The Nicaragua Radio Mathematics Project

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Introduction
The use of radio for instructional purposes has a long history, yet the number of studies directed toward the development and improvement of instructional techniques appropriate for radio is relatively small. Responding to the growing use of instructional radio in developing countries and the need for research, the Technical Assistance Bureau within the division of Education and Human Resources of the United States Agency for International Development (AID) has provided funds for research on improving the effectiveness of teaching by radio in the primary grades. Under the aegis of AID, the Institute for Mathematical Studies in the Social Sciences at Stanford University has initiated a project to teach mathematics by radio in the lower primary grades and is presently working in Nicaragua.

The 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, (instructions are provided 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. Work sheets are distributed by the project. Teachers are asked to supply simple materials, such as bottle caps and sticks and the project occasionally provides other supplementary materials such as rulers printed on cardboard. The focus of our research is how best to use these limited resources—the radio, a worksheet, a teachers' guide, some simple materials—to teach mathematics effectively.

Among the various technologies of instruction now being used around the world, ranging from programmed instruction booklets to color television and computers, a good case can be made that radio is the most economical for mass distribution of instruction. For the Radio Mathematics Project the most significant contribution to the cost per student is that of the supplementary materials used with the radio instruction. We intend to search for ways of reducing the level of support materials that accompany the broadcasts in order to lower still further the instructional cost per student.

In discussing the current project we have found some scepticism that mathematics can be effectively taught by means of radio. It is a primary purpose of this project to test this hypothesis. The success of this experiment would be of some importance because of the low cost of radio technology. If good achievement results can be obtained then the cost-benefit ratios for radio in the case of teaching primary school mathematics may be the best of any of the feasible technologies, including even traditional instruction with adequately trained teachers.

Location of the project
The project is located in the Department of Masaya, an area close to Managua, the capital city of Nicaragua. The department has one large and several small municipalities. The total primary school population is close to 18,000, with approximately two-thirds of the children in urban schools and the remainder in rural schools. Class size ranges from 15 to 60, with rural schools frequently having more than one grade in a classroom. Roughly 30% of the urban and 50% of the rural school population is in first grade. Children attend school for three to four hours a day during a school year that extends from mid-February to mid-November. Student performance is evaluated at the end of each school year by final tests constructed by the teacher or school. Students who fail more than two subjects are held back; those who fail one or two subjects may be re-examined before the start of the next school year. Most teachers in the department are school graduates (with five years of post-primary education) and they are, on the average, better qualified than teachers in areas more remote from the capital.

The project chose to work in the Department of Masaya because of its geographical compactness and its proximity to Managua and because of the enthusiasm and co-operativeness of the Departmental Inspector, whose support has greatly facilitated our work with the schools.

Overview of a mathematics lesson
Each mathematics lesson consists of two parts, the broadcast portion and the teacher-directed portion, with the broadcast designed to be presented first. Before transmission each child is given a worksheet on which to write his name and student number; a task which 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, forty to fifty times during each twenty-minute lesson. Sometimes children handle concrete materials during the broadcast, for example, counting or grouping bottle caps. 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 directions given in the teacher's guide. Usually children continue working on the worksheet during this portion of the lesson. When the lesson is completed the worksheets are collected and returned to the project for analysis.

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 might include the following:
1. Instruction is more effective when children respond actively.
2. Reinforcement—knowledge of...
results—increases rate of learning.
3. Children’s thinking progresses from the concrete to the abstract and therefore practice with concrete materials facilitates learning.
4. Practice is more effective when distributed over many sessions rather than concentrated in fewer, longer sessions.
5. Children learn at different rates.
   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
We distinguish at least three types of responses which we ask of children. They may speak aloud, they may write, or they may move. For each of these an observer can determine whether a child is responding. (There is a fourth type, which we do not use since responses cannot be observed, 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 programme 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 genuine 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 directly, 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?

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. Almost all 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 that the radio characters ask of the children. They may play games—one game has the children patting their knees, their shoulders, 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 in multiple-choice format 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 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 radio 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, 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, are not needed for maintaining interest level.

Reinforcement
We have experimented with various methods for providing children with knowledge of results. In a pilot test of five recorded lessons, using Californian 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 answers but with exercises presented orally this procedure gives no reinforcement 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 don’t 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 not widespread and therefore not familiar 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 so each teacher must be responsible for their provision.

Problems of an entirely different sort arise when children are asked to handle materials themselves. Bottle
caps 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 (never 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 first graders are able to count to five when they start school. We are at present undecided about continuing the use of these materials during the radio lesson. We felt that the use of fingers (although currently out of favour 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 practised regularly to be maintained, and that frequent practice at regular intervals is superior to infrequent, concentrated sessions. For this reason we have developed a lesson structure that provides for the inclusion of several different topics in each lesson, as well as different types of activities and different modes of responding.

A lesson is constructed from segments, each of which is based on a small bit of curriculum. (The construction of the curriculum is described in a later section.) Each segment description specifies the exercises, the method of presentation, and the kind 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 below.

**Segments**

**Radio**

1. **Show the addition facts 2 + 2, 3 + 2, 4 + 1, 1 + 2 using fingers.** “How much is 2 plus 2?”
2. **Rote count from 1 to 20, two times.**
3. **Give successors orally for 5, 8, 7, 9, 10.** “What number comes after 5?”
4. **Write numerals from dictation.** “Write the number 4 (3, 5, 2, 6).”
5. **Write the successors to 2, 1, 4, 3, 1.** “Write the number that comes after 2.”

**Oral drills**

1. **Sound drill**
   - Listen to the teacher and repeat after her.
2. **Phonetics**
   - Listen to the teacher and repeat after her.
3. **Rhyme**
   - Listen to the teacher and repeat after her.
4. **Story**
   - Listen to the teacher and repeat after her.
5. **Counting**
   - Listen to the teacher and repeat after her.
6. **Ordinal numbers**
   - Listen to the teacher and repeat after her.
7. **Addition**
   - Listen to the teacher and repeat after her.
8. **Subtraction**
   - Listen to the teacher and repeat after her.
9. **Multiplication**
   - Listen to the teacher and repeat after her.
10. **Division**
    - Listen to the teacher and repeat after her.

**Written drills**

1. **Reading numerals from 1 to 7 (printed on worksheet).** “Circle the 3 (6, 2, 4, 7, 5).”
2. **Read numerals 1 to 9 on cards (prepared by teacher).**
3. **Count objects, from 1 to 10 (materials chosen by teacher).**

This outline 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 above (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. Segments are not delineated in the lesson script and writers are encouraged to embed the mathematics in story contexts in those lessons where stories are used.**

**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 regular tests incorporated in 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 observers’ and teachers’ reports to investigate this.

We have given some thought to ways of providing a range of levels of instruction to different children during broadcasting. In our testing programme we developed exercises that had a variety of printed materials associated with a single set of verbal instructions, allowing children who were listening to a common set of instructions to work on different exercises. We think this method holds promise for allowing children to practise skills at a number of levels of difficulty. Providing post-broadcast materials suitable for mixed-ability classes would also contribute to differentiating instruction.

**Structure of the curriculum**

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. Vitallia Rojas de Vrooman who is now Nicaraguan Director of the project. Some changes in emphasis and some reorganization have proved necessary
in structuring the radio lessons but in general the content of project lessons meets the national specifications.

The process of obtaining lesson segment descriptions from the rather general curriculum specifications of the Ministry of Education curriculum guide involves several steps. First, the mathematical content is divided into topics or strands. For first grade the strands are Basic concepts, Number concepts, Addition, Subtraction, Applications, and Measurement. Then, for each strand a set of behavioural objectives is formulated, defining the behaviour expected of a student who has successfully completed the first-grade instructional programme. 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 sub-objectives 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 sub-objective 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 sub-objectives, called classes. The classes of exercises 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.

We have now a series of classes specifying the material that is to be taught for each strand, 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 practise it and then, later, they need further opportunities to review it. When the instructional sequence for a strand is constructed each class appears several times, providing for these instructional tasks. The lesson segment descriptions, discussed above, are taken from these class descriptions which characterize the entire curriculum. The class descriptions may be sampled at any time to provide test items to measure student progress in attaining curriculum objectives.

**Experimental design**

Because of our interest in techniques of instruction, great care is taken in the development and pre-testing of lessons. Sixteen classrooms are participating in the pilot testing of first-grade lessons which are being developed during 1975. The classrooms are distributed among urban schools in the city of Masaya, municipal schools in smaller towns, and rural schools. Some classrooms have only first-grade students, others have students at two or three grade levels. 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 programmes for the analysis of worksheet data have been prepared by programmers at a computer centre 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.

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 and the same level of observation and data collection will be used as 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 the pilot testing year will be almost exclusively formative, focusing attention on student attainment of the project's instructional goals. Weekly tests are incorporated 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 end of year attainment of curriculum goals.

During the next year, 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 the proportion that they occur in the department. 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 pre-tested and post-tested 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 and a comparison of mathematics achievement of the two groups is therefore feasible.

As an additional method of comparing achievement the project will examine the performance of students in the end of year school tests and compare repetition rates due to failure in mathematics for control and experimental students. A more broadly based examination of drop-out rates is also planned as a component of an analysis of the economic consequences of the use of radio for instruction in this setting. We will also analyse the costs of expanding the use of radio in various ways to provide guidelines for Ministry of Education decisions about continuing the project and expanding the student base.

Experimental and empirical studies of the effectiveness of teaching by radio were recently surveyed by Jamison, Suppes, and Wells1 (1974). Although radio instruction has been used in various parts of the world for over forty years, the number of detailed studies of the effectiveness of radio, and especially detailed studies of the relation of the curriculum structure to achievement, is small. It is a primary objective of the project in Nicaragua to make a significant contribution to this literature on the effectiveness of radio teaching.

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