DOCUMENT RESUME

ED 100 307 IR 001 392

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TITLE	Instructional Radio: The Nicaraguan Connection.
INSTITUTION	Stanford Univ., Calif. Inst. for Mathematical Studies in Social Science.
SPONS AGENCY	Agency for International Development (Dept. of State), Washington, D.C.
PUB DATE	19 Nov 74
NOTE	28p.; Paper presented at the National Association of Educational Broadcasters Annual Conference (50th, Las Vegas, Nevada, November 19, 1974)
EDRS PRICE	MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS	Arithmetic; *Curriculum Development; *Developing Nations; *Educational Radio; *Elementary Grades; *Mathematics; Program Descriptions; Teaching
IDENTIFIERS	*Nicaragua; Radio Mathematics Project

ABSTRACT

The Radio Mathematics Project is being undertaken in Masaya, Nicaragua, to assess the feasibility and effectiveness of radio as the medium of instruction for primary school mathematics in the developing nations. The curriculum is based upon a series of segments, each of which contains several conceptual or topical strands. Thus, for example, one segment of the first-grade curriculum contains four strands, Number Concepts, Addition, Subtraction, and Application. Behavioral objectives are established for each strand. Student responses are both oral and written. Class observation and pupil response data will be used to revise the lessons currently being tested. Each segment will be considered individually and in relation to the entire curriculum. Preliminary work is underway in the analysis of lesson scripts. The dimensions of the broadcasts to be analyzed are: (a) attitude of the sender, (b) expected behavior of the receiver, (c) language and codes through which the message is expressed, (d) the subject of the message, (e) the contact established between the sender and the receiver, and (f) the form of the message. (DC)

INSTRUCTIONAL RADIO:

THE NICARAGUAN CONNECTION

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Paper presented at the Fiftieth Convention of the National Association of Educational Broadcasters

Las Vegas, Nevada

November 19, 1974

I am going to talk today about a research project funded by the Agency for International Development (AID) and being carried out by the Institute for Mathematical Studies in the Social Sciences (IMSSS) at Stanford under the direction of Professor Patrick Suppes. The project concerns the use of radio for classroom instruction in a developing country. The Agency for International Development, primarily through its Technical Assistance Bureau, has been involved in the evaluation of several projects concerned with using television for instruction. Although television has been shown to be an effective instructional medium, its high cost is a barrier to its adoption in many developing countries. Radio, because of its lower cost, is gaining increased attention as an alternative to the use of television. Over the next decade, the Technical Assistance Bureau of AID plans to sponsor a series of studies on the use of radio for both formal and nonformal education. Our project is the first of these.

We have chosen to experiment with instruction in mathematics, typically a difficult primary school subject, and one in which teachers are likely to be poorly trained. We plan to present daily mathematics lessons broadcast directly into classrooms. Children will listen to the broadcasts under the supervision of the classroom teacher. The children will be asked to respond, both orally and in writing, during each broadcast. After the broadcast they will be asked to do further work under the supervision of the teacher. All of the student activities will be described in guides prepared for the teachers. Written responses both during and after the broadcast will be made on worksheets prepared by the

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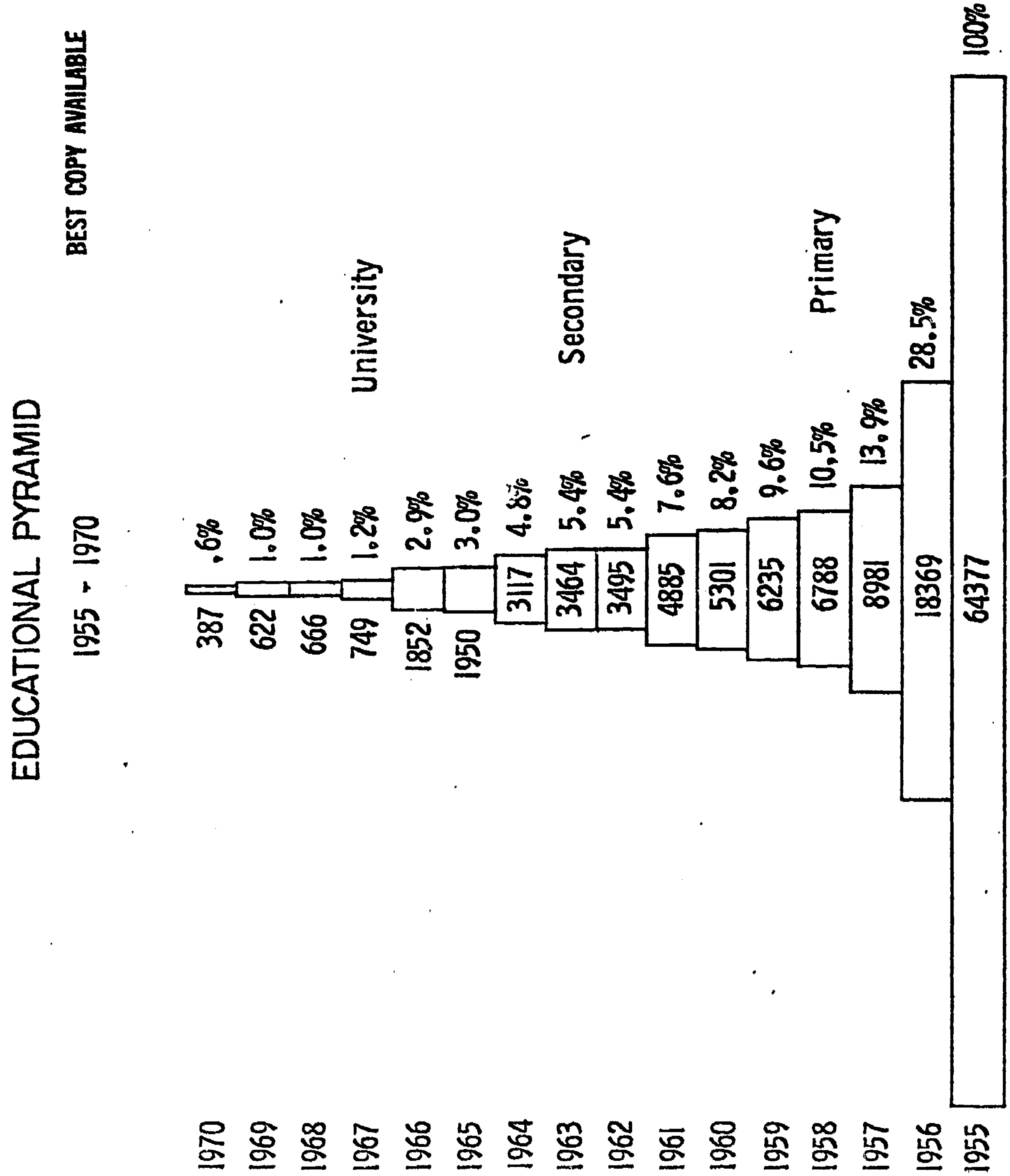

Figure 1. Educational pyramid for Nicaragua, 1955-1970.

in 1957. By the sixth year of primary school in 1960, only 8.2 percent of the original first-graders remain in school.

The educational pyramid shown in the figure represents primary school attendance patterns of the 1950's. In Nicaragua the situation has improved in recent years. Of the children who started first grade in 1970, 54 percent were in second grade in 1971. Thus, in 1956 only one-fourth of the first-graders entered second grade, whereas in 1971 more than half of the first graders continued to second grade.

One of the aims of educational reform in developing countries is to decrease the steepness of this pyramid by increasing the holding power of schools. The goal is to assure each child a full primary education. Another thrust of educational reform is to improve the quality of education at each level, and particularly in the early primary grades. If children will be in school for only one or two years, they have only a short time in which to acquire basic literacy and arithmetic skills. Much current research is directed toward finding ways to teach these skills efficiently and well. It is this problem of teaching more effectively that is primarily addressed by our study.

The Department of Masaya, where the project is located, has one large and several small municipalities. The total primary school population is close to 18,000. Approximately two-thirds of the children are in urban schools, the remainder in rural schools. Class size ranges from 15 to 60, with rural schools frequently having more than one grade in a classroom. Supplies and materials are scarce; the Ministry of Education provides a blackboard for each classroom, and at the beginning of the school year, a box of chalk for each teacher, but no money. Funds for everything else, including cleaning supplies, must be raised by the school from its own community. The children usually spend three or four hours a day in school. They provide their own writing supplies and, where they have them, textbooks.

The classrooms of Masaya are not well designed for good radio reception. In many cases there are only partial walls between classrooms. Urban schools are often located in buildings next to busy streets and traffic contributes considerably to the noise level. The rural schools are more isolated, but frequently have students from several grades in the same room. We will be investigating the degree of difficulty imposed by noise conditions. We do not anticipate trying to make any special arrangements for listening rooms, but will concentrate on adjusting the broadcasts to adapt to the school setting as it presently exists.

Another obstacle to the effective use of radio is the high absentee rate. Attendance at school tends to be irregular, and quite low during times of peak agricultural activity. At these times children are needed at home to help plant or harvest. Because of limitations of radio time, we will not be able to rebroadcast lessons. We will work toward building redundancy into radio lessons, so that important concepts and skills are taught more than once. We will also provide materials for teachers to use in helping students make up for missed broadcasts.

The project began operations in Nicaragua this past June when we opened an office in Masaya. The initial professional staff consisted of three North Americans and two Nicaraguans. The two Nicaraguan staff members recently completed a revision of the primary school mathematics curriculum for the Ministry of Education and are highly qualified collaborators. Several more Nicaraguans have since joined the staff. The Nicaraguan school year ended in mid-November. During the last few months staff members have gathered data about schools and students and visited classrooms. They have developed a preliminary version of an achievement test for first-grade students and have administered it to approximately 1200 students. They have also prepared several radio lessons, which have been pilot tested in classrooms (using cassette recorders) and extensively revised.

During the next school year, which starts in February, 1975, lessons will be developed covering the entire first-grade curriculum. These lessons will be presented daily by tape in a small number of classrooms. Each lesson presentation will be observed by a project staff member, and student response data will also be collected and analyzed. The lessons will be further revised where necessary, and during 1976 they will be broadcast to approximately fifty first-grade classrooms. During 1976, along with broadcasting of first-grade programs, lessons for second grade will be developed and pilot tested.

The project will use the broadcasting facilities of a small private radio station located in Masaya. At the request of the Minister of Education, the station has agreed to make time available to the project. I might note at this point that we have been received enthusiastically by both national and local school authorities, and their cooperation has helped make it possible for us to begin working in the field with more speed than is perhaps characteristic for such projects.

I would like to turn now to the first of my three main topics, how we plan to structure the mathematics curriculum and incorporate that structure into daily radio lessons. There are two fundamentally different ways to construct lessons. The first is to devote each broadcast to a single topic. The second method is to include several different topics in each broadcast. For several reasons we have chosen the second approach. We have found in our work with computer-assisted instruction (CAI) that children perform well on lessons containing different types of problems. The research literature shows that children learn better when instruction and practice is distributed over many sessions than when practice is massed. Furthermore, presentation of several topics within a lesson allows the curriculum designer more flexibility in the amount of time, and the degree of emphasis given to each topic.

The procedure for constructing a single lesson starts with the organization of the curriculum for the entire school year. As will be described below, the curriculum is divided into successively finer units. The smallest unit, which will ultimately be incorporated into a lesson, we refer to as a segment. The script is written only after the mathematical content has been fully specified.

I will illustrate the process of constructing lesson segments with the first-grade mathematics curriculum. We begin the process of segmenting the curriculum by dividing the topics covered into strands. There are several different ways we might divide the curriculum into strands. Let us choose to use four strands, Number Concepts, Addition, Subtraction, and Applications. A partial list of the contents of each of these strands is shown in Figure 2.

For each strand a set of behavioral objectives is formulated that defines 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. Each

FIRST GRADE MATHEMATICS CURRICULUM STRANDS

Number concepts

Counting up to 100
Place value - units and tens
Which number is larger, smaller
Which number comes after, before
.....

Addition

Basic facts
Algorithms - one and two column problems without carrying
.....

Subtraction

Basic facts
Algorithms - one and two column problems without borrowing
.....

Applications

Money
Time
Relations - larger, smaller
nearer, farther
taller, shorter
.....

Figure 2. Sample content of strands comprising first grade mathematics curriculum.

objective 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 5 or less, the second might use from 6 to 10 objects, and so on. Thus, the next step in curriculum preparation is to break each objective into a series of subobjectives. These subobjectives, or classes of problems, must then be put in order so that for any given concept or problem type, all those prerequisite to it come earlier in the instructional sequence.

Figure 3 shows a hypothetical strand that has three terminal objectives. The first of these has three subobjectives, A, B, and C; the second, four; and the third two subobjectives. These have been arranged in what might be a typical order. The ordering is determined by the subject matter specialist. In the case of first-grade mathematics, we have good criteria for determining an appropriate ordering. 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 CAI courses. We have collected over the years a large body of performance data which provide information on the relative difficulty of problem types and furnish additional guidelines for the ordering of subobjectives.

Let's see where we now stand in the process of curriculum development for the first-grade mathematics course. For each strand we have now broken down objectives into subobjectives. Each subobjective determines a set of problems which the student must learn how to work

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 3. Structure of a hypothetical strand.

or respond to correctly. We call the group of problems corresponding to a subobjective a class. The classes of problems are then put in an order appropriate for instruction. This strand structure is illustrated schematically in Figure 4. Within each strand we have ordered the classes so that all problem types that are prerequisite for a given class are to its left in our schematic ordering.

Now we must note that the strands are not independent. There may be classes in one strand that are prerequisites for classes in another strand. Thus, the interconnections between the strands must be established. How this might look is shown in Figure 5. In the example illustrated here, 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.

We now have the mathematical content of the curriculum laid out, but the diagram represents each class of problems only once. For each class, students must be taught how to perform the task, they must be given the opportunity to practice it, and then, later, they need further opportunities to review it. When we actually construct the instructional sequence for the strand, each class will appear three or more times, for these different instructional tasks.

The classes of problems as I have described them do not specify the mode of student response. Students may be asked to give their answers orally or to write them on the worksheets. (We could, of course, formulate the objectives so that they include the mode of student response.) In addition, we have not yet specified the context within which each task will be presented to children. We might embed a task

DIAGRAM OF THE CLASS STRUCTURE OF STRANDS

First Grade Mathematics

Number Concepts Strand

Class	1	2	3	4	5	6	7	8	9	10

Addition Strand

Class	1	2	3	4	5	6	7	8	9	10

Subtraction Strand

Class	1	2	3	4	5	6	7	8	9	10

Applications Strand

Class	1	2	3	4	5	6	7	8	9	10

Figure 4. Diagram of the class structure of strands.

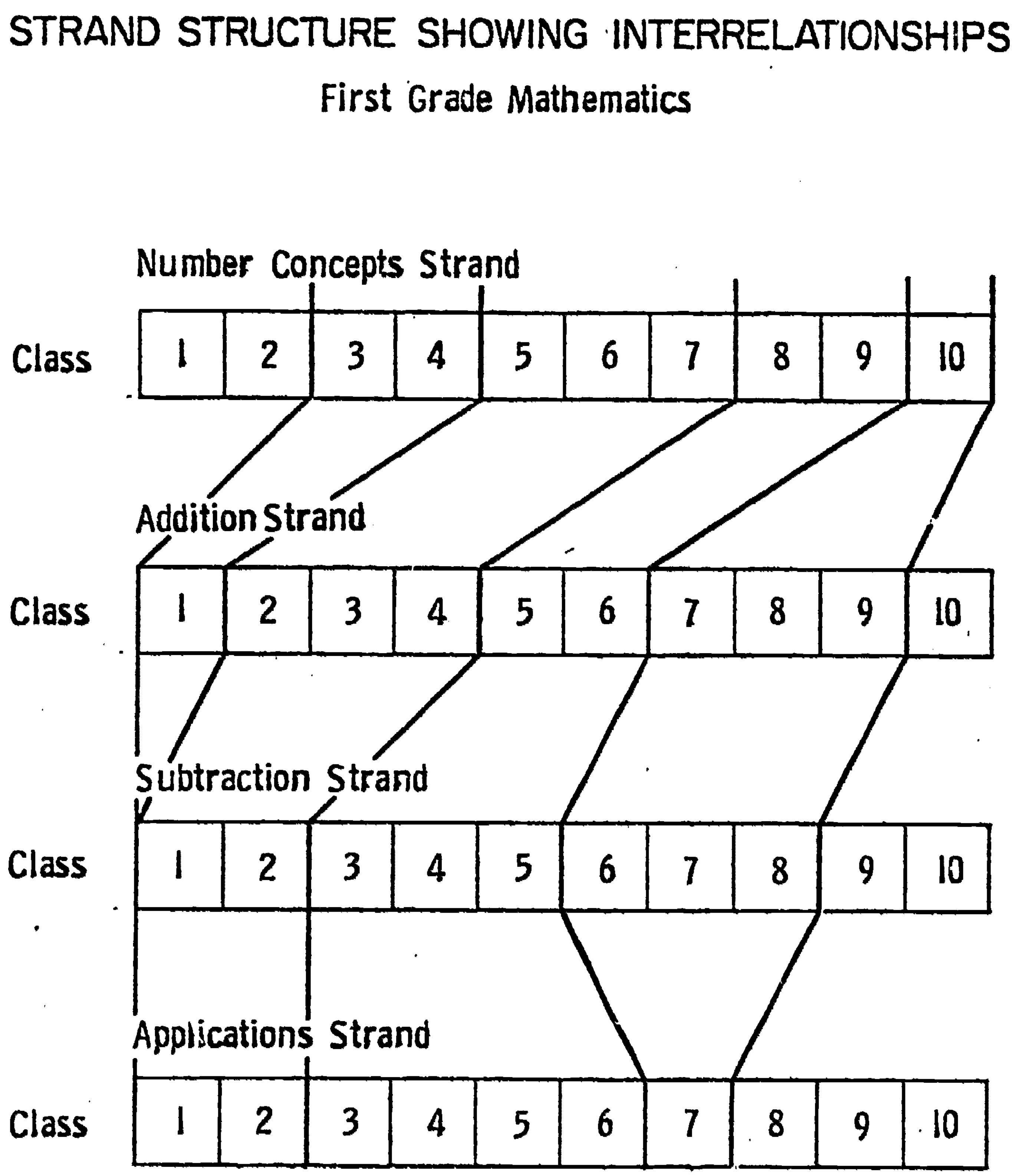

Figure 5. Strand structure showing interrelationships between strands.

within a story; we might use a realistic situation familiar to the children; or we might simply present a mathematical statement and ask for a response (for example, how much is two plus two).

To summarize, we must augment the strand structure pictured here so that each class appears at least once for teaching, once for practice, and once for review. In addition, we must specify the mode of presentation and the student response mode. When we do this we have the skeletons from which we build a radio script. Typically, for each lesson from four to seven skeleton segments are selected from several different strands. There will probably be at least one segment devoted to each type of presentation: teaching, practice, and review. The curriculum designer writes detailed specifications for each segment and these are given to the script writer who prepares a radio script.

The next two figures illustrate the type of specifications the curriculum designer prepares for the script writer. The example describes a segment of one of the lessons now being pilot tested. The students for whom the lesson is written have never listened to school broadcasts before, and most of the tasks are designed to help them learn to listen and respond appropriately and to follow their worksheets. In this case, the task is to identify pictures of common objects, and the purpose of the segment is to give practice in using a multiple choice answer format.

Figure 6 gives some general information about the segment. The strand and class are identified, the type of student response required is specified, and the type of exercise is described. Figure 7 presents further details, including the exact content of the exercises, and the response time allowed for each exercise.

The student worksheet for the lesson segment we are discussing is

DESCRIPTION OF LESSON SEGMENT : PART I

Segment: 2 Version: I Strand: APP Class: I

No. of exercises: 5 Analysis of data: yes or no

Title: Identifying common objects, multiple choice. Broadcast.

Contents and/or example:

3 selections, one of which will be asked for by the radio teacher

"Circle (the item named)"

Presentation: Radio or Teacher or Both

Response Mode: Oral or Written

Individual work or Group work

Responses on worksheet: Numeral or Multiple choice or Other

Figure 6. Description of lesson segment, part 1.

DESCRIPTION OF LESSON SEGMENT: PART 2

Exercise No.	Content	Correct answer given?	Correct answer
1.	Socks, hat, woman's shoes	No	C
2.	Ring, watch, bracelet	No	B
3.	Slacks, skirt, dress	No	C
4.	Ring, hair ribbon, earring	No	B
5.	Hairbrush, mirror, bottle of perfume	No	B

Response time: 5 seconds each response

Notes to the script writer:

Exercises can be set in a story.

First multiple choice answers.
Explain how to find proper exercise.
Explain how to mark answers.

Notes for the teacher's guide:

1) Goal: To teach the children to use the multiple choice format, in which they mark the correct answer. To help develop listening ability.

2) Suggestions to the teachers: (none)

Figure 7. Description of lesson segment, part 2.

shown in Figure 8. The pictures shown here are those described in the specifications in Figure 7. In the current version of the script the radio teacher describes these objects as gifts and asks the children to circle the appropriate present in each set of three.

The script writer has the responsibility for integrating the mathematical content from several segments into a coherent presentation. We have experimented with two methods for doing this. The first method uses a series of lessons written using a single story line. In our trial lessons the story concerned an adventure to the 'enchanted world of mathematics'. The writer describes the story as, "a fantasy of mishaps and adventures filled with mystery and at times humorous events." She continues, "Throughout, the mathematical exercises and activities are interwoven into the story; often the children's response is used as a way to rescue one of the characters." The story line provides a central theme that continues from one lesson to the next. Usually, an episode is left unresolved at the end of a lesson, and provides the beginning point for the next lesson. The second method we have experimented with uses short stories and episodes, usually several within the same lesson. The stories are independent units and do not carry over from one lesson to another.

We expected the first type of organization, with the continuing story line, to be more successful. We thought the children would enjoy the story and that their interest in the story would increase their attentiveness to the mathematical tasks. In pilot testing in two settings--in the United States and in Nicaragua--this prediction has not been borne out. Rather, children appear most engrossed and attentive when they are actively responding, either orally or in

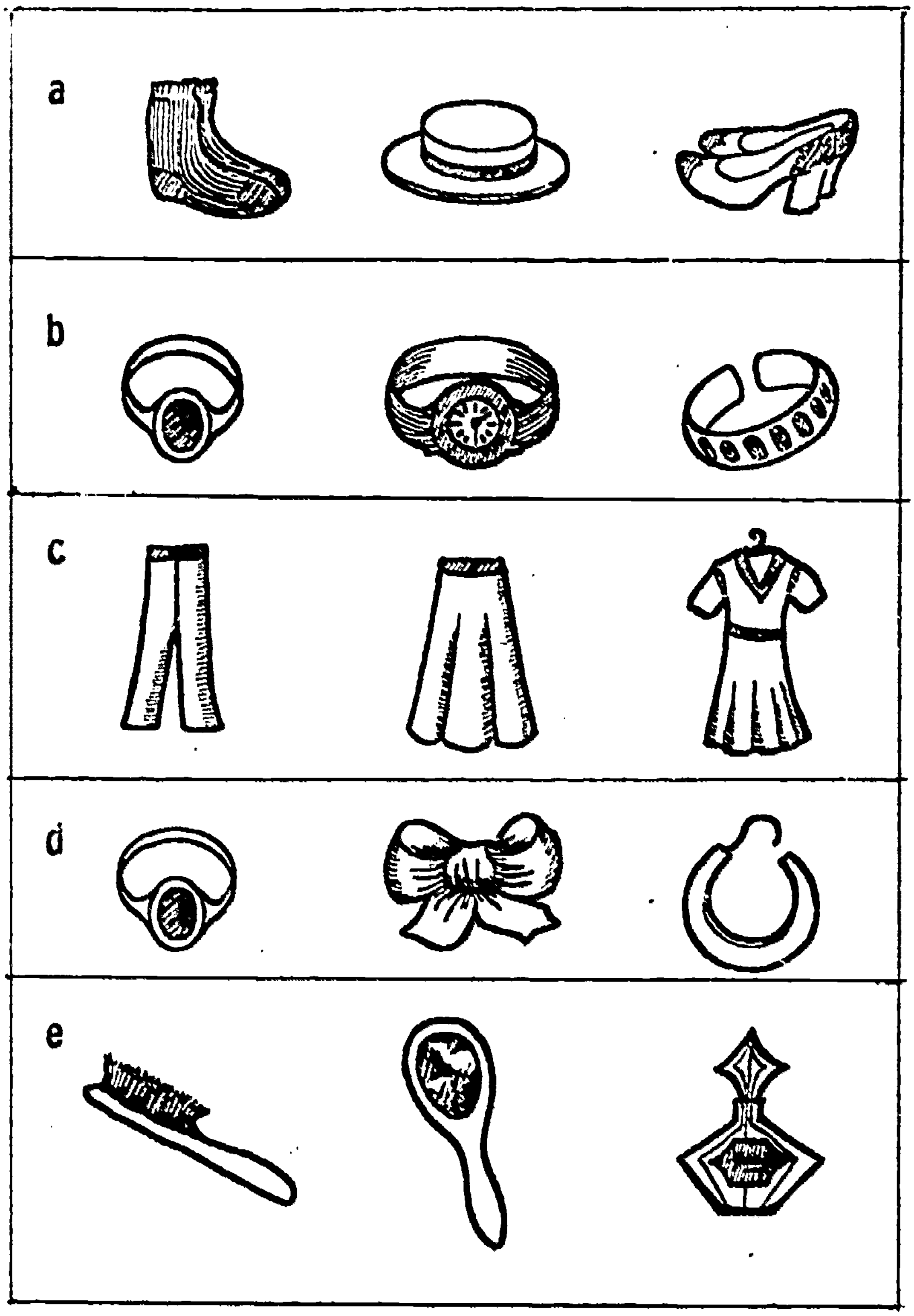

Figure 8. Sample worksheet for one lesson segment.

writing. We are aware that children naturally look more animated when they are doing something than when they are just sitting, and that children who do not appear to be attentive may be listening and absorbing material. However, the purpose of the story when it is used is to support the mathematical tasks, and our evidence to date clearly indicates that children will respond, and appear to enjoy themselves, without the encouragement of a supporting story. I want to make clear that the crucial aspect of this finding is that students are called upon to respond actively during the broadcast. At present we are constructing lessons so that children are responding either orally, physically, or in writing on the average of every 15 to 20 seconds.

We consider revision of lessons to be a central part of our development effort, and I will turn now to my second topic, our plans for using observation and response data in the process of lesson production. As I mentioned earlier, we plan to pilot test each lesson with a small number of classes before it is broadcast. We expect to obtain information about the lessons in essentially three different ways. I will describe in turn the use of observational data, student response data, and test data.

During the initial stages of lesson production, observations are likely to provide the most useful information about the suitability of the broadcasts. Here are some of the things we watch for:

a. Do the children seem attentive during the program? Is their attention focused on the program, or are there diversions?

b. When the program asks the students to respond as a group, do they respond, and if so, do they respond appropriately? Does the task seem appropriate for them, that is, does it seem that most of the children respond simultaneously or are there a few strong leaders and many followers? How much encouragement is needed from the teacher to get a group response?

c. When the program asks the students to use their worksheets, can they find the right place to put their answers? Are they using the correct side of the worksheet, the correct section, the correct space?

d. Are the worksheet exercises appropriate? Do the students seem to be able to work on their own or do they copy from one another or need help from the teacher?

e. Is there enough time allowed for the responses?

f. What is the noise level? Can the program be heard?

g. When the program has a story line, do the students understand the plot? The answer to this question may not be clear from observation, so classroom observers talk to students and the teacher about the story after the program has been played.

The observers also watch the post-broadcast activities to see if the children can do the exercises, the degree of help they need from the teacher, the time required, and whether the teacher can successfully supervise the activities after having read the instructions in the teacher's guide.

Next the responses on the student worksheets are examined. We calculate the average percentage correct for each exercise. Is that percentage in the right range? Over 90% correct usually indicates that an exercise is too easy, under 80% correct that it is too difficult. The interpretation of these percentages must be tempered by the observations made in the classroom. An exercise may show a high percentage correct because the teacher has told the children the answer, or a low percentage correct because a truck went past the room as the exercise was presented. We next compare the percentage correct for all the exercises in a segment. We expect a slight increase in percentage correct from the first exercise in the segment to the last. If performance on any exercise is far out of line--either much higher or much lower than the mean for the segment--we look for causes, which may be in the exercise content or its presentation.

We look at student scores for each segment to find if they cluster satisfactorily or if there are a large number of students with zero scores or with perfect scores. It is best if only a few students get perfect scores. A large number of zero scores may mean not that the exercises are too hard but rather that the students do not understand how to respond or did not understand our explanation of the task.

We then look at the frequency list of wrong answers. If the diversity of wrong answers is very low we know that many students are making the same wrong responses. An inspection of the most frequent wrong responses may give us a clue about the source of the difficulty. On the other hand, if there are many different wrong answers, we suspect that there is confusion over the task itself, and students do not understand what they are being asked to do.

The type of revision proposed for each lesson depends on a joint analysis of the observational data and the response data. When the level of student performance falls outside the limits of 80-90 percent correct for an entire segment, we may decide that the segment is inappropriately placed in the curriculum, and place it either earlier or later. We may conclude that a task is appropriately placed but has not been presented clearly, and hence the instructional message must be revised. When performance on a single exercise within a segment falls outside the desired limits we look first to see if the exercise uses the same task as the others in the segment. It may happen that a set of exercises we thought of as homogeneous actually separates into two groups, one harder than the other. If the exercise set seems homogeneous, we suspect that some special aspect of the exercise presentation is making it unusually easy or difficult.

We plan to insert short tests into the lessons at intervals of one or two weeks. These will measure performance on topics that have been presented earlier in the instructional program. They will tell us whether students are retaining skills they have learned earlier and will indicate areas where reteaching or more practice is needed.

I will turn now to my third topic, an analysis of the broadcast message. We have just recently begun work with Osvaldo Kreimer of the Institute for Communication Research at Stanford University. Kreimer, building on work by Roman Jakobson, differentiates six components of the broadcast message as shown in Figure 9. These components are elements or parts of the message that refer to, (a) the attitude expressed by the sender of the message, (b) the expected behavior of the receiver, (c) the language and codes through which the message is expressed, (e) the contact established between the sender and receiver, and (f) the form of the message.

Let's look at each of these briefly, as they relate to the lessons being prepared in Nicaragua. The radio characters represent for the student the authority that has produced them. Thus, the attitudes of the radio characters towards classroom teachers, students, and mathematics are likely to carry great weight with the students. These attitudes may be expressed directly through opinions and judgements

ASPECTS OF BROADCAST MESSAGE

1) Attitude of sender
2) Expected behavior of receiver
3) Language and codes of message
4) Subject of message
5) Contact between sender and receiver
6) Internal structure of message

Figure 9. Aspects of the broadcast message.

of the characters. They may also be conveyed by the roles assigned by the radio cast to the teacher and to the student. The classroom teacher may be portrayed as a source of information, as an authority, as a person with status equal to that of the radio teacher, or perhaps may be cast in a more dependent role, as subservient to the cast of radio characters. Similarly, the students may be addressed as active participants in the radio presentation, or in a more passive role as listeners and observers.

The attitudes of the sender are closely linked to the behaviors expected of the receivers. The expected student responses will probably vary from imitative behavior and following instructions to autonomous or innovative responses, and will call for individual and group work. In what proportions will these various types of responses be required? We would hope that the mix of expected responses will contribute to the student's view of himself as capable and active, rather than incompetent, or dependent.

The language and idioms of the radio characters convey attitudes towards people of different status and social class. When all the characters speak with the tuning and pitch of city people, the idea of the central city as the source of knowledge and prestige is reinforced. The introduction of voices with the typical accents of different regions of the country, at the same level as the main characters, can help both in the identification of the students with the characters and in the increase of self-esteem.

The purpose of each of the broadcast lessons is to teach. However, each lesson contains not only didactic material but the contextual material within which the instructional message is embedded.

An important and difficult aspect of lesson construction is to make the contextual material supportive of and consonant with the instructional material. Perhaps an example will make clear what I'm driving at. We might, in a lesson concerned with addition, have a character called Mr. Adding, or Captain Plus, who always tries to put similar things together. Thus, we personify the abstract element--addition--using the analogy between the characteristics of the 'person' and the characteristics of the abstract element. In this way, the story line, the context within which the instruction is presented, supports the instructional intent of the lesson.

Maintaining contact between sender and receiver is a major problem for broadcast messages where no immediate feedback can check for the existence of contact, and where there is no direct control over the attention of the receiver. We are experimenting with ways of establishing a form of dialogue with students. With care and sensitivity in choosing the radio questions and responses, the students can get the impression that the radio is listening to them. Our goal is to have the radio characters speak to and relate directly to the children, rather than carry on dialogue which is merely overheard by the children.

We can gain a more complete understanding of the effect of a message if we examine the way the form of the message relates to its content, that is, the way in which the message is structured. The function of supporting the intent of a message through its structure is called the poetic function. Using Paul Valery's words

> The primary characteristic of ordinary language is that as soon as it is understood it vanishes, being replaced by the impressions, ideas, acts, etc. which it conveys... The particular quality of poetic language is that it lasts. In poetry, both form and impression remain...

Kreimer's model provides an operational definition of the poetic function. It makes possible an analysis of the poetic qualities of a message and the extent to which these support the content of the message. As an example let's look at the way Sesame Street treats the concept of exclusion. Compare the statement, "of these things, one is different from the others and doesn't belong" with the rhythmic

> one of these things is not like the others
> one of these things just doesn't belong,

with the phrase, "doesn't belong" stretched out to emphasize the exclusion. The poetic effect can be sought after not only at the level of the sentence or paragraph, but also in terms of larger units and even the whole lesson. We might make an analogy to how a symphony is structured, each part developing the basic themes and adding new elements, but also keeping an overall balance and rhythm. We want to improve the effect of our lessons--in terms of attention, enjoyment, and recall--and will use Kreimer's method of analysis to become more aware of how we can improve the poetic quality of the lessons.

Let me summarize briefly. In the Radio Mathematics Project we have accepted the challenge of assuming the major instructional burden using the medium of radio. The lessons we are preparing are not intended to be supplemental or motivational, but, with the support and cooperation of the classroom teacher, are designed to teach mathematics, to primary school children. I have discussed some aspects of the translation of curriculum material into instructional messages. I have stressed our concern with the rational and systematic organization of the didactic material. I have discussed our plans for obtaining frequent feedback to provide guidelines for the continuing development of lessons. And lastly, I have indicated some of the aspects of the broadcast message that we will be attentive to during the course of our work.

Our project has just barely started. I hope in the future to have an opportunity to give you a progress report, to let you know how this is all working out.