currently great interest in the developing world in designing curriculums that meet the needs of local populations, especially in the rural areas. We feel that attention to the needs of the rural population would not produce

a mathematics curriculum that is fundamentally different from the one in use in Nicaragua today.

There is also great interest, in the United States as well as elsewhere in the world, in designing instructional systems that make use of a variety of media. The challenge is to select from among TV, radio, films, modules of programmed instruction, individual cassettes, games, manipulative materials, books, and other types of media, the optimal mix for helping students meet the objectives of an instructional unit. Our examination of such possibilities suggests that we will lose little by restricting ourselves to a limited use of printed and display materials in conjunction with the regularly scheduled daily broadcast lesson. The main thrust of any systematic variations of media auxiliary to the radio lessons will be towards the reduction of costs.

1.3. Site of Project Activities

The project is located in the Department of Masaya, which is approximately 30 kilometers southeast of Managua. The department has an area of about 543 square kilometers, and is the smallest of the 16 departments in the country. The population is about 94,000 and approximately 30,000 people live in the city of Masaya, capital of the department.

The use of the Department of Masaya was suggested to the Stanford staff during its initial visit to Nicaragua. Among the advantages cited for locating the project in the department were proximity to Managua, the presence of a compact and relatively large population in and around the town of Masaya, and an energetic School Inspector who welcomed change and took an active role in promoting it.

The school inspectorate in the Department of Masaya classifies a school as urban if it is located within the limits of one of the ten towns in the department; otherwise it is rural. Information about the characteristics of schools is given in the next several tables. Data for 1971 on the number of schools and classrooms in Masaya are presented in Table 1. Urban schools are, on the average, larger than rural

---

Insert Table 1 about here

---

schools. The extent to which children of different grade levels are taught in single classrooms is indicated in Table 2. More than a

---

Insert Table 2 about here

---

third of the rural classrooms have more than two grades being taught simultaneously, while this is true of fewer than 1% of the urban classrooms. A comparison of Tables 1 and 2 shows that some classrooms are used for double sessions, and that this double usage is almost entirely urban. The number of pupils at each grade level in 1971, for urban and rural students, is shown in Table 3. The school population

---

Insert Table 3 about here

---

declines with grade far more sharply in urban than in rural areas. For urban schools the sixth-grade population is 27% of the first-grade population, while for rural schools the comparable figure is 9%.

A question of some interest is how typical the schools of Masaya are of the country as a whole. The Department of Masaya is compared with the whole of Nicaragua for several indices in Table 4. Although Masaya

---

Insert Table 4 about here

---

teachers seem to be somewhat better trained (probably a reflection of the proximity to Managua) and a higher percentage of rural Masaya children attend school, the department is, in most respects noted in the table, typical of the country.

After Masaya was chosen as the project site a more careful study was made of the composition of the department. A comparison of several indices of urbanization for the ten towns in the department is shown in Table 5. Two towns, Masaya and Masatepe, stand apart from the others

---

Insert Table 5 about here

---

on almost all of the indices. They have larger populations and more paved streets, movie theaters, banks, and telephones than any of the other towns. Visits to the towns supported the conclusion suggested by the data in Table 5, namely that Masaya and Masatepe are far more urbanized than the other towns. The project staff therefore decided to stratify schools into three levels, calling those in Masaya and Masatepe urban, those in the other eight towns municipal, and the remainder rural.

Almost all classrooms in the department have a chair and a writing surface for each child and at least one blackboard, but few other teaching materials. Attendance ranges roughly from 20 to 50 (although some classes have as many as 60 or 70 students matriculated).

In many mathematics classes we observed that teachers group students by ability, forming from two to four groups and providing each group with different instruction. It was our impression that teachers spent more time with the more able students. Certainly the range in instructional content was wide--in several classrooms observed during the second half of first grade some students were working on basic

number concepts (copying one-digit numbers and counting from one to ten) while others were working on multiplication and division exercises.

In view of the wide range of topics taught in first-grade mathematics classes we felt it imperative to obtain measures of student achievement. Nicaragua does not use a nationwide testing program (although one is currently being considered). Therefore the project staff developed a test designed to measure attainment of curricular objectives of the Nicaraguan mathematics program. We found that, in general, achievement levels for traditional first-grade topics were quite low--most items were answered correctly by fewer than half the children. Although teachers were teaching multiplication and division, and operations with fractions, students were not learning these topics.

The design of the test also allowed a comparison of performance levels of children from urban, municipal, and rural schools. Much to our surprise, test scores for urban, municipal, and rural children were not significantly different (mean estimated scores were, respectively, 37.2, 36.4, 34.2). This finding must be confirmed by further testing. Of the possible explanations, we were able to test one--the effect of age. Mean ages for urban students (8.2 years) and for rural students (8.5 years) are not significantly different. The proportion of children attending school may be lower for rural children, resulting in a more highly selected population, although we have no data to support this hypothesis. Alternatively, the urban environment of the Department of Masaya may not be sufficiently different from the rural environment to produce the differences typically found. The development of the test, the results, and the method of estimating total scores are discussed more fully below, and in a forthcoming project report on the testing program.

2. Preparation of the Radio Lessons

2.1 Implementing Psychological Principles of Instruction

A fundamental question facing designers of radio instruction is: How can we implement principles of good teaching using radio as the instructional medium? A list of such principles includes the following:

Instruction is more effective when children respond actively.

Reinforcement--knowledge of results--increases rate of learning.

Children's thinking progresses from the concrete to the abstract, and therefore practice with concrete materials facilitates learning.

Practice is more effective when distributed over many sessions rather than concentrated in fewer, longer sessions.

Children learn at different rates, and instruction for each child should be tailored to his learning rate.

A good teacher uses these principles as he makes decisions about organizing classroom activities, preparing lesson outlines, and even about arranging the furniture in the classroom. We are attempting to use these principles as guidelines for determining the structure and content of radio lessons.

Active responding. Experimental evidence that active responding improves learning of young children is to be found in

Suppes and Ginsberg (1962), which is contrary to evidence that active responses do not strongly influence the behavior of adults (Burke, Estes, and Hellyer, 1954).

We distinguish at least three types of responses that we ask of children. They may speak aloud, they may write, or they may respond physically. For each of these an observer can determine whether a child is responding. (There is a fourth type which we do not use--asking the children to think of a response without communicating it.) We will discuss each of the three response types in turn.

Characters in a radio program may talk either among themselves or directly to the listeners. We make a careful distinction between these two modes. When characters are talking to each other, we expect children to listen without responding. When a character talks directly to the children, we expect and plan for the children to respond. In this way a type of dialogue can be established between a radio character and the children. Student responses are highly structured, and there is, of course, no complex interaction; nevertheless the process engages the attention of the children.

Oral responses include such 'conversations' between the children and radio characters, and also answers to exercises presented in both free-response format and multiple-choice format. An example of an oral exercise in multiple-choice format is

> I am thinking of two objects--a box and a ball.
>
> Which is round?

An oral exercise in free-response format, presented abstractly, is

> What is 5 plus 10?

and presented in story form,

> Juan earned 5 centavos yesterday and 10 centavos today.
>
> How much did he earn altogether?

Recitation--rote counting, reciting the days of the week or months of the year--is also used. As another type of oral response, children sing songs. A song is taught by having radio characters sing it several times at its first presentation and then at least once in several successive lessons. After only a few repetitions the children are able to join the singing. Many of the songs we use are about mathematics. Lyrics are written by the project staff and set to music and recorded by Nicaraguan musicians.

Physical activity is a second kind of response (nonverbal) that the radio characters ask of the children. Children may play games--one game has them patting their knees, their shoulders and their cheeks a specified number of times--or they may be asked to hold up fingers, handle materials, or point to pictures or numbers on the worksheet.

Finally, the children are asked to write on the worksheet. Once again, exercises are presented either in multiple-choice or in free-response format. In the former, children mark the correct choice, while in the latter they may draw pictures or write numerals or words.

We are experimenting to find an appropriate level of activity for the children. Our present lessons are much faster paced and ask for more responses than the initial lessons we pilot-tested. At present the lessons ask for an average of two to three responses per minute, and our classroom observations suggest that this rate of responding could be increased. The children appear inattentive while radio characters talk to each other, but as soon as a character adopts the tone of voice used to talk to the children they become attentive.

Maintaining children's attention is, of course, a necessary prerequisite for effective radio lessons. Our initial view was that we would use stories to engage the children, and embed mathematical work in a story context to maintain interest. Pilot tests of lessons designed in this way, using kindergarten and first-grade children in California and first-grade children in Nicaragua, have convinced us that the mathematical activities are intrinsically interesting to the children and do not need story support, as long as the children are asked to respond frequently. Thus, our view of the role and importance of stories has changed markedly.

At present we are experimenting with the use of lessons that have songs, games, and oral and written exercises, but no stories. These lessons are presented alternately with lessons containing story episodes. Both types of lessons use the same main characters, but subordinate characters appear only in the lessons containing stories. Our current view is that stories are useful for presenting mathematical material in a realistic setting but, at least for young children in the classroom, are not needed for maintaining interest level.

Reinforcement. Providing children with knowledge of results has been shown to facilitate learning in many settings (Stolurow, 1961). Similar results have been obtained for adults in highly controlled experimental situations by Bower (1962) and others. We have experimented with various methods of reinforcement. In a pilot test of five recorded lessons, using California kindergarten and first-grade children, we found that few children changed their written answers, or even appeared to listen, when the radio lesson provided a correct answer several seconds after an exercise was presented. We found

first-grade children familiar with the procedure for checking a group of written answers, but this procedure gives no reinforcement with oral exercises, because the children do not remember what the exercise was.

To date, the most successful method we have found for providing knowledge of results is to ask the children to respond orally. In this way, children who do not know the correct answer learn from those who do. This method can be used in conjunction with written exercises by first asking the children to write their answers, then to say them aloud.

Concrete materials. There is almost universal agreement today that lower primary-level students should use concrete materials while studying mathematics. However, there are many obstacles to the use of materials during radio lessons. Although the best Nicaraguan teachers use materials, the practice is limited, and therefore unfamiliar to many teachers. Nicaraguan schools have no money available for the purchase of materials, nor any central method for distributing even those that might be obtained free. Thus, each teacher is individually responsible for their provision.

Problems of an entirely different sort arise when children are asked to handle materials themselves. The objects are dropped, misplaced, argued over, even thrown around the room. The fast pacing of the radio lessons does not allow time for coping with such problems. Even more serious problems arise when the teacher has failed to distribute the materials, or has handed out the wrong number, and the children are unable to follow the directions given by the radio.

Notwithstanding these difficulties, we are attempting to use materials--for the most part, bottle caps--during radio lessons, with only partial success. We ask the teachers to distribute a specified number of caps, no more than five, to each child, and most of the time

they do so. We ask the children to leave them alone until they are asked to use them, and this works reasonably well. The primary use of these small numbers of caps is to illustrate addition and subtraction; most entering first graders are able to count to five. We are at present undecided about continuing the use of these materials during the radio lesson. We feel that the use of fingers (although currently out of favor among many teachers) has all the advantages and none of the disadvantages of using bottle caps.

The use of materials during the post-broadcast segment of the lesson has fewer disadvantages because the flexibility of the classroom permits the teacher to cope with difficulties that arise. We will continue to encourage teachers to provide concrete experiences for students and will use the teachers' guide to suggest materials and activities.

Mixed drills. The research literature on the effect of practice on learning supports the proposition that skills need to be practiced regularly to be maintained, and that distributed practice is superior to massed practice (Underwood, 1961). Thus, a specified amount of practice is more valuable when it occurs in short, frequent sessions than in longer, less frequent sessions. In a classic paper that summarized 48 unpublished studies, Wilson (1925) concluded that drill should have the following attributes in order to be effective:

1. It should be on the entire process.
2. It should come frequently in small amounts.
3. Each unit should be a mixed drill.
4. It should have a time limit.
5. Examples in a unit drill should be in order of difficulty.

6. It should include verbal problems.

7. It should facilitate diagnosis.

With these experimental results in mind, we have developed a lesson structure that provides for several different topics in each lesson, as well as different types of activities and different modes of responding. (The structure of the lessons is described more fully in a later section.) Once a topic has been introduced, it reappears at regular intervals, sometimes in the same, sometimes in different contexts, providing continuing practice for the children. Weekly tests (included to provide information for curriculum development) are not identified to either students or teachers as such, but are presented as reviews. These sets of exercises provide a further opportunity for students to practice skills already learned.

Differential learning rates. Coping with differential learning rates is the most difficult problem facing the developer of curriculum for radio. During this first experimental year we are concerned primarily with exploring the extent of the problem. How large is the spread in achievement at the beginning of the year, and as the school year progresses? We will use results of tests embedded throughout the radio curriculum to examine this question. Do children who are performing very well or very poorly appear to lose interest in lessons? We will rely on classroom observers and teachers' reports to answer this question.

We have given some thought to ways of providing different levels of instruction to different children during broadcasting. In our testing program we developed exercises that had different printed materials associated with a single set of oral instructions, allowing children who were listening to a common set of instructions to work

different exercises. We think this method holds promise for allowing children to practice skills at different levels of difficulty. Providing post-broadcast materials for children of different ability levels would also contribute to differentiating instruction.

2.2 Curriculum Structure and Lesson Production

Project lessons are based on the mathematics curriculum specified by the Nicaraguan Ministry of Education. A thorough revision of the primary mathematics curriculum was completed in 1973, under the direction of Mrs. Vitalia Vrooman, who is now Nicaraguan Director of the project. An abbreviated version of the new curriculum outline for first grade appears in Figure 1. The list of topics is that of a

---

Insert Figure 1 about here

---

typical 'modern mathematics' program. Except for the inclusion of formal work on multiplication and division, the outline closely resembles those prepared in the United States. It is also very similar to outlines we have examined from other developing countries, an illustration of the great commonality in primary school mathematics curriculums throughout the world.

There are several reasons for adopting the Nicaraguan curriculum as the basis for project lessons. First, the curriculum is certainly satisfactory as a basis for the radio lessons. Second, the Ministry has expended much effort in the last several years revising the curriculum and retraining teachers. We feel that teachers will be less resistant to a change in mode of presentation of lessons if the curriculum is not changed (once again) at the same time. Finally, the use of the same curriculum in experimental and control classes facilitates evaluation of the radio lessons.

Some changes in emphasis and some reorganization of the Nicaraguan curriculum have proved necessary in structuring the radio lessons. As shown in Figure 1, each topic in the Nicaraguan curriculum is allotted a specific period for instruction. Teachers customarily follow these guidelines, presenting all instruction on a topic in a single block of time. Because of the demonstrated superiority of distributed practice we chose not to follow this procedure, instead dispersing instruction on each topic throughout the school year.

The process of designing radio lessons from the rather general specifications of the Ministry of Education curriculum guide involves several steps. These are the steps, as we conceive them.

1. The curriculum specialist, in consultation with local experts, specifies the general content of the curriculum, and then divides the curriculum into small units that can serve as a basis for lesson design.
2. The curriculum specialist designs an individual lesson.
3. The script writer translates the specifications for the lesson into a radio script.
4. To produce the lesson,
    a. the artist prepares the worksheet,
    b. a teacher training expert prepares the teacher's guide, and
    c. the recording artists record the lesson, under the direction of the radio producer.
5. The components of the lesson (worksheets, teacher's guides) are reproduced and distributed to schools.

Between each of these steps the curriculum specialist and the script writer review the work in progress so that the script writer

fully understands the instructional intent of the lesson and the final script accurately reflects the original specifications. We will discuss each of these steps as it is implemented by the project in Nicaragua.

Step 1: Preparation of the curriculum

As discussed above, the mathematical content of the radio lessons is that specified by the Nicaraguan curriculum guide. The curriculum specialists have divided that content into topics or strands. For first grade the strands are Basic Concepts, Number Concepts, Addition, Subtraction, Applications, Geometry, and Measurement. For each strand a set of behavioral objectives is formulated, defining the behavior expected of a student who has successfully completed the first-grade instructional program. The objectives specify only what the student should be able to do at the end of the year, and each must be broken down into subobjectives appropriate for instruction. Consider, for example, an objective that states

> The student will count the number of objects in a set of N objects, where N is less than or equal to 25.

The first subobjective might restrict the number of objects to five or fewer, a second might use from six to ten objects, and so on. Thus, the next step in curriculum preparation is to subdivide each objective into a series of subobjectives, called equivalence classes. The equivalence classes must then be put in order so that for any given concept or exercise type, all those prerequisite to it come earlier in the instructional sequence.

Figure 2 shows a hypothetical strand that has three terminal

Insert Figure 2 about here

---

objectives, A, B, and C. Objective A has three subobjectives, B has

four, and C has two. The subobjectives are used to define equivalence classes and these have been arranged in the figure in what might be a typical order. The order of equivalence classes within a strand is determined by the curriculum specialist.

In the case of first-grade mathematics, we have good criteria for determining an appropriate ordering of classes. The subject matter itself is hierarchical; in many cases concepts and problem types build logically on one another. Moreover, at the Institute at Stanford we have developed several elementary-level mathematics courses, two of them using computer-assisted instruction. We have collected over the years a large body of performance data, which provides additional guidelines for the ordering of subobjectives based on the relative difficulty of exercise types. These results are reported in Suppes (1972, 1974), Suppes and Morningstar (1970), and Suppes, Searle, and Lorton (in press).

Once a set of classes has been ordered to form a strand, the curriculum developer must consider the interconnections among strands. There may be classes in one strand that are prerequisites for classes in another strand. Figure 3 shows this relationship among four strands.

Insert Figure 3 about here

In this example, students must receive instruction in the first two Number Concepts classes before they receive instruction in the first Addition class. Similarly, the first Addition class is a prerequisite for the first two Subtraction classes, and so on.

Each strand now consists of a series of classes specifying the material that is to be taught, in units appropriately designed for instruction. For each class of exercises, students must be taught how

to perform the task, they must be given opportunities to practice it, and then, later, they need further review. When the instructional sequence for a strand is constructed, each class appears several times, providing for all three activities.

In addition, for any given presentation of a class of exercises we must specify the mode of presentation and the student response mode. An exercise may be embedded within a story or a realistic situation familiar to the children, or it may be presented abstractly, without embellishment. Students may be asked to answer orally or in writing.

Step 2: Design of an individual lesson

A radio lesson is specified by selecting an appropriate group of classes from several strands. Each class defines a lesson segment, and the segment description specifies the exercises, the mode of presentation, and the mode of response required. From four to seven segments are presented by radio, and from three to six by the teacher in the post-broadcast period. For example, Lesson 18 (near the beginning of first grade) has seven radio segments and three post-broadcast segments. The segment descriptions, as they appear in the outline for script writers, are shown in Table 6.

Insert Table 6 about here

Table 6 illustrates the variety of topics and response modes that may be incorporated in a single lesson. However, as is evident from the outline, topics are not chosen at random, but in relation to one another. Segments 1 and 7 give different types of practice with roughly the same addition combinations. Segment 4 provides practice in writing the numerals needed in segment 5, and so on. An outline like that shown in Table 6 (with additional information concerning

response modes, timing, and worksheet layout) provides the basis from which script writers produce a script for the radio lesson, curriculum writers produce the teachers' guide, and the artist prepares the worksheet.

Step 3: Translation of lesson specifications into a radio script

Before the lesson outline reaches its final form, the script writer reviews it and makes a preliminary plan for the script. This process often suggests revisions, which the curriculum specialist and the script writer make together. Then the script writer prepares an outline for the projected script and reviews this with the curriculum specialist. No dialogue is written until the two specialists have come to full agreement about the outline.

Although the lesson is initially structured by segments, these are not delineated in the lesson script and the writer is encouraged to embed the mathematics in story contexts in those lessons where stories are used. The placement of songs and games, unless these are included in the outline, is also at the discretion of the script writer. The translation of a segment description into radio script is illustrated in the following excerpt (translated from Spanish) from Lesson 18, which is based on the description for Segment 1 (see Table 6).

> The setting is a carnival, with happy background music. The radio characters--Lulu, Carlos, and Lobo--are laughing and talking excitedly about how many things there are to see and buy. Lobo (a character who often makes mistakes) asks the classroom children to help him count all the things he bought.

Lobo: First I got 2 balloons, then 3 more...I think 2 plus 3 equals 5.

Carlos: Wait. Let's see if he's right. Attention, children. Hold up two fingers on one hand...and hold up three fingers on the other hand. How many fingers are there? (pause) That's it--2 plus 3 is 5.

And what else did you get, Lobo?

Lobo: I got 2 caramels, and then 2 more.

Carlos: Children, tell me--how much is 2 plus 2? (pause) That's it--4. But let's prove it. Hold up 2 fingers on one hand, and on the other hand hold up 2 more. Now tell me, how many fingers are there? (pause) Very good--2 plus 2 is 4.

Lobo: I also got roman candles. First I got 3 roman candles, and then 2 more.

Carlos: Okay, children--how much is 3 plus 2? (pause) Now let's prove it with our fingers. Hold up 3 fingers on one hand, and hold up 2 on the other. How many fingers are there? That's right--3 plus 2 is five.

(Carlos does the same thing with 4 + 1 (balls) and 1 + 2 (flags).)

Lobo: Three flags--one for you, Lulu, one for you, Carlos, and one for me! Oh, how many things I have now!

In asking the children to 'prove' the correctness of their answers, the instructional program is teaching them a method for finding a sum of two numbers that does not depend on memorization.

When the first draft of a script is completed, the writer reads it to a group of staff members including those involved with curriculum, teacher training and classroom observation. The listeners use their knowledge of children to comment on the clarity of instructions, the level of difficulty of the language used, and the interest likely to to be generated by the stories and characters. The script is then rewritten (if necessary) in response to the criticisms of the staff.

The penultimate version of the script is timed and any necessary adjustments are made. It is then ready for recording. We have found in Nicaragua that an experienced script writer, following the process we have described, can write two or three 20-minute scripts a week.

Step 4: Lesson production

While preparing the lesson outline, the curriculum specialist makes a sketch of the student worksheet that will accompany the lesson. The artist makes a preliminary drawing which is checked for accuracy and clarity, and then is redrawn in final form. Most worksheets use both sides of the paper and, especially for early first grade, contain many illustrations. We employ an artist full time to produce five worksheets a week. The worksheet for Lesson 18 is shown in Figure 4.

Insert Figure 4 about here

A list of suggestions about the contents of the teachers' guide is prepared together with the lesson outline. A curriculum writer uses these to produce a 2-3 page guide for each lesson, describing the instructional content and the teacher's role in the post-broadcast activities. Suggestions for optional activities are also included. We find that one writer can write five guides each week, with some time left for visiting classrooms.

The final step in lesson production takes place in the recording studio. We use professional recording artists--three people play all the parts. We use pre-recorded sound effects and songs and produce an entire tape in real time. That is, unless some flaw in the tape is found, it is not edited after the recording session. All music and sound effects are taped at the same time as the spoken parts and the timing of pauses for student responses is precisely controlled. We find that an experienced staff--the artists, the producer, and the radio technician--takes about an hour to produce a 20-minute tape.

Step 5: Reproduction of materials and distribution to schools

We use an electronic scanner to make a stencil of the worksheet prepared by the artist, and all materials are mimeographed at the project office. During the pilot-testing phase materials are delivered to classrooms weekly.

This completes the description of the process of lesson construction, but a few remarks remain to be made. We consider it crucial that every person involved in lesson production observe the use of the lessons in the classroom. Thus we require all writers (of curriculum, scripts, or guides) to visit classes regularly, and encourage visits by other staff members (artists, research staff, even secretaries) as well.

We want to emphasize also that close cooperation and mutual understanding between the curriculum specialist and the script writer is essential for the production of good instructional radio programs. The training of each of these professionals does not predispose them to working well together. The curriculum specialist talks about precisely specifying goals and objectives, while the script writer

values intuition and literary creativity. To forge a working relationship between these two takes much skill, understanding, and good will.

3. Research

3.1 Research Objectives

Lesson development at each grade level proceeds in two phases, and the activities associated with each phase are shown in Table 7.

Insert Table 7 about here

During 1975 the project is implementing Phase A for first grade. Sixteen first-grade classrooms, distributed among urban, municipal and rural schools, are participating in the pilot-testing of lessons. Some classrooms have only first-grade students while others have students at both first and second-grade level. Although all of the teachers participating during the pilot testing phase are doing so voluntarily, we attempted to enlist teachers with differing levels of experience and competence.

Student worksheets are collected from all sixteen classrooms. In addition, in six classrooms the mathematics lesson is observed daily by project staff members who complete rating sheets covering both general aspects of the lesson and specific questions posed by the lesson developers. This system of observations provides immediate feedback to the curriculum specialists and radio script writers and allows for much informal experimentation with teaching techniques.

Computer programs for the analysis of worksheet data have been prepared by programmers at a computer center in Nicaragua, and summary statistics and item analyses are available to

curriculum developers within a few days after presentation of each lesson. Further analyses of greater complexity are conducted by the project staff at Stanford University.

Teacher attitudes about radio instruction and about teaching mathematics were surveyed before their participation in the project, and will be resurveyed at the end of the school year. Although teacher training activities were scheduled before the start of the school year, the schedule is continually revised in response to the needs expressed by teachers and project staff members. Thus, the major thrust of the Phase A work is exploratory and developmental.

Following pilot testing, first-grade lessons will be revised and during 1976 they will be broadcast to fifty classrooms, using the facilities of a local radio station. Initial development and pilot testing of second-grade lessons will proceed simultaneously, using the same level of observation and data collection as was used for first grade. On the proposed schedule of lesson development the project is currently funded through third grade.

For each grade level, the evaluation conducted during Phase A will be almost exclusively formative, focusing attention on student attainment of the project's instructional goals. Weekly tests are embedded in the radio lessons to provide a continuing assessment of student performance on material previously taught. In addition, student worksheet responses provide information about levels of student performance on each aspect of the curriculum. A final test will measure the year-end attainment of curriculum goals.

During Phase B, when lessons are delivered to classrooms by radio, project evaluation efforts will be more summative in character. A stratified random sample of classrooms from among those in the

Department of Masaya that have good radio reception will be assigned to the experimental treatment. Classrooms will be chosen from urban, municipal, and rural schools in equal proportions. A random set of control classes, similarly stratified, will be selected from classrooms both within and outside the radio reception area. Both experimental and control classes will be pretested and posttested using mathematics achievement tests. Since the project lessons are based on the mathematics curriculum designed by the Nicaraguan Ministry of Education, both experimental and control classes can be expected to have studied roughly the same material during the school year, allowing for a comparison of mathematics achievement of the two groups.

As an additional method of comparing achievement, the project will examine performance of students on the school year-end test, and compare repetition rates due to failure in mathematics for control and experimental students. A more broadly based examination of dropout rates is also planned, as a component of an analysis of the economic consequences of the use of radio for instruction in this setting.

3.2 Design and Testing of Pilot Lessons

Preliminary information about many aspects of the design of radio lessons was obtained from the administration of pilot radio lessons to first-grade classrooms. Two lessons were written, tested in three classrooms, and then completely rewritten. Four more lessons were produced and all six form the set of pilot lessons described here. These lessons were given in six classrooms during November, 1974, close to the end of the academic year.

The content of the lessons was chosen to provide a variety of topics, with at least one topic that was new to the children,

presented in a coherent sequence of lesson segments.

Several types of responses (oral, written, physical, manipulation of materials) were used to find out what the children were able to do, what types of instructions were needed, and how much time must be allowed for responding. In addition, we experimented with reinforcement by providing answers to some questions after the students had responded.

Some portions of the lessons were designed to be handled entirely by the teachers, so we could assess the effectiveness of our instructions to teachers. We also asked the teachers to motivate the lessons and to assist during the broadcast by encouraging the children to respond orally and by displaying a sample worksheet.

We tried to arouse interest in the lessons by using stories with lots of action and adventure, augmented by many sound effects. The same skeleton cast was used throughout the six lessons and additional characters were brought in as needed.

Lesson content. The six lessons contained 48 segments, of which 39 were presented during and 9 after the broadcast. Segments were chosen from five strands: Number Concepts (NUM), Applications (APL), Geometry (GEO), Basic Concepts (BAS), and Addition (ADD), as shown in Table 8. Segments from the Basic Concepts strand were

---

Insert Table 8 about here

---

used to teach students to use the worksheets. (These tasks were nonmathematical, asking the students to identify common objects.) Number Concepts segments asked students to play a number game, count aloud, count sounds, write numbers from dictation, and give successors. Segments from the Applications strand covered measuring with a ruler,

days of the week, and money, while Geometry segments centered around comparing lengths of lines. Addition segments contained oral arithmetic exercises.

Response mode. In each lesson approximately half the segments required written responses, except for the first lesson, which had only one such segment. Other segments required oral or physical responses. Oral responses included constructed responses to arithmetic exercises (What is 2 plus 3? What number comes after 17?), responses to mathematical questions phrased as choices (Which is longer, a broom or a pencil? Which is worth more, a 5-cent coin or a 10-cent coin?), responses to general-interest or organizational questions (children, are you ready?), and recitation (rote counting, naming days of the week). Written responses were made on worksheets. Some were constructed (write the answer: how much is 5 + 2?), some were multiple choice (circle the empty glass), and some were drawn (draw a line longer than the one shown on the worksheet).

Physical responses were mostly in the "mando mando" game--"mando" means "I command" in Spanish--in which children followed the instructions of a leader (clap your hands, raise two fingers). In addition to worksheets and pencils, the only materials used were cardboard rulers.

Almost all segments requiring written responses contained five exercises (some of those presented after the taped lesson had 6 or 8 exercises).

Results. In general, the children responded actively. They gave oral responses readily, even answering rhetorical questions (which we now try to avoid). At first the teachers were quite active in

eliciting oral responses (as we had suggested), but this seemed unnecessary and we now discourage the practice.

Because we anticipated that children would have difficulty in following oral instructions, we made frequent use of repetition. We found that this often confused and rarely helped the children. They followed instructions well, experiencing difficulty only when the instructions were ambiguous or the content too difficult. However, occasionally an unexpected noise drowned out an essential word. This caused problems only when children were working individually on worksheets, and we now repeat only key words or phrases that provide instruction for written work. In one lesson we used a "cartoon" voice to give exercises. Only a small proportion of the students understood the voice and we have dropped that practice.

The children's high level of listening skills when instructions were presented contrasted strongly with their response to stories. They appeared bored and uninterested in the characters. When questioned after the lessons, students indicated that they did not follow plots. We have decreased both the amount and the complexity of story material used in lessons.

The children had more difficulty using the worksheets than we had anticipated. They often marked answers in the wrong spaces and we have redesigned the worksheet to add an identifier for each section. (We use pictures of familiar objects drawn inside flags so they are not confused with other pictures on the worksheet.) Before presenting an exercise we ask the children to put a finger on the identifier that marks the space for the answer.

We experimented with the amount of time allowed for various types of responses, and developed the following set of guidelines:

oral response to a question with an obvious answer	2 sec.
counting 1 to 5 bottle tops	5 sec.
circling one choice among 2 or 3 pictures	5 sec.
writing a 1-digit number	8 sec.
drawing 1 to 3 circles	12 sec.

In several segments we tried to supply reinforcement by announcing the correct answer after the children were given time to write a response. This procedure seemed to confuse many children and not to help the others. We have not found a successful substitute, and do not presently give reinforcement for written responses.

Teachers seemed to be receptive to the program. Some teachers apparently did not believe that children would listen to and obey instructions from a recording machine, and therefore repeated every question, thereby shortening the time allowed for the children to respond. We now urge teachers not to repeat unless there is a noise or distraction that prevents children from hearing the tape.

For the first version of the first two lessons we wrote lengthy and detailed teachers' guides, but these proved to be confusing; a much briefer guide format was used for the six lessons, and is still in use.

We turn now to an examination of student response data, which are reported for all segments requiring written responses. During the lessons we made no attempt to inhibit cooperative answering or "copying", which certainly occurs. (We once observed a child marking two worksheets while her friend searched for a pencil.) Cooperative answering probably inflates scores (at least for easy exercises) but there remains a wide variation in scores.

The number of students taking each lesson ranged from 155 to 186. The mean percentage correct for segments requiring written responses is shown in Table 9. (The identifier L1-4 is for lesson 1,

---

Insert Table 9 about here

---

segment 4). On the basis of previous experience we consider a performance level of between 80 and 90 percent correct to be optimal for first-grade children (lower levels are too discouraging). The performance level for the pilot lessons was acceptably high, falling below 70% correct for only two segments (L2-7 and L5-9).

Evidence for learning appears when we examine scores for three segments presenting the same task, which had not been previously taught. Exercises in segments L2-8, L3-8, and L4-7 asked students to measure pictures of objects (which varied in length from 3 to 10 centimeters). As seen in Table 9, the percentage correct increased from 71.0 to 88.3.

Our experience with the pilot lessons suggests the following general conclusions about the design and use of radio lessons.

1. Children are most attentive to radio lessons when they are responding actively.
2. Mathematical activities are more engaging than stories for first-grade children.
3. Rhetorical questions are answered by the children; such questions should be used only sparingly and time must be allowed for responses.
4. Children listen to instructions and, in most cases, repetition is not needed.
5. Children can learn new topics from the radio lessons.

3.3 Design and Administration of an Achievement Test

To obtain information about student achievement levels before the initiation of radio lessons, the project designed a year-end test for first grade, and administered it in November, 1974. The purposes of the test were to measure student performance at the end of the school year on first-grade curriculum objectives, and to determine both the extent of performance differences between rural and urban students and the range of variation among classrooms. A multiple matrix-sampling design, in which each item is given to only a subset of students and each student takes only a subset of the items, was used. This design tests a large number of items, providing more information than a design requiring that each student answer each item; this advantage is partially offset by less stable estimates of student performance, leading to less accurate comparisons between groups of students.

A pilot test was developed and given to approximately 90 students in two classrooms. After modification the test was administered to all students in 44 classrooms.

The test was developed in the following steps:

1. The equivalence classes that defined the curriculum to be tested were chosen.
2. The structure of the test and the number of items needed were determined.
3. A procedure for sampling equivalence classes was chosen and implemented.
4. The chosen equivalence classes were assigned to test forms.

5. A test item was written to represent each equivalence class.

Definition of the appropriate curriculum. Two sources of information about the first-grade mathematics curriculum were used to choose the strands and the equivalence classes within each strand appropriate for a first-grade achievement test. These are the curriculum guide prepared by the Ministry of Education, described in Figure 1, and our observations of the topics teachers were presenting in the classroom. The universe of achievement test items is called the test curriculum; it is not identical to the curriculum which forms the basis for radio lessons.

The strands in the test curriculum are listed in Table 10.

Insert Table 10 here

Numeration topics include counting to 100, reading and writing integers and simple fractions, place value, size comparisons for both integers and fractions, and the use of ordinal numbers up to 'tenth'. Because some teachers were teaching concepts more advanced than those specified by the Ministry curriculum guide, the Addition and Subtraction strands were extended to include problems with 'carrys' and 'borrows' and addition and subtraction of fractions. As shown in Figure 1, multiplication and division are considered first-grade topics. Geometry includes 'readiness' topics such as the concepts of shape, similarity, position and length, and the Applications strand covers money, linear measure, pairs and dozens, time, and word problems. The test curriculum consisted of 554 equivalence classes distributed among strands as shown in Table 10.

Structure of the test. The pilot test and the final test had the same structure except for the number of items. The test had three

parts, none of them overlapping. Part A was prepared in one form, and was given in all classrooms. Part B was prepared in five forms and all students in a classroom received the same B form. Part C was prepared in five forms, and these were assigned randomly to students within each class, so that in each classroom roughly equal numbers of students worked on each C part. Each student received a single test booklet, which included the appropriate combination of all three parts.

Test items were of two types. For some items, part or all of the content of the exercise was presented orally. For others, only the instructions were presented orally--the exercise itself was printed. For the first type of item, all students in a classroom must receive the same item. Thus, such items could not be included in Part C of the test. For items of the second type the test administrator could read instructions that apply to exercises with different content. ("Now work the next exercise" is the simplest instruction of this type.) These items could appear on all parts of the test. Because some items were unsuitable for use in Part C, it was not possible to assign items randomly to test parts.

In the pilot test, each form of each part contained 10 items. Thus, there were 10 Part A items, 50 Part B items, and 50 Part C items, for a total of 110. To obtain these items it was necessary to sample 110 equivalence classes from the test curriculum. These classes were distributed among strands as shown in Table 10 in the column labeled Proposed Pilot Test. The proportion of classes for each strand roughly corresponded to that of the test curriculum as a whole.

Results of the pilot test. A trial run of the entire test as described here would have required five classrooms, one for each B form

of the test. However, because time did not permit such extensive testing only two classrooms, one with 50 students, the other with 41 students, were tested. Thus, eight forms--Part A, two forms of part B and all five forms of Part C--were tested. The 10 different test booklets used contained 80 items, distributed among strands as shown in Table 10 in the column labeled Actual Pilot Test. Each test booklet contained 30 items, 10 from each part. The number of students who took each Part C ranged from 17 to 20.

Table 11 shows the mean percent correct and the range of scores

---

Insert Table 11 about here

---

for items from each strand. Results are shown separately for integers and fractions because error rates for these are markedly different. The scores suggest that very few curricular goals are being met satisfactorily in these two classrooms.

Administration of the pilot test revealed several short-comings in the testing procedures. There was much cooperative answering, especially where students sat at tables or long desks. Some test questions were worded in such a way that students answered orally instead of in writing. The pilot test proved to be very long--administration took about an hour.

On the basis of the pilot testing experience, the guide for administering the test was revised to include special instructions about rearranging seating patterns to decrease cooperative answering. The results of the pilot test also served to guide revision of test content. The length of the test was shortened from 30 to 21 items by reducing to 7 the number of items from each part. The topics of addition and subtraction of fractions, and division were entirely

eliminated from the test curriculum. Small changes were made in the distribution of items and the total number of equivalence classes sampled in the final test was 77.

Selection of the classrooms to be tested. A list of all first-grade classrooms was made, stratified by region (urban, municipal, rural). From each stratum 10 classes were chosen at random with the single restriction that only one class was chosen from a school. The restriction was adopted because we did not have the manpower to test two classes simultaneously and we felt that conversation between teachers or students in the interval between test administrations might contaminate the results.

In addition to the 30 randomly chosen classes, 14 were tested for special reasons. Some classes had already taken experimental radio lessons, and some would be using radio lessons in 1975; we were interested in these students' performance on the test. Fourteen such classes were nonrandomly selected. In all, 1241 students were tested. All teachers were assured that the test would not be used to evaluate them or individual students but that the data would be used to guide curriculum development and evaluate the project activities.

Test administration. Tests were administered by two staff members. One read the instructions, the other taped the testing session. While the children were being tested the teacher was asked to fill out a short form for each child giving background information including age, sex, and years in school.

The test took 30 minutes to administer (including a short break). About 45 minutes before and 10 minutes after the testing period were spent on administrative matters. Examiners reported

many of the usual problems encountered when testing first-grade students--the tendency to answer aloud, confusion about following directions, and so on. These problems seemed especially severe because of the novelty of the test situation for these students. They had never experienced any of the following: people from outside coming in to give them a test, printed tests, the exercise presentation formats used in the test, handing out of pencils, mathematics exercises presented orally (requiring written response), a test with a variety of mathematical operations presented, and the tape recording of classroom activities. In many classrooms children seemed bewildered by the situation. Although children had difficulties with the test situation, and we must certainly keep these in mind when inspecting test results, it is important to note that for four of the 77 exercises the percentage correct was over 90. Thus, at least for some exercises, almost all the children were able to respond correctly.

The examiners noted that the six classes that had just completed taking the experimental radio lessons seemed to find the test examination situation much less confusing. The format for the test was quite similar to that used for worksheets during the lessons, and the examiners felt that the radio lessons had provided some training in those skills needed to respond successfully during the test.

Test results. The mean number correct for each part of the test is shown in Table 12 (data are for 1256 students from 44 classes).

Insert Table 12 about here

Scores for the A and B forms of the test were higher than those for

the C forms. It is possible that the exercises in the C parts are harder. It is also possible that the reduction in cooperative answering (because children had different forms of the test) is responsible for the somewhat lower scores.

The structure of the test provided an opportunity to assess the extent of cooperative answering. Each test booklet was organized so that questions 1, 2, 6, 13, 14, 17 and 18 were from part A, questions 3, 4, 7, 8, 11, 12, and 21 were from part B, and questions 5, 9, 10, 15, 16, 19, and 20 were from part C. The examiner led the children through the test, so that all children worked on the same question at the same time. For example, for question 5 (Part C), children were told "Read the numbers carefully. Write the numbers that are missing." The child had printed on his test booklet one of five exercises, depending on which C form he had.

A child who copied an answer from his neighbor ran the risk of copying a correct (or incorrect) answer for an exercise different from the one printed in his test booklet. It seems reasonable to conclude that a child copied from a nearby paper when his response is correct for an exercise from a different form. The complexity of the questions supports this conclusion. For question 5 the number of children who apparently copied is shown in Table 13. The numbers along the diagonal

---

Insert Table 13 about here

---

show the number of students who gave the correct answer to the exercise they were given. The numbers off the diagonal show the number who gave the correct answer for an exercise on a different form. uestion 5, therefore, 80 children, represented by numbers off the diagonal, gave the correct answer to an exercise from a different form. These

80 children are approximately 9% of the total number of children who responded incorrectly to this question.

Performance on test items summarized by strand is shown in Table 14. Percentage correct for the five geometry readiness items

---

Insert Table 14 about here

---

ranged from 73.0 to 98.9. (Two of these items are shown in Table 15.)

Insert Table 15 about here

The high scores for these items provid .onfirmation that students were able to understand directions and respond correctly when they knew the answer.

The range of performance is shown for all strands in Table 15. The performance level was quite low for addition and subtraction items; only slightly more than half the students responded correctly to the easiest items. Approximately 44% of the students responded correctly to the easiest multiplication exercise.

Applications exercises included word problems presented orally and in written form. The oral exercises required a free-format response; the written exercises were in multiple-choice format. Word problems (customarily presented in written form) are considered very difficult for young children. However, we have long suspected that children would find such problems easier if they were presented orally. (For some positive experimental results on the reasoning abilities of young children when problems are given orally, see Suppes, 1965). The results shown in Table 16 support this supposition. The percentage

---

Insert Table 16 about here

---

correct ranged from 49.6 to 71.3 for five word problems presented orally. (Note that 71.3% is higher than the performance on any of the computation items--see Table 15) As shown in Table 16, performance on written word problems ranged from 5.4 to 40.2 percent correct. Since these exercises were presented with three answer choices, the expected percentage correct by chance is 33.3.

Comparison of students from different regions. An important aspect of our testing program was to compare performance of students from urban, municipal, and rural schools. For this purpose we obtained for each student an estimated score for the 77 items of the entire test. The method used was adapted from that of Kleinke (1972). In brief, the estimated score is obtained by adding together the scores for a student on the parts of the test he took, the mean scores (for all students) on the parts of the test that he did not take, and an adjustment for the student based on the difference between his own scores and the mean scores on the parts of the test he took. The maximum possible estimated score is 77, the total number of exercises tested. The mean estimated score for all students was 37.1.

Neither the comparisons using estimated scores nor those using scores obtained on individual parts of the test show a significant difference in performance between students from different regions. The various means and standard deviations are shown in Table 17. As

---

Insert Table 17 about here

---

we mentioned earlier, this finding is somewhat surprising, and we hope to investigate the situation more thoroughly in the future. The group of students who took the pilot radio lessons attained the highest

mean test score. This may reflect their nonrandom selection, or may in fact result from the test-taking practice afforded by the radio lessons.

The results of the administration of the mathematics achievement test suggest the following general conclusions about first-grade students in the Department of Masaya in Nicaragua.

1. Most children, even though unfamiliar with the testing situation, are able to respond to test exercises.
2. Test results are contaminated by cooperative answering.
3. Children perform well on items that test general knowledge.
4. Children perform poorly on most items that are characteristic of the formal mathematics curriculum.
5. Children perform better on arithmetic items presented as oral word problems than on those presented abstractly.
6. There is little difference in performance between children from urban, municipal, and rural schools.

4. Summary and Conclusion: The Project Today

The choice of Nicaragua as the project site was communicated to the Nicaraguan Minister of Education in February, 1974. During the following months arrangements for establishing the project office were made, two Nicaraguan educators began work, and in June, 1974, three Stanford staff members joined them to make an initial staff of five. The Nicaraguan staff has continued to grow and now includes 11 professionals and 10 others in the support staff.

Since March, 1975, children in 16 first-grade classrooms have been taking daily mathematics lessons prepared by the project. We have

taken great care to assure that children experience success in their first exposure to radio lessons. The mean percentage correct for written exercises in the first 20 lessons was above 90. These early exercises involved reading and writing numbers from 1 to 6, using a variety of response formats. Today, June 6, 1975, Lesson 56 is being presented, and children are counting to 100, reading and writing numerals up to 24, finding basic sums to 9, adding and subtracting in the context of word problems, and beginning to work (orally) on sums of the form 10 + 6 and 20 + 3.

Teachers have responded well to the program, cooperating fully with data collection procedures, and following lesson outlines provided by the teachers' guides. The program also has the active support of the Minister of Education and the School Inspector of the Department of Masaya.

It is too early to reach any general conclusions about the project in Nicaragua but we are encouraged by what has been accomplished during the first year. Our experience thus far has confirmed our belief that it is not only possible but practical to produce attractive radio lessons in primary school mathematics. On the other hand, we do not underestimate the many problems that must be solved in the future in order to make teaching elementary mathematics by radio an educationally sound venture beyond the confines of our target schools in the Department of Masaya in Nicaragua.

References

Bower, G. An association model for response and training variables in paired-associate learning. Psychological Review 69, 1962, 34-53.

Burke, C. J., Estes, W. K., & Hellyer, S. Rate of verbal conditioning in relation to stimulus variability. Journal of Experimental Psychology, 1954, 48, 153-161.

Jamison, D., Suppes, P., & Wells, S. The effectiveness of alternative instructional media: A survey. Review of Educational Research, 1974, 44, 1-67.

Kleinke, D. J. A linear-prediction approach to developing test norms based on matrix-sampling. Educational and Psychological Measurement, 1972, 32, 75-84.

Searle, B. Site selection process: Radio Mathematics Project. Stanford, California: Stanford University, Institute for Mathematical Studies in the Social Sciences, 1974.

Stolurow, L. M. Teaching by Machine. Washington: U. S. Department of Health, Education, and Welfare, 1961.

Suppes, P. On the behavioral foundations of mathematical concepts. Monographs of the Society for Research in Child development, 1965, 30, 60-96.

Suppes, P. Computer-assisted instruction at Stanford. In Man and computer. (Proceedings of international conference, Bordeaux 1970.) Basel: Karger, 1972, pp. 298-330.

Suppes, P. A survey of cognition in handicapped children. Review of Educational Research, 1974, 44, 145-176.

Suppes, P. and Ginsberg, R. Application of a stimulus sampling model to children's concept formation with and without overt correction responses. Journal of Experimental Psychology, 1962, 63, 330-336.

Suppes, P. and Morningstar, M. Technological innovations: Computer-assisted instruction and compensatory education. In F. Korten, S. Cook & J. Lacey (Eds.), Psychology and the problems of society. Washington, D. C.: American Psychological Association, Inc., 1970, pp. 221-236.

Suppes, P., Searle, B ., and Lorton, P. The Stanford CAI arithmetic strands program. In press.

Underwood, B. J. Ten years of massed practice on distributed practice. Psychological Review, 1961, 68, 229-247.

Wilson, G. M. Arithmetic. In Research in constructing the elementary school curriculum, Third yearbook of the Department of Superintendence. Washington, D. C. : NEA, 1925, pp. 35-109.

Table 1

Number of Schools and Classrooms in Masaya in 1971

	Number of schools	Number of classrooms[a]
Urban	51	245
Rural	66	118
Total	117	363

[a] Some classrooms are used for both morning and afternoon sessions.

Table 2

Extent of the Use of Combination Classes in Masaya in 1971

	Number of classes			
	One grade taught	Two grades taught	Three or more grades taught	Total
Urban	319	10	2	331
Rural	63	13	47	123
Total	382	26	49	454

Table 3

Number of Pupils per Grade

Department of Masaya, 1971

Grade	Urban	Rural	Total
1	4,357	2,825	7,182
2	2,502	1,256	3,758
3	2,201	832	3,033
4	1,741	550	2,291
5	1,338	359	1,697
6	1,172	258	1,430
Total	13,311	6,080	19,391

Table 4

Comparison of Masaya and Nicaragua

Index	Masaya	Nicaragua
Percentage of rural children in school	83	68
Percentage of certified teachers	94	79
Percentage of classrooms with		
one grade	84	79
two grades	5	5
more than two grades	11	16
Pupil-teacher ratio	35	38
Percentage of school children in		
Preprimary	.8	2.7
Grade 1	36.7	36.6
Grade 2	19.2	19.0
Grade 3	15.0	14.9
Grade 4	11.2	11.5
Grade 5	9.5	8.6
Grade 6	7.6	6.7
Percentage of illiterate adults (1970)		
Urban	21.1	16.6
Rural	57.0	62.5

Note. Data is for 1971 unless otherwise noted.

Table 5

Indices of Urbanization

Index	Masaya	Masatepe	Niquinohomo	Nindiri	San Juan de la Concepcion	La Concepcion	Nandasmo	San Juan de Oriente	Catarina	Tisma
1. Population	30,000	6,300	2,300	2,000	1,200		2,600	600	2,000	2,200
2. Post-primary schools										
a. Commercial	3	0	1	0	0	0	0	0	0	0
b. "Ciclo Basico"	0	1[b]	2[b]	0	0	0	0	0	0	0
c. "Bachillerato"	4[a]	1	0	0	0	1	0	0	0	0
3. Commuting time by bus to post-primary schools if none exist in the town (in minutes)				15	15		30	20	15	40
4. Time between buses to either Managua or Masaya (in minutes)	10	30	20	10[c]	45	45	30[d]	20	20	120
5. Percentage of paved streets	25%	30%	0	0	0	0	0	0	2 streets	0
6. Number of movie theaters	3	2	0	0	0	1	0	0	1	0
7. Number of banks	5	2	0	0	0	0	0	0	1	0
8. Number of bookstores	4	0	0	0	0	0	0	0	0	1
9. Number of daily newspapers from Managua	2	2	2	2	1	2	0	2	1	1
10. Number of private telephones	6,500	130	28	7	2	10	2	0	2	6

[a] Includes 2 private schools.

[b] Includes 1 private school.

[c] After 10 minute walk.

[d] After [illegible] minute walk.

Table 6

Segment Descriptions for Lesson 18, Grade One

Segment number	Presented by	Description
1	Radio	Show the addition facts 2+2, 3+2, 4+1, 1+2 using fingers. "How much is 2 plus 2?"
2	Radio	Rote count from 1 to 20, two times.
3	Radio	Give successors orally for 5, 8, 7, 9, 10. "What number comes after 5?"
4	Radio	Write numerals from dictation. "Write the number 4 (3, 5, 2, 6)."
5	Radio	Write the successors of 2, 1, 4, 3, 1. "Write the number that comes after 2."
6	Radio	Ordinals 'first' and 'second', oral, then written response, using drawings. "There is a plate on the first table. What is on the second table? Circle the first table (second basket, second box, first dish).
7	Radio	Readiness for addition, drawing. "Draw 2 balls on the first line. Draw 1 ball on the second line. How many are there in all? (oral response) (1+2, 1+3, 3+2, 2+2)
8	Teacher	Reading numerals from 1 to 7 (printed on worksheet). Circle the 3 (6,2,4,7,5)."
9	Teacher	Read numerals 1 to 9 on cards (prepared by teacher).
10	Teacher	Count objects, from 1 to 10 (materials chosen by teacher).

[a] Translated from Spanish.

Table 7

Activities Characterizing Two Phases of Lesson Development

	Phase A	Phase B
Experimental year	1	2
Lessons	new	revised
Presentation mode	tape recorder	radio
Number of classrooms	about 15	about 50
Control classes used	no	yes
Character of evaluation	formative	summative

Table 8

Number of Pilot-lesson Segments by Strand and Lesson

Strand	Lesson						Total
	1	2	3	4	5	6	
Number concepts	6	4	5	3	2	1	21
Applications	1	2	1	2	4	4	14
Geometry	1	0	0	1	2	0	4
Basic concepts	0	2	1	1	0	0	4
Addition	0	0	0	0	3	2	5
Total segments per lesson	8	8	8	8	9	7	48

Table 9

Performance on Pilot Lesson Segments

Lesson & segment	Strand	n	Mean percentage correct	S.D.
L1-4	NUM	169	88.8	3.2
L2-4	BAS	174	78.0	25.3
L2-5	NUM	174	80.1	3.2
L2-7	BAS	174	66.9	4.5
L2-8 P[a]	APL	174	71.0	4.5
L3-4	BAS	186	71.5	10.0
L3-6	NUM	186	73.2	3.2
L3-7	GEO	186	88.0	8.4
L3-8 P	APL	186	78.3	5.5
L4-2	GEO	173	94.5	4.5
L4-4	NUM	173	70.1	8.4
L4-5	BAS	173	83.9	4.5
L4-6	GEO	173	83.7	.0
L4-7 P	APL	173	88.3	5.5
L5-4	APL	155	85.5	5.5
L5-7	ADD	155	78.8	8.4
L5-8 P	APL	155	80.6	7.7
L5-9 P	APL	155	49.1	4.5
L6-3	ADD	174	83.8	3.2
L6-4	APL	174	76.9	16.4
L6-6	APL	174	83.5	7.7
L6-7 P	APL	174	91.4	.0

[a] P means presented after the taped lesson (postbroadcast).

Table 10

Distribution of Equivalence Classes among Strands in Curriculum and Test

Strand	Number of Classes		
	Test curriculum	Proposed pilot test	Actual pilot test
Numeration	218	35	21
Addition	113	19	17
Subtraction	71	16	16
Multiplication	45	10	9
Division	11	5	5
Geometry	26	5	2
Applications	70	20	10
Total	554	110	80

Table 11

Proportion Correct on Pilot Test by Strand

Strand	Number of items	Mean percentage correct	Range of percentages
Numeration	21	53.6	5.6 - 94.5
Integers	19	55.2	5.6 - 94.5
Fractions	2	37.6	17.1 - 58.0
Addition	17	33.2	0 - 70.0
Integers	13	42.6	5.6 - 70.0
Fractions	4	2.8	0 - 5.6
Subtraction	16	21.3	0 - 52.7
Integers	12	27.0	5.0 - 52.7
Fractions	4	4.2	0 - 11.8
Multiplication	9	21.4	5.6 - 38.9
Division	5	10.8	0 - 22.0
Geometry	2	68.2	44.4 - 92.0
Applications	10	36.0	5.0 - 84.0

Table 12

Performance on Eleven Subtests of Final Test

Part	Form	Number of students	Mean score[a]	Standard deviation
A	1	1241	4.51	1.98
B	1	246	4.07	1.53
B	2	265	4.60	1.54
B	3	223	4.45	1.50
B	4	240	3.95	1.86
B	5	267	3.70	1.93
C	1	248	2.79	2.15
C	2	255	2.37	1.86
C	3	243	1.92	1.58
C	4	246	3.15	2.14
C	5	249	2.09	1.87

[a] Maximum score = 7.

Table 13

Extent of Cooperative Answering

on Question 5[a]

Form student took	Form for which student's response was the correct answer				
	1	2	3	4	5
	Number of students				
1	104	4	3	3	5
2	9	47	2	1	7
3	4	1	40	7	1
4	4	4	2	122	6
5	9	5	0	3	52

Note. About 250 children took each test form.

[a] Question 5: "Read the numbers carefully. Write the numbers that are missing."

Form 1: 30 40 50 __ __ Form 4: 72 73 74 __ __

Form 2: 2 4 6 __ __ Form 5: 8 7 6 __ __

Form 3: 5 10 15 __ __

Table 14

Proportion Correct on Final Test by Strand

Strand	Number of items	Mean percent correct	Standard deviation
Numeration	29	57.0	22.4
Integers	24	56.6	23.1
Fractions	5	58.6	20.8
Addition	11	45.4	15.0
Subtraction	12	32.4	13.9
Multiplication	4	33.3	9.2
Geometry	5	89.4	11.1
Applications	16	40.2	21.2

Table 15

Items with Highest and Lowest Percent Correct

on Final Achievement Test by Strand

Strand	Highest		Lowest	
	Percent correct	Item	Percent correct	Item
Numeration	91.46	"Write the number 7."	16.46	"Write the numbers that are missing." 72 73 74 __ __
Addition	67.71	"How much is 5 plus 1?"	11.76	38 + 55
Subtraction	60.00	"How much is 6 minus 3?"	7.62	42 - 5
Multiplication	43.62	2 X 5 = ____	25.00	9 X 10 = ____
Geometry	98.87	"Circle the longest ladder." (3 choices)	73.03	"Circle the glass that is on the right."
Applications	71.30	"Manuel had 4 buttons to play with. Playing with another boy he lost 3. Write the number of buttons he has left."	2.88	"Write the hour the clock says." (10:30)

Table 16

Performance on Word Problems

Comparison between Oral and Written Problem Presentation

Presentation and response mode	Required arithmetic	Percent correct
Oral, free response	3 + 2 = ___	65.9
Oral, free response	3 + 2 + 2 = ___	70.2
Oral, free response	4 - 3 = ___	71.3
Oral, free response	2 X 4 = ___	49.6
Oral, free response	6/2 = ___	52.4
Written, multiple choice	5 - 3 = ___	31.1
Written, multiple choice	6 + 1 = ___	36.1
Written, multiple choice	5 + ___ = 6	5.4
Written, multiple choice	4 + 2 = ___	40.24
Written, multiple choice	3 + 3 = ___	35.7

	Mean	Standard deviation
Oral	61.9	10.2
Written	29.7	14.0

Table 17

Summary Statistics Using Total Scores Estimated by Kleinke Procedure

Student group	n	Mean	Standard deviation
44 classes	1241	37.10	12.76
10 urban classes	301	37.24	12.47
10 municipal classes	310	36.42	13.00
10 rural classes	263	34.24	12.70
total 30 classes	874	36.05	12.77
6 radio classes	157	40.13	12.34

First Unit: Basic Concepts (2 weeks)

size, height, position, width, quantity, weight

Second Unit: Sets (4 weeks)

set, element, comparing sets, equality, inequality

Third Unit: Systems of Counting (8 weeks)

counting up to 99, ordinals, place value

Fourth Unit: Addition and Subtraction (4 weeks)

addition and subtraction as inverse operations, sums, differences to 18, addition and subtraction of 2-digit numbers without carrying or borrowing

Fifth Unit: Multiplication and Division (3 weeks)

Readiness work, multiplication combinations up to 27, division with dividends up to 15, divisors of 2 to 5

Sixth Unit: Common Fractions (2 weeks)

halves, thirds, and fourths

Seventh Unit: Money (2 weeks)

monetary unit--el cordoba, 5, 10, 25, 50 centavo coins, equivalencies

Eighth Unit: Measures (5 weeks)

length, volume, time, weight, pairs and dozens

Ninth Unit: Geometry

point, line, plane, curved and straight lines, angles, figures with 3, 4, more sides

Figure 1. Nicaraguan first grade curriculum: condensed version of outline prepared by the Ministry of Public Education.

STRUCTURE OF A STRAND

Objectives	Subobjectives
A	1, 2, 3
B	1, 2, 3, 4
C	1, 2

INSTRUCTIONAL ORDER OF SUBOBJECTIVES

A1	B1	A2	C1	B2	B3	A3	C2	B4

Figure 2. Structure of a strand.

STRAND STRUCTURE SHOWING INTERRELATIONSHIPS

First Grade Mathematics

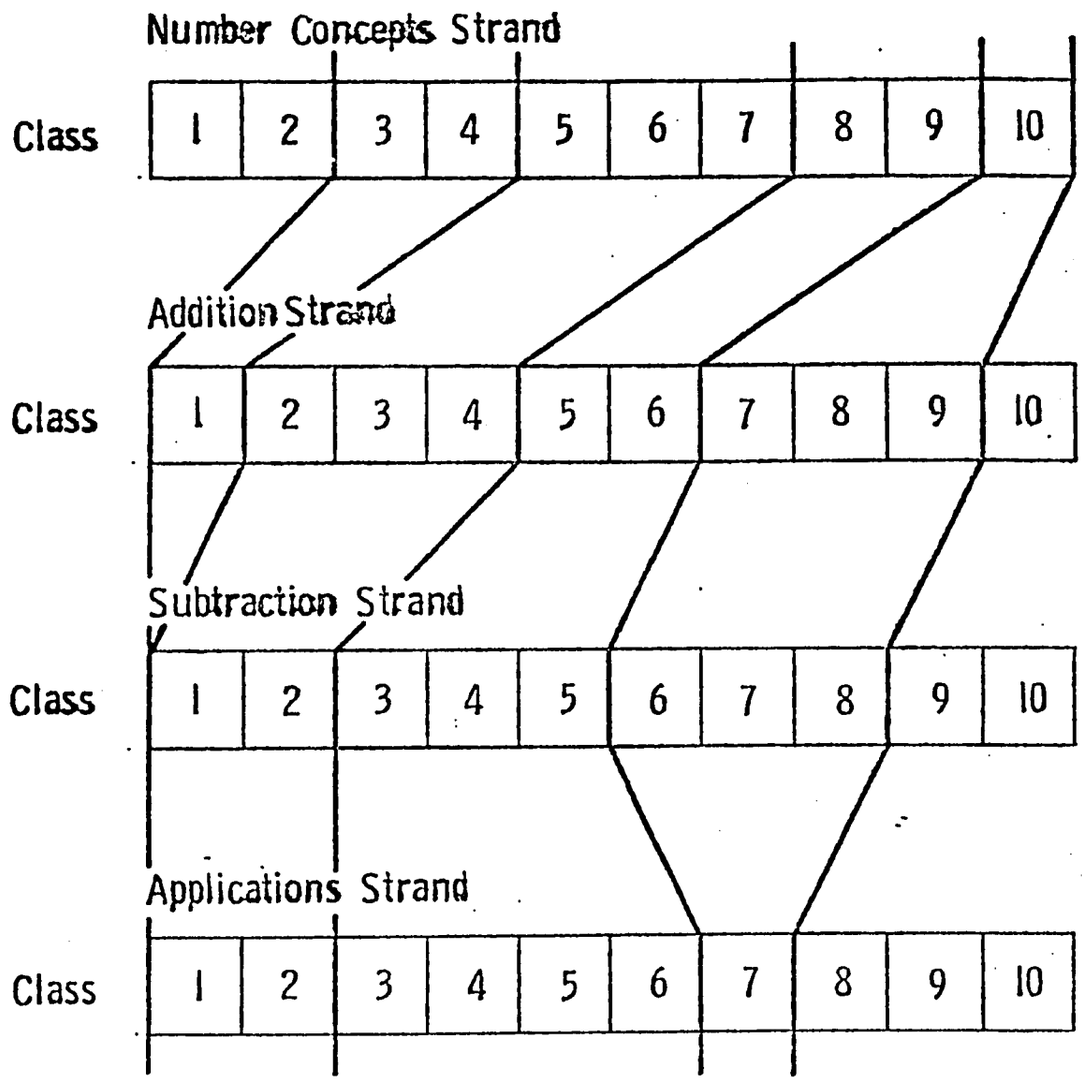

Figure 3. Strand structure showing interrelationships.

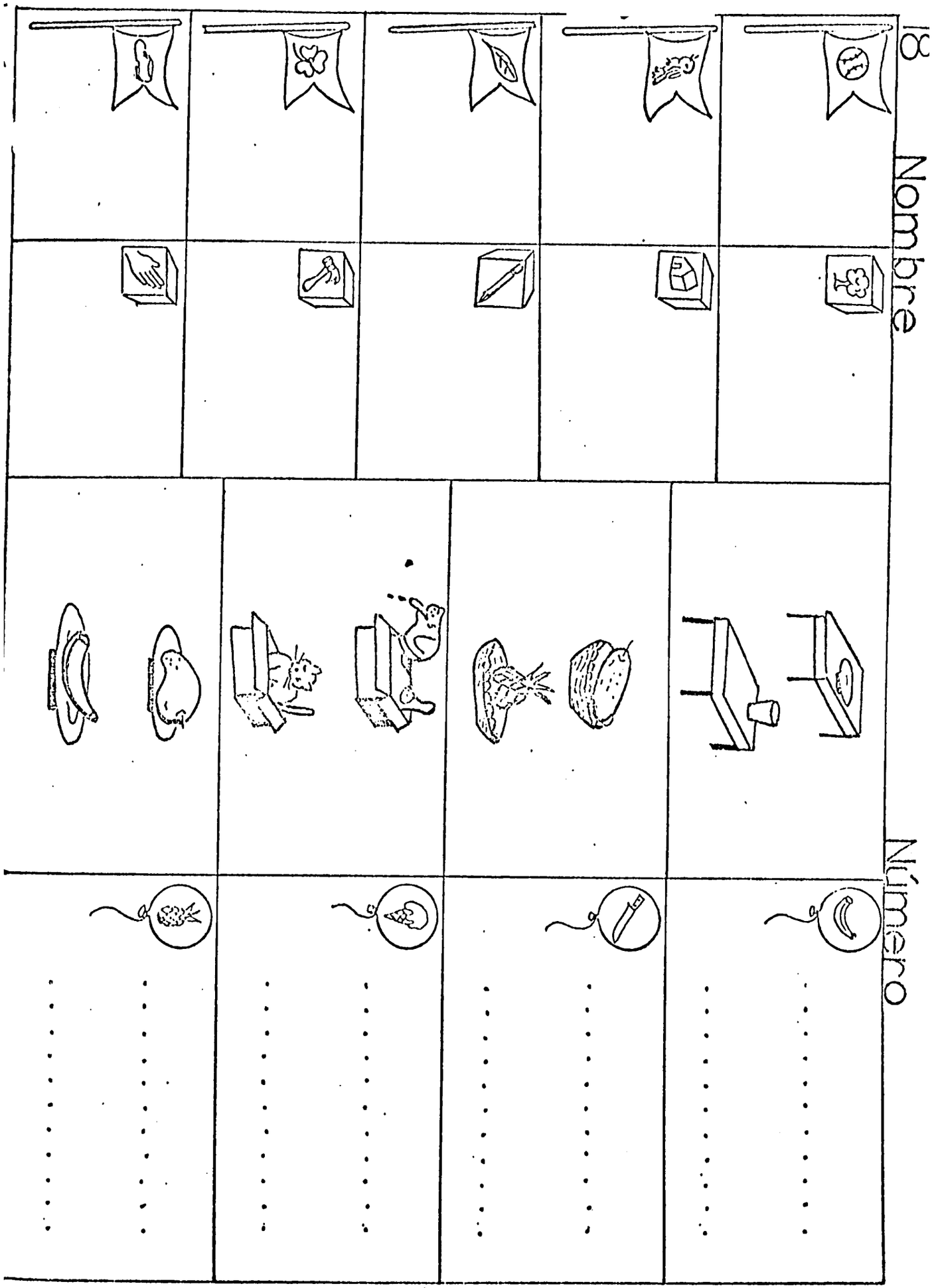

Figure 4. Side 1 of worksheet for Lesson 18.