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PRODUCING RADIO LESSONS FOR CHILDREN

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CONTENTS

LIST OF FIGURES x

LIST OF TABLES xi

INTRODUCTION 1

PART I THE RADIO MATHEMATICS MODEL

Chapter 1. THE RADIO MATHEMATICS PROJECT 5

1. A Typical Lesson in the Classroom 6

2. Effectiveness of Radio Mathematics Lessons 14

Chapter 2. PRINCIPLES USED IN THE DEVELOPMENT OF THE INSTRUCTIONAL SYSTEM 17

1. Principles Involving the Students 17

The Principle of Student Participation / 17
The Principle of Providing Correct Answers / 18
Principle of Appropriate Exemplars / 20
The Principle of Distributed Practice / 21
The Principle of Encouraging Attention / 22

2. Principles Pertaining to Teachers 23

Principle of Reducing the Teacher's Workload / 23
Principle of Avoiding Personal Expenditures / 24
Principle of Adapting Content to Teachers / 24

3. The Principle of Integrating Feedback and Production 24

PART II DESIGNING THE CURRICULUM

Chapter 3. ESTIMATING COSTS 27

1. The Components of Average Cost 27

2. Utilization Costs 31

3. Some Sample Calculations 32

4. Some Cautions About Cost Estimations 37

5. Reducing Utilization Costs 38

6. Worksheets and Other Individual Materials 38

7. Teacher Training 41

8. Supervision of Teachers 42

9. Teachers' Guides 43

10. Radio Receivers 44

11. Maintenance of Radios 44

12. Batteries 45

13. Posters and Other Classroom Materials 45

14. Summary of Utilization Cost Savings 45

15. Development Costs 46

Chapter 4. PLANNING THE CURRICULUM 47

1. Describing the Topics 47

2. Scope of Objectives 49

3. Determining the Necessary Skills 50

4. Grouping Exercises 52

5. Determining Prerequisite Relationships 53

6. Deciding on Teaching Strategies 57

7. Setting Minimal Proficiency Standards 58

8. Determining the Scope of the Course 59

9. Producing a Time Schedule 59

10. Producing Pools of Exercises 60

PART III PRODUCING RADIO LESSONS

Chapter 5. PLANNING A LESSON 63

1. The Production Cycle 63
2. The Lesson Plan 63
3. Listing the Topics 69
4. Assigning Topics to Radio or Classroom Teacher 69
5. Selecting Exercises 70
6. Specifying the Time for Response 72
7. Specifying Supplementary Materials 72

Chapter 6. PRODUCING LESSONS 75

1. Instructional Segments 75
2. Structure of Instructional Segments 76
3. Structure of Exercises 77
4. Instructional Part of Exercise 79
5. Response Part of Exercise 83
6. Reinforcement Part of Exercise 84
7. Assembling the Instructional Segments 86
8. Entertainment Segments 87
9. Adding Transitions Between Segments 89
10. Finishing Touches 90
11. Studio Production 90
12. Producing Supplementary Materials 91
13. Producing Worksheets 92
14. Teachers' Guides 93

PART IV USING FEEDBACK

Chapter 7. FIELD TESTING THE LESSONS 95

1. Selection of Field-Test Classrooms 95
2. Intervention in Field-Test Classrooms 96
3. Teacher Training 97
4. Delivery of Materials 100
5. Supervision 100
6. The Use of Cassettes 101

Chapter 8. TESTING THE CHILDREN 103

1. Yearly Plan 103
2. Item Pools 106
3. Writing Test Items 107
4. Assembling Weekly Tests 111
5. Test Administration 112
6. Tests with Oral Instructions 113
7. Completely Oral Items 115

Chapter 9. GATHERING OTHER INFORMATION 117

1. Classroom Observation 117
2. Training Observers 119
3. The Observation Form 121
4. Individual Interviews and Tests 123
5. Suggestions from Teachers 124
6. Children's Written Work 125

Chapter 10. DATA ANALYSIS FOR DECISION MAKING 127

1. Analyzing Classroom Observations 129
2. First Analysis of Test Data 129
3. Analysis of Errors 133
4. Collecting Further Information 135
5. Making Formative Evaluation Work 136

Appendix A. SCRIPT LESSON 171 139

Appendix B. TEACHERS' GUIDE, LESSON 171 157

REFERENCES 159

INDEX 161

LIST OF FIGURES

Figure		Page
4-1.	An example of a prerequisite hierarchy of curriculum topics	54
4-2.	An example of a pruned prerequisite hierarchy of curriculum topics	56
5-1.	Production cycle	64
5-2.	Production cycle with editorial checks	65
5-3.	Lesson outline	66
5-4.	Sketch for worksheet (front)	67
5-5.	Notes to accompany lesson outline	68
9-1.	The observation form	122
10-1.	Feedback into the production process	128
10-2.	Example of report of weekly test results	130
10-3.	Test results and number of exercises given	131
10-4.	Incorrect responses to two items testing subtraction with borrowing	134

LIST OF TABLES

Table		Page
1-1.	Outline of Lesson 171, Second Grade	13
3-1.	Average Cost per Student per Year as a Function of the Number of Students	30
3-2.	Worksheet for Computing Average Cost per Student per Year	33
3-3.	Worksheet for Computing Line (1) of Table 3-1. Average Cost per Student per Year When There are 1,000 Students	34
3-4.	Worksheet for Computing Line (1) of Table 3-1. Average Cost per Student per Year When There are 256,000 Students	35
7-1.	Topics and Guidelines Discussed in Teacher Training	98
8-1.	Typical Testing Schedule	105
8-2.	Three Tests with Common Oral Instructions	114
8-3.	Tests with Two Forms of Oral Instructions for Completely Oral Items	116

INTRODUCTION

In 1973, in response to the needs of the many developing countries in the world that are not able to supply an adequate education to their growing populations, especially in rural areas which do not share in the cultural and economic advantages of urban centers, the United States Agency for International Development conceived and funded an educational radio project that was to serve as a model for improving the educational opportunities of children in the developing world. The goal of the project was not simply to produce and broadcast radio lessons but also to develop a methodology for the production of effective radio instruction, a methodology that would be applicable beyond the confines of the subject matter and geographic area that would serve as the first testing grounds.

This model project, the Radio Mathematics Project, operated in Nicaragua under the management of Stanford University from 1974 to 1978 during which time it produced radio-based instruction for first through fourth grade, using a method of production that ensured high quality instruction specifically tailored to the needs and abilities of the children who formed the audience.

The method of production used by the Radio Mathematics Project has two aspects: careful, detailed planning and production of materials; and continuous monitoring of the effect of the programs on the children and their teachers. It is the purpose of this book to explain this method to others who might wish to apply it to the production of educational broadcasts for school children. Radio producers and directors, script writers, curriculum designers, radio actors, evaluation experts, trainers of teachers, educational researchers--it is hoped that all will find some information here that will be helpful as they struggle with the challenge of improving the educational opportunities of the many underprivileged children of the developing nations of the world.

This book is intended as a manual, not as a research report; there are few statistics or scholarly footnotes. The primary concern is with educational aspects of radio production; there are few technical details about studio production or broadcasting. Much is said about content, from the global level of goal setting to the detailed level of selecting specific words to use in instructional messages. There is much about children's reactions to instruction, their interests, their understanding of language, their ability to generalize, their joy in learning. There is also a great deal about evaluating the effects of instruction--on the children's abilities, on their interests and attitudes, and on the attitudes and abilities of the teachers--and about how the results of such evaluation can be used as feedback to increase the effectiveness of the programmed instruction.

Although most of the examples given in this book are taken from mathematics, the methodology is applicable to many school subjects--reading, language arts, biology, foreign languages, etc. Each of these subjects consists of a fairly large, structured body of knowledge that must be taught in a well-organized sequence of lessons over a period of months, perhaps years. The method of production used by the Radio Mathematics Project was designed specifically for the production of an extensive course in a subject with an internal logical structure that imposes an order upon the sequence in which the topics can be learned.

Since the radio mathematics lessons were planned to be a part of the regular school program, many of the techniques described in this book depend upon the support of a classroom teacher, who will organize and distribute supplementary materials and supervise the children both during the broadcast and as they do the recommended postbroadcast activities. This role could well be played by any responsible, literate adult who is willing to act as monitor for an organized listening group. Thus, the methods described here are applicable to the production of some kinds of out-of-school broadcasts as well as in-school broadcasts.

With some modification, the techniques would also be useful for producing materials for home study; the third-grade and fourth-grade series produced by the Radio Mathematics Project were designed to serve the dual purpose of school and home study. To produce home study programs the data collection methods described in Part IV would need to be revised; the group tests and classroom observations used for the feedback by the Radio Mathematics Project would be inappropriate when students do not gather together to study. Also, some of the instructional techniques, particularly oral responses, are not entirely appropriate for individual study.

Part I of this book provides a background. A typical radio math lesson is described in Chapter 1. Chapter 2 enumerates the principles used in the development of the instructional system.

The design of the curriculum is the subject of Part II. Chapter 3 discusses the cost constraints that affect the design of radio-based instruction for schools in developing countries. In Chapter 4, curriculum planning is discussed.

Part III is concerned with production. Chapter 5 contains details about planning daily instruction for children. Chapter 6 includes advice on script writing, on studio production of radio programs, and on the production of printed supplementary materials.

Part IV elaborates the feedback system. Chapter 7 discusses how to select classrooms that will provide feedback, and how to implement the programs in those classrooms. The design and administration of tests is the subject of Chapter 8. Chapter 9 discusses gathering information

about the effect of the programs by observing children as they take the radio lessons. Chapter 10 discusses the thorniest problem of all, that of analyzing and synthesizing the information collected and determining future directions.

The examples used in this book are largely drawn from mathematics, primarily to serve as a constant reminder to the reader that the advice given here derives directly from the experiences of the Radio Mathematics Project and may need to be modified for use with other subjects. Most of the examples are from translations of actual scripts that were broadcast and proved successful. Some examples--especially those in other subject areas--were invented for this book and have never been tested with real children. In keeping with one of the major tenets of the feedback methodology, I advise that if you use them you also use a feedback system to find out if they really work.

Although I am the one who is committing these words to paper, I cannot take credit for the ideas presented. These were the product of the expertise and experiences of nearly 50 people who contributed to the work of the Radio Mathematics Project during its four years in Nicaragua. Dr. Patrick Suppes, the principal investigator, formulated the first concept of the feedback model for production. During the project he was a constant source of innovative suggestions that sparked many of the research studies that were conducted in conjunction with the project. Dr. Barbara Searle, who served as Stanford coordinator of the project, had administrative responsibility for the project during its entire life. She supervised most of the research conducted by the project, and contributed substantially to curriculum development, test design, and production methodology. Dr. Thomas Tilson, who was assistant director of the project for three years, contributed much to training of teachers and of staff members engaged in classroom observations and in research. He also conducted two important studies of teacher attitudes and behaviors, and assisted in curriculum development and test design as well as the multitudinous administrative details of the daily operation of the project. Dr. Klaus Galda, who was assistant director of the project for a year and later director, contributed substantially to the research efforts of the project in addition to taking responsibility for ongoing production. He studied the logical thinking of Nicaraguan children, conducted investigations of the determinants of failure, and conducted an informative survey of the home listening audience. Ms. Julia Ledee, who was radio director for two years, trained script writers, studio directors, and actors. Her lively and imaginative scripting and professional production contributed much to the high quality of the finished product.

Mr. Juan Jose Montenegro Pineda, Ms. Norma Guadamuz, Ms. Alicia de Quintanilla, and Ms. Vitalia Rojas all served as group leaders, and became the nucleus of the Nicaraguan staff that took over the project after the Stanford commitment ended in 1978. The Nicaraguan staff

included Luis Ramírez, Marvin Saballos, David Cardoza, Francisco Herrera, Dorys Mejía, Inez de R. Larios, Elba García de Flores, María Auxiliadora Cerrato, Sonia Centeno, Emigdio Quintero Casco, María de los Angeles Araya, Noel Alvarez, and Klemen Altamirano.

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Special credit is due to Dr. David Sprague, who was Project Manager for AID from its inception, for his cheerful and patient assistance with innumerable details, and for his deep understanding of the problems that abound in field implementation of educational systems.

Chapter 1

THE RADIO MATHEMATICS PROJECT

Most of the developing countries of the world have severe educational problems, especially in rural areas. Illiteracy rates are high and achievement in school subjects is low. Teachers are poorly trained, overworked, and underpaid. School buildings are small, badly constructed, and poorly equipped. There are not enough textbooks or other teaching materials. And these countries do not have the resources to alleviate these problems.

Radio is seen as one way of improving educational opportunities without straining the limited financial resources of the country. As part of its effort to explore the potentials of educational radio, the United States Agency for International Development funded the Radio Mathematics Project. The project was managed by Stanford University's Institute for Mathematical Studies in the Social Sciences.

Nicaragua, which also contributed to the financial support of the project, was chosen as the site for the project for several reasons, primarily because Nicaragua's educational problems typify in many ways the educational problems of the developing world.

During the experimental phase, from 1973 to 1978, the project was managed by Stanford personnel. During that period, four years of radio-based curriculum materials were developed and broadcast to children in 300 classrooms in four of the sixteen departments (provinces) that constitute Nicaragua. At the end of the experimental phase in 1978, the Nicaraguan Ministry of Public Education assumed the management of the project. Curriculum development was continued and the geographical coverage of the broadcasts was extended. However, with the change of government in 1979, work on the project was suspended for an indefinite time.

The radio mathematics lessons are intended for use within the formal educational system. Radio programs are broadcast directly to children in classrooms as part of their daily lesson in mathematics. Each radio lesson is a half hour long; after the broadcast the children, under the supervision of their teacher, participate in fifteen or twenty minutes of activities suggested by a guide the project supplies to the teachers.

The radio lessons are lively and entertaining as well as instructive. Their most notable characteristic is the high degree of student participation. The students answer aloud, write, draw, do written arithmetic exercises, sing, count bottle tops, answer riddles, and do calisthenics. On the average there is a response from the children every twenty seconds.

Another characteristic of the radio lessons is the rapid change of pace and topic. A single lesson may contain exercises on the multiplication tables, column subtraction, reading numerals, the concept of division, telling time, and problem solving. Interspersed among these instructional segments are songs, riddles, jokes, physical exercises, stories, and tongue-twisters. One minute the children will be seated quietly working on a column addition exercise under the step-by-step tutelage of the radio teacher, the next minute they will leap to their feet to do stretching and bending exercises, shortly to reseat themselves to listen to a dramatization of a real-life mathematics problem.

These features are not the only reasons for the success of the lessons with both students and teachers. Even more important, though less visible, is the careful adaptation of the instructional material to the abilities of the children being served. The frequency with which new topics are introduced, the mix of explanations and practice, the rate at which instruction is reduced, and the scheduling of review are all adjusted to the needs of the children by means of a system of feedback that is integrated into the production process. Feedback is also used to adjust vocabulary, length of instructional messages, and timing.

1. A TYPICAL LESSON IN THE CLASSROOM

The characteristics of the radio lessons can be shown by describing how a typical lesson would proceed in an ordinary classroom in Nicaragua. The lesson described below, Lesson 171 of the second-grade series "En el País de los Números," won the internationally respected Japan Prize for educational radio in 1977. That lesson was chosen for submission to the contest because it incorporated many of the most effective instructional techniques developed by the Radio Mathematics Project. It illustrates such features as the continuous active participation of the children, the simple language used in instructional messages, and the vivacious scripting that arises from the use of a segmented lesson structure.

The lesson is nearly an hour long; about five minutes is spent in preparing for the radio broadcast, the broadcast itself is thirty minutes long, and another fifteen to twenty minutes of postbroadcast activities are conducted by the teacher. Both the prebroadcast and the postbroadcast activities are specified in a daily teacher's guide produced and distributed by the project (see Appendix B).

About five minutes before broadcast time, the teacher copies the following exercises onto the chalkboard from the teacher's guide:

Part One

$$\frac{1}{3} + \frac{1}{3} = ___ \qquad \frac{2}{5} + \frac{1}{5} = ___$$

$$\frac{4}{10} + \frac{1}{10} = ___ \qquad \frac{1}{4} + \frac{2}{4} = ___$$

Part Two

$$\begin{array}{r} 45 \\ \underline{+\ 27} \end{array} \qquad \begin{array}{r} 52 \\ \underline{-\ 17} \end{array} \qquad \begin{array}{r} 76 \\ \underline{+\ 19} \end{array} \qquad \begin{array}{r} 82 \\ \underline{-\ 45} \end{array}$$

The teacher asks the children to copy these exercises into their notebooks but not to do them; during the broadcast the radio teacher will help the children with these exercises. As the children copy the exercises, the teacher goes to another part of the chalkboard to write the following numbers, also given in the teacher's guide. These numbers are not to be copied by the children, but will be used in an oral exercise conducted by the radio.

Part Three

A.	258	582	825
B.	706	670	607
C.	341	413	134

The teacher then walks about the classroom checking the written work of the children, seeing that they have written the fractions correctly, leaving adequate room for answers that are to be written in later, that plus and minus signs are copied correctly, and that columns are correctly aligned in the column addition and subtraction exercises. A few children are still copying the exercises as the teacher switches on the radio. The theme music fills the air as the teacher adjusts the volume. The children immediately join into the song, the words to which were taught earlier in the year; their pleasurable anticipation is evidenced by smiles and tapping feet. Within a few seconds the lesson "countdown" starts, and many students join in the chant, "ten . . . nine . . . eight . . . seven . . . six . . . five . . . four . . . three . . . two . . .

one . . . GO!" (The complete script for the lesson, translated from Spanish, is in Appendix A.)

Without pause the lesson begins with a simple song that the children have been practicing for several lessons:

> Hi, good morning, hi, good morning,
> How are you? How are you?
> We are very happy,
> We are very happy,
> We are fine, we are fine!

The radio characters enter to comment on the song, and at the request of one of the students in the studio "classroom" another short song is sung. This time the children in the classroom participate with some hesitation for it is a new song that not all students have learned. This song blends immediately into a "commercial" which begins the lesson proper:

> The clock, the clock
> It goes tick tock.
> One hour, sixty minutes,
> Sixty minutes, one hour.
> One hour, sixty minutes,
> Sixty minutes, one hour.

Following this introduction the two radio teachers, Lita and Ramon, pose questions such as:

> Yesterday Mary mended socks for sixty minutes.
> Did she mend socks for one hour or more?

The answers are given orally--and loudly--both by the children in the classroom and by the child actors in the radio cast. This segment, which lasts a little over a minute, requires four oral responses of the audience.

Following is another set of oral exercises, this time rapid-fire addition exercises:

> How much is 40 plus 8?
> And . . . 60 plus 3?
> . . . 90 plus 2?
> . . . 70 plus 5?

The children answer without hesitation and finish the few exercises in less than a minute.

Now comes what the children think of as their "real" work--the written exercises. Following the instructions of the radio teachers the

children open their notebooks and find the first exercise they copied from the chalkboard. Together with the child actors they read, "one-third plus one-third," thus translating a relatively difficult written exercise into a simple oral exercise that they can all answer with ease: "two-thirds." This oral answer must then be written as the numeral 2/3, a task which is still quite difficult for some of the children. For this reason, the radio teacher, Lita, reminds the children of the correct form: "Tell me, did you write *two* over *three*?" The remaining fraction exercises are solved in the same way:

RAMON: Let's go to the next exercise. Tell me, what are you going to add?

CHILDREN: Two-fifths plus one-fifth.

LITA: *Two*-fifths plus *one*-fifth . . . . How much is it?

CHILDREN: Three-fifths.

RAMON: Three-fifths. Next to the equal sign write *three-fifths.*

(MUSIC:08 SECONDS)

LITA: Tell me, how did you write it?

CHILDREN: Three over five.

RAMON: (CONFIRMING) Three over five. That's the way to write three-fifths.

This example shows several typical features of the radio mathematics lessons. The exercise requires several oral responses as well as a written response. Every response, whether oral or written, is immediately confirmed by one of the adult authority figures. Most verbal messages are addressed directly to the children in the classroom; there is relatively little traditional radio dialogue--one actor addressing another. The instruction to the children is brief and precise; there are no unnecessary words and the pace is rapid. Explanations and generalizations are used sparingly. Most instruction is given by examples that are carefully sequenced to help children internalize the basic concepts being taught.

The fractions segment, one of the most difficult parts of the lesson, takes three minutes; it requires four written responses and twelve oral responses--about five responses per minute, or one every twelve seconds. Even three minutes of this level of intense mental activity activity is enervating, so the children take a breather while they listen to a quick joke:

BOY: Mommy, Mommy, give me a peso.

MOTHER: Another one? What did you do with the one I gave you this morning?

BOY: (PIOUSLY) I gave it to an old man.

MOTHER: Why, that's very nice! You're a good generous boy! Here, you can have another peso . . . . But wait a minute! You won't give this one to the old man too, will you?

BOY: Oh, yes, I will, Mommy, 'cause he's the candy man and he won't give me any candy if I don't.

The lesson continues with another set of oral exercises; these are subtraction combinations that most children have not yet memorized: 12 - 4, 17 - 8, 15 - 8. To find the answers to such exercises the children must resort to counting or some other relatively slow method of mental calculation. There are, of course, some children who already have these combinations committed to memory, so if the radio teacher were to ask directly, "How much is twelve minus four?" the few children who have already memorized the answer would shout it out immediately; the other children, robbed of their initiative for solving the exercise, would simply echo the responses of these few leaders and would gain little from the practice. To provide all the children with the opportunity to practice mental computations, a "deferred" oral response is used. In this type of response the children are asked *not* to give the answer immediately. Instead, they are asked to think in silence for several seconds preparatory to a group oral response.

RAMON: Think of *twelve* minus *four*.

(MUSIC:05 SECONDS)

LITA: How much is it?

CHILDREN: Eight.

RAMON: Eight. Twelve minus four . . . eight.

The children now return to their notebooks to do the column addition and subtraction exercises in Part Two. The first exercise is done step by step. The children are first asked to read the sign and decide what operation is required. Then each column is done separately, with answers given orally before they are written, and with special attention to the carry operation. The second exercise is also done step by step but the third and fourth exercises are done independently by the children after a reminder that they must look at the operation sign to

find out whether to add or subtract. This segment, the longest in the lesson, has four exercises and requires twenty-one oral responses and seven written responses. The entire segment takes a little over four minutes.

A popular game, "Simon Says," is used for another breather. In it the children enthusiastically participate in imitating a piano player, a drummer, a guitar player and a trumpet player, all with a background of appropriate music.

The next mathematical activity requires the children to read the numbers written in Part Three on the chalkboard. They first read aloud the numbers 258, 582, and 825 from Line A, and then decide which of these is the largest number. This activity, without using formal mathematical terminology or abstract rules helps the children internalize important principles of the numeration system.

The children now turn back to their notebooks to do some drawings representing the process of division. In these exercises the children draw marbles, which they have already learned to represent by small, unadorned circles. The instructions for drawing and grouping the marbles are direct and simple:

LITA: You are going to draw some marbles to solve some division problems.

RAMON: First you are going to solve thirteen divided by five.

LITA: Tell me, how many marbles are you going to draw?

CHILDREN: Thirteen.

RAMON: (CONFIRMING) Thirteen. Draw them.

(MUSIC:12 SECONDS)

LITA: Since the exercise is thirteen divided by *five*, circle *five* marbles.

(MUSIC:08 SECONDS)

RAMON: Circle another five.

(MUSIC:08 SECONDS)

LITA: Tell me, how many marbles were left uncircled?

CHILDREN: Three.

RAMON: Three. Now tell me, how many groups did you make?

CHILDREN: Two.

LITA: Two. Look carefully at the whole drawing.

RAMON: Tell me, how much is thirteen divided by five?

CHILDREN: Two, and three left over.

LITA: Two, and three left over.

Following the division exercises there is a riddle. Then the lesson continues with a set of dramatized story problems in which the children must calculate the differences 42 - 2 and 56 - 6. The setting is a racing meet. In the first race, 42 motorcycles compete, with all of the appropriate and exciting sound effects; two motorcycles fall by the wayside as the race progresses, and the problem is to determine how many of those who started are still left in the race.

The last segment of the lesson is on multiplication and is introduced by a short song about multiplication. This segment is a transition between the broadcast and postbroadcast parts of the lesson. During the broadcast several multiplication exercises are dictated by the radio teachers; the children copy the exercises into their notebooks, and are left working quietly as the radio characters exit.

The classroom teacher allows the children sufficient time to complete the exercises and then asks a few children to solve the same exercises on the chalkboard so that all can check their work.

The rest of the lesson proceeds pretty much as in conventional classroom mathematics lessons. The children do practice exercises in subtraction and division, as recommended by the teacher's guide (shown in Appendix B). Then they practice writing four-digit numbers like 5091 and 4101 from dictation.

The outline of the radio portion of Lesson 171 is shown in Table 1-1. The lesson has fifteen segments, nine with mathematical content and six solely for entertainment. There are 32 exercises in all. Many of these require more than one response. Students are asked to make a total of 98 responses, an average of 3.3 per minute, classified as follows:

71 oral responses
14 written responses
7 drawn responses (in the division exercises)
4 physical responses (in the "Simon Says" game)
2 songs

The lesson also contained four other short songs which the children could sing if they wished although they were not expressly invited to do so.

Table 1-1

Outline of Lesson 171, Second Grade

Description of segment	Number of arithmetic exercises	Number and kind of responses
Introduction: Song and countdown		
Song: "Good Morning"		singing
Song: "Monday a Baby Girl was Born"		singing
Oral problems on time	4	4 oral responses
Oral problems on addition	4	4 oral responses
Addition of fractions, exercises copied from chalkboard	4	12 oral responses
Joke: "The Candy Man"		
Oral exercises on subtraction	4	4 oral responses
Column addition and subtraction exercises copied from chalkboard	4	21 oral responses 7 written responses
Game: "Simon Says"		4 physical responses
Comparing numbers, referring to chalkboard	3	10 oral responses
Division concept	3	13 oral responses 7 drawn responses
Riddle: "The Drum"		1 oral response
Dramatized problems: "The Race"	2	2 oral responses
Multiplication exercises, dictated	4	7 written responses

The teacher's role is of critical importance both before and after the broadcast. During the broadcast, because the lessons are addressed directly to the children in language they can understand, the teachers assume a supporting role only. While the radio lesson is going on, they may provide individual help for children who are having difficulty following the radio instruction or, if they have more than one grade to teach, they may devote this half hour to the children in another grade who are not taking the radio lesson. About half the rural teachers in Nicaragua have two, three, or four grades in a single classroom; for them, the radio serves as a needed assistant.

During the experimental phase of the project, 650 lessons like the one described above were produced and broadcast.

2. EFFECTIVENESS OF RADIO MATHEMATICS LESSONS

Formal evaluations of the effectiveness of the radio lessons were conducted as part of the research activities of the Radio Mathematics Project. For each grade, the mathematical ability of children who received radio instruction was compared with the ability of those who received conventional classroom instruction. The comparison, made by means of year-end achievement tests designed to test the learning objectives prescribed by the Ministry of Public Education, showed that radio lessons had a highly significant effect on the children's mastery of mathematical topics. On the second-grade posttest, the average score of children in ordinary classrooms was 58% correct, while children who used radio lessons achieved 66%. The first-grade posttest results showed an even greater difference (39% vs. 65%). There is no doubt that well designed radio-based instruction can provide a means to better education.

Detailed analyses of test results also showed that radio lessons help to close the gap between rural and urban students, that boys and girls of equal ability learn equally well from radio, and that both low ability and high ability students benefit equally from radio lessons. (Searle & Galda, 1980)

The formal evaluation of the radio mathematics lessons considered cost as well as quality. No matter how high the quality of radio lessons, if the cost is prohibitive they will be of little use to countries with financial resources as limited as Nicaragua's. The costs that were considered included implementation costs such as radio transmission and reception, production and distribution of printed materials, and training and supervision of teachers. Cost projections for the radio-based mathematics curriculum showed that for a wide-scale implementation the cost per pupil per year would be less than $2.00 *including* the amortized cost of production. (Wells & Klees, 1978)

Another aspect of the evaluation was concerned with teachers' attitudes. A study conducted in 1976 showed that teachers were enthusiastic supporters of the radio programs; they felt that the radio lessons helped the children to learn, motivated them, made the class more interesting, and helped the teacher. (Tilson & Searle, 1978)

The radio programs also attracted a sizable home audience, despite the fact that the programs were designed for use in schools. A survey of 476 households in various areas of Nicaragua showed that 37% had members who listened to the radio mathematics lessons, with half of them listening regularly. The potential clearly exists for providing simultaneously for both home and school study. (Saballos, Galda, & Gonzalez, 1980)

Chapter 2

PRINCIPLES USED IN THE DEVELOPMENT OF THE INSTRUCTIONAL SYSTEM

The principles underlying the design and implementation of the radio-based mathematics curriculum came from many sources. Most of the pedagogical principles came from research in learning theory, and from experience with instruction delivered by means of textbooks, programmed workbooks, teaching machines, television, and computers. These general principles were adapted by the Radio Mathematics Project to the design of instruction that was to be delivered to the children through the medium of radio.

Not all of the underlying design principles had to do with children. Some had to do with the classroom teacher whose support was crucial to the success of the project.

But of all of the principles that guided the work of the Radio Mathematics Project there was none so important as the concept of integrating the production schedule with the data collection and analysis procedures that constituted the feedback system.

1. PRINCIPLES INVOLVING THE STUDENTS

When we first started producing radio lessons, we had only a few general principles for instructional design and no guidelines about how best to implement those for radio teaching. The pedagogical principles listed below are a distillation of a philosophy of curriculum design that evolved gradually over several years of working with children in the classrooms of Nicaragua.

The Principle of Student Participation

One principle of which we were firmly convinced from the beginning was the principle of student participation. Skills like reading and arithmetic are learned from practice, not from instruction cast in the form of lectures and demonstrations. The provision for frequent, active student participation has become the hallmark of the radio mathematics lessons. Student participation is used not only to increase learning but also as a device to attract and hold student attention; even those parts of the broadcast that are solely for entertainment rely heavily on participation to increase their appeal.

A variety of formats for student participation were used in the radio mathematics lessons. Oral responses were used in every lesson from first through fourth grade. In first grade, many of the activities involved worksheets; children circled, underlined, or pointed at

pictures or numerals; they wrote numerals; they drew pictures; they counted objects depicted on the worksheet; they solved arithmetic exercises. Work with concrete materials was also started in first grade; children counted bottle tops and seeds; they measured with rulers; they sorted small objects into groups of ten. The lessons also elicited physical responses that did not require special materials; the children counted on their fingers; they played games that required them to touch their nose, their shoulders, their knees; they did stretching and bending exercises for calisthenics.

In second grade, the children's responses also included reading and copying from the chalkboard. They also copied into their notebooks numbers that were dictated by the radio teacher. In third grade, entire exercises were dictated.

Although we had been committed to the value of student participation from the beginning, our ideas about the frequency of such participation changed as we gained experience. In the beginning of first grade, we included daily stories, stories that required the children to listen for fairly extensive periods of time without participating actively. We soon found that the children became bored and restless. Since the stories served no teaching purpose but were solely for entertainment, we eliminated them in favor of the more popular songs and games, in which the students could participate. In the teaching segments, we found that not only could the children maintain quite a high response rate but also that they seemed to enjoy doing so and to learn more as a result. Consequently, we decreased extraneous dialogue and concentrated more on activities in which the children could participate.

As children grow older, their attention span increases and their language develops. For fourth graders we were able to include some material that did not require overt participation. We serialized a popular children's book and found that the children enjoyed it very much even though they were only listening. We also wrote a few staged quiz shows, mainly incorporating mathematical topics, and found the children to be quite receptive. We used these non-participant activities quite sparingly however because we felt they had little teaching value in comparison to the activities that required more active student involvement.

The Principle of Providing Correct Answers

A second principle to which we were committed from the beginning was that the answers children give must be corrected immediately. There is ample research to show that children learn faster when they are told immediately whether their responses are correct or not. With a mass medium like radio, children's work cannot be corrected individually, unless we ask the teacher to grade papers. Such grading could provide specific correction for individuals but could not be given immediately after the child completed the exercise. We felt that the greatest

learning gains would accrue from immediacy rather than specificity. The method we used, and one that seems to be reasonably effective, is to announce the correct answer as soon as all children have had a chance to respond. The children can then compare their own answers with the announced correct answer to determine for themselves whether they were correct or wrong. There are several disadvantages to this method of correcting children's work. One disadvantage is that children may not always make a correct comparison between their response and the announced answer. Another is that the teachers do not always know which children need special help, because they do not have the opportunity to look at students' uncorrected papers.

Another disadvantage--or so we thought--of supplying correct answers after *every* exercise was that the children would learn that the radio teacher would always give the answer so they would simply wait for that instead of doing the work themselves. Our conviction that this would occur was so great that we produced a large number of first grade lessons without giving correct answers. Later, we tried a strategy of giving correct answers for only a few, randomly selected exercises so the children would not know when to expect the answer to be given by the radio. Observations of children taking radio lessons eventually convinced us that what we feared did not happen: children participated willingly and just as fully when answers were given as when they were not. It was only on rare occasions that we found a child who waited until the answer was given. We were convinced that these children were making an intelligent decision--that is, they knew they could not do the exercise correctly and were willing to wait for the radio teacher to tell them the correct answer in hopes that it would help them to see how the exercise should have been done. Our finding that our original assumption was incorrect was valuable in more than one way. It not only freed us to provide the correct answers to every exercise, it also helped to convince the staff of the value of classroom observation.

As a result of our observations, we committed ourselves fully to the idea of supplying answers immediately--whenever that was possible. Since we were communicating with the children orally, not all answers could be given. If children are asked to hold up four fingers, for example, there is no way a "correct answer" can be given orally. Also, if the task is to draw seven circles on the worksheet, the answer cannot be given orally. We resorted to various other devices in these situations. If the children were to draw a certain number of objects, we asked them to check their own work by counting the objects they had drawn. If the children were to hold up four fingers, we relied on peer-group reinforcement; children could look at their neighbors to see what they were doing. Of course, there is some danger that their neighbors will be responding incorrectly, but this is rarely a real problem; children are generally quite good at knowing which of their classmates are likely to answer correctly. Also the rate of correct responses during radio lessons is quite high, so *any* neighbor is quite

likely to have the right answer. (We considered it a failure of the radio lesson if a large number of children gave incorrect responses.)

Principle of Appropriate Exemplars

A third pedagogical principle is that children learn general rules best by inducing them from appropriate exemplars. The ability to learn a general principle and then apply it is poorly developed in children, who do better by working from the specific to the general. If tasks and examples are chosen appropriately, the child will eventually internalize the concepts being illustrated. He will not necessarily be able to verbalize the principle. There is even some evidence that early verbalization is deleterious to concept formation. This independence of concept formation and verbalization sometimes causes adults to misjudge children's abilities. Children who can parrot rules taught by their teacher are frequently perceived as having learned the concept, even though they cannot apply it when appropriate; in contrast, children who cannot describe the concept they are using are sometimes judged to need remedial instruction. The true test of concept formation is to find out how well the student performs on tasks that are similar but not identical to the ones he has practiced.

In order to help the child form correct concepts, the curriculum designer must choose and sequence examples carefully to prevent the child from forming incorrect or incomplete generalizations. This is perhaps one of the most difficult aspects of curriculum design since children often ignore or misunderstand explanations and form their ideas solely from the examples given. As an example, imagine a young child--a second grader, perhaps--who is just learning to carry in addition. His teacher gives him many exercises like these:

$$\begin{array}{r} 47 \\ \underline{+\ 29} \end{array} \qquad \begin{array}{r} 28 \\ \underline{+\ 54} \end{array} \qquad \begin{array}{r} 16 \\ \underline{+\ 48} \end{array}$$

The child soon learns to do these exercise correctly, neatly writing the carried number above the tens column:

$$\begin{array}{r} \scriptstyle 1 \\ 47 \\ \underline{+\ 29} \\ 76 \end{array} \qquad \begin{array}{r} \scriptstyle 1 \\ 28 \\ \underline{+\ 54} \\ 82 \end{array} \qquad \begin{array}{r} \scriptstyle 1 \\ 16 \\ \underline{+\ 48} \\ 64 \end{array}$$

The teacher explains the process in words like these: "First, add 7 and 9. That's 16. Since 16 is a two-digit number you must carry. Write the 6 down here (gesturing) and the 1 up here. Now in the next column add [illegible] plus 4 plus 2. That's 7, which you write down here." After the child

masters exercises of the above type, he is given some three-column addition exercises, and produces the erroneous answers shown below:

```
  1          1          1
 417        238        176
+ 259      + 524      + 418
 766        852        684
```

The child had formed an incorrect concept of carrying: he believes that you should add the carried number to the column furthest to the left. Since the leftmost column is the correct place when there are only two columns, he succeeded in giving correct answers for all two-column exercises; it is only when he has to deal with three columns that his misconception is unveiled. Unless they are dispelled early, such misconceptions may take strong root in the child's mind and he may be unable to shake the bad habit even after he knows, intellectually, that it is not correct. The prevention of such misconceptions requires great skill, knowledge, and imagination on the part of the curriculum designer, as well as ample field testing, observation, and perhaps even interviews with children to detect unintentional ambiguities in the instructional materials.

The Principle of Distributed Practice

Another principle used in the radio mathematics lessons is concerned not with initial learning but with retention of learned skills: retention is greatest when there is sufficient, well-spaced practice. Everyone has had the experience of forgetting something that was once well known; skills and knowledge deteriorate rapidly if not refreshed by review and practice. Although isolated bits of information can sometimes be acquired at first hearing and remembered for years, this is quite unlikely to happen with the kind of complex skills that are needed in mathematics. Dull, repetitious drill is not the ideal implementation of this principle. Luckily, in highly structured subjects like reading or mathematics, ample practice can frequently be provided in the context of the introduction of new tasks and ideas.

In applying the principle of adequate, distributed practice decisions must be made about how much practice is needed and how often it should be provided. Those decisions are best made by testing the children at regular intervals to find out how well they can do the tasks. The amount and distribution of practice depends on the specific topic as well as the abilities and previous experiences of the children. We generally included daily practice (of perhaps only two or three minutes) for a week or two after the topic was first introduced and then decreased the number of practice sessions until test results showed that the children had adequately learned the topic. Whenever possible we tried to vary the form of the practice by incorporating it into instruction on some other, related topic.

The Principle of Encouraging Attention

One problem that we found very puzzling had to do with so-called listening skills. And the reason we were puzzled was that we had very few teaching problems that seemed to stem from the children's lack of listening skills. We were nevertheless persistently questioned about what we did to cope with the (assumed) lack of listening skills, and what we did to develop such skills. Looking back over four years of curriculum materials, I am still unable to ferret out the underlying but unarticulated principles that we used. From a practical standpoint, the view we adopted was that the burden of communication was ours: if the children did not understand what we said, the fault was ours; we had used language the children could not understand, or the radio actors had spoken too rapidly or not enunciated clearly or we had asked the children to do a task that was beyond their capacity.

We may have helped somewhat with the development of listening skills simply by encouraging the children to listen. We did not do this by warning them to pay attention, but by delivering messages that we thought they would want to hear and need to hear. A child who let his attention wander for a minute would soon find that everyone else in the room was busily engaged in some interesting activity that he could not do because he had not heard the instruction; to be left out of some activity sharpened the children's desire to listen much more than any number of demands for attention.

We also encouraged children to listen to an instruction the first time it was given by the simple expedient of never repeating it. Many teachers fall into the habit of repeating every instruction they give, either verbatim or in paraphrase, probably because they have such a low regard for the children's ability to attend and comprehend what they are saying. The net effect of constant repetition is that the children are taught *not* to listen; they learn that they need to listen only half the time since everything will always be repeated. We were careful to phrase instructions so the children could understand them (hence there was no need to paraphrase) and we never repeated. (One exception to this: when the children were to copy from dictation a very large number, we repeated the number--but not the entire message.)

Another well-known "fact" about children is that they have a short attention span. Our decision to write 30-minute radio lessons for first graders has been questioned since most other radio projects plan only fifteen-minute radio programs for young children. Nevertheless, we found that the children's attention held up quite well. This is partly due to the nature of the instruction; because it is fast-paced and because the children are actively involved they tend to be more interested. But it is also partly due to the concessions we made to short attention spans by changing topics every two or three minutes.

2. PRINCIPLES PERTAINING TO TEACHERS

Although one thinks of radio as the "medium" of instruction for the radio mathematics lessons, there was also another medium--the teachers. The teachers bring the radio receivers to class and turn them on at the right time. They distribute worksheets or write exercises on the chalkboard. They encourage the children to participate, help those who have special need, and conduct postbroadcast activities. Without the cooperation and support of the teachers, the project might have failed.

The principal reason the teachers welcomed the radio lessons was the obvious benefit to the children themselves. Teachers are dedicated people, who have chosen their profession because they want to improve the lives and minds of the children who are placed in their charge. They are continually searching for ways to provide better educational opportunities to their students. Any program that can help them to do this will be viewed favorably.

Principle of Reducing the Teacher's Workload

Teachers are busy people. They can never find time for all the tasks that they need to do in order to provide a stimulating learning environment. Lesson plans need to be written, papers need to be corrected, materials need to be procured, special remedial lessons need to be prepared, and on and on. To be accepted, an innovative program should not add to the teachers' duties but should instead free them of whatever tasks it can.

The Radio Mathematics Project imposed very little on the teachers' time. The teacher training consisted of one three-hour session per year. Teachers were not asked to take on any additional record keeping or report writing. We also relieved teachers of several tasks they would have to do if they did not use the radio lessons; they were freed from the need to plan the daily mathematics lesson, and, because most of the children's work was corrected by the radio teacher, they were freed from a part of the task of grading papers.

The teachers did have to prepare for each day's class by reading the teachers' guide. In our first year, we wrote fairly lengthy guides for each day's lesson, but with experience we learned to prepare more concise instructions for the teachers. We omitted descriptions of the radio lessons since the information proved to be of no use. At first, we listed teaching objectives for each instructional segment of the lesson but found that teachers gained little from these abstract discussions and often did not read them. The most effective teachers' guides proved to be those in which recommended activities are described as parsimoniously as possible.

Principle of Avoiding Personal Expenditures

Another principle we applied was not to put any financial burden on the teachers. Since the Ministry of Public Education has no funds for classroom supplies or equipment, special materials that are needed must be purchased by the teachers (or more rarely by the community). Radios, teachers' guides and worksheets were supplied by the project. The only other materials used during the daily lessons were things that could be obtained locally at no cost.

Principle of Adapting Content to Teachers

Because the teacher and the radio were to work together as a team, we adapted the content and style of the radio lessons to the teachers as well as to the children. We taught only traditional topics, things that were within the teachers' experience, rather than introducing less traditional mathematical topics that might have seemed threatening to the teacher. We taught traditional algorithms as well as traditional topics, feeling that to do otherwise would mean that the untrained teacher would not be able to contribute to the teaching process; for example, although we believe that both the column subtraction algorithm and the long division algorithm traditionally used in Nicaragua are not the best algorithms either to learn or to use, we nevertheless opted for the traditional approach so as not to alienate or confuse the teachers.

3. THE PRINCIPLE OF INTEGRATING FEEDBACK AND PRODUCTION

We held none of the above principles as dogma. Throughout the project, we had only one inviolable principle: every idea we had, every word we wrote, every assumption we made was suspect until proved by the final test, the reactions of the children themselves.

To study the reactions of the children, and to incorporate necessary changes into the curriculum materials, we devised a fairly elaborate system of production that incorporated a feedback mechanism for collecting and analyzing data from the classrooms.

We used two primary sources of data, weekly paper-and-pencil tests, and daily observations of radio classes. On occasion we also interviewed children, both formally and informally. Teachers contributed also; we chatted with them and noted their suggestions; sometimes we asked them to fill out questionnaires; and we conducted structured interviews with selected teachers. Once a week all the data were gathered together and analyzed to find out how well the children were learning, what specific difficulties they had, whether or not they enjoyed the lessons, and how much they participated. *No new lesson was planned or written without first consulting the results of this data analysis.*

The key word in this principle is "new:" no *new* lesson was written without taking the data into account. This sentence characterizes the

feedback system of formative evaluation. Many people upon hearing the word feedback think of a process of revision, since the word feedback has been loosely used by educators to mean improving an education package by field testing it and then revising to obtain higher quality. This, however, is a revision process which lacks the dynamic quality of a feedback system. Feedback, as the term was originally used, means altering an ongoing process by collecting information about the effectiveness of the process and making the necessary changes without halting the process to do so. Revision, in contrast, can be a more leisurely activity; the process does not continue while the changes are made.

The greatest effect of this difference between the revision and feedback systems is that a feedback system does not affect the past, but only the future. Thus, a feedback system is not appropriate for error correction but is used instead as a tool for refining strategies and for adjusting the parameters of lesson design to the continually changing needs of the audience of students.

Some of the design parameters that we adjusted as the children developed were the length of instructional segments, the number of exercises per segment, the amount and kind of review, the syntactic complexity of instructional messages, the vocabulary, the speed of speech used by the actors, the amount of time allowed to do different kinds of exercises and the complexity of the responses expected of the children.

When using an integrated feedback system, it is essential that the information be timely and that it be pertinent. Collection, analysis, and synthesis of data must be conducted on a schedule that is as demanding and rigid as the production schedule. And the results must be reported in a form that will be understandable and useful for all members of the production team. Because of these demands, the feedback system must not be undertaken lightly by projects that are understaffed and poorly financed.

Chapter 3

ESTIMATING COSTS

Cost is a major factor in many of the decisions that go into the design and production of teaching materials. Radio is often chosen for delivering instruction because it is perceived to be a low cost medium.

But it cannot be assumed that a low cost will automatically be attained simply because radio is used. Although radio by itself is not expensive, it is rarely used alone. When used for educational purposes there is usually a complete instructional package that also includes printed materials in the form of textbooks, worksheets, posters, flipcharts, teachers' or monitors' guides, tests, and record forms. If the programs are to be used within the established school system there will undoubtedly also be teacher training and supervision. If the programs are used outside the schools there will probably be monitors or field supervisors who, even if not paid, will need special training. Thus the costs of two different radio-based instructional systems can vary greatly depending on the kinds of support components required.

Since the non-radio components of the instructional system are decided while the instructional materials are in the design phase, it is in this phase that the eventual total costs of the system are largely determined. Although there are some costs of utilization that are outside the control of the curriculum and media designers, many of the determinants of long-range cost are found in the initial planning of the lessons, the printed materials, and of the teacher-training components. The total add-on cost to the educational system is not, then, something to be computed after the innovation is in place in the schools but rather something to be considered in advance so that there is a well specified objective to work toward during the preparation of the curriculum package.

1. THE COMPONENTS OF AVERAGE COST

In comparing the costs of different media mixes for use in the established school system, the cost most often used is the average cost per student per year.

In radio-based instruction this average cost has two main components, the development cost and the utilization cost:

TOTAL COST = DEVELOPMENT COST + UTILIZATION COST

The development cost is a one-time-only cost (unless regular program

revisions are scheduled) whereas the utilization cost recurs every year. To find the total annual cost, the development cost must be annualized by dividing the total development cost by the program life (in years). Thus,

$$\text{TOTAL ANNUAL COST} = \text{ANNUALIZED DEVELOPMENT COST} + \text{ANNUAL UTILIZATION COST}$$

and the average cost per student per year is the total annual cost divided by the number of students who use the program every year:

$$\text{AVERAGE COST PER STUDENT PER YEAR} = \frac{\text{TOTAL ANNUAL COST}}{\text{NUMBER OF STUDENTS}}$$

The total development cost is independent of the number of students, as is the program life. Assume that the cost of developing a complete year's curriculum package is $180,000 and that the programs are expected to be in use for 6 years. The annualized development cost is $180,000 ÷ 6 which is $30,000.[1] That is,

$$\text{TOTAL ANNUAL COST} = \$30{,}000 + \text{ANNUAL UTILIZATION COST}$$

The annual utilization cost itself is dependent upon the number of students, since more students need more worksheets, more radio receivers, etc.

Suppose that the utilization cost would be $7,800 if there were 1,000 students. Then,

$$\text{TOTAL ANNUAL COST} = \$30{,}000 + \$7{,}800 \text{ (for 1000 students)}$$

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[1]This is a simplistic calculation that would not be satisfactory for calculating true cost; true cost can only be obtained if the $180,000 is considered to be a capital investment and an appropriate interest rate is assumed. Allowance for inflation should also be made in this and other calculations if a true cost estimate is desired. In the following we will be concerned only with comparative costs, and since the same (erroneous) assumptions will be made in all calculations the conclusions will be unaffected.

and the average cost per student per year would be computed as follows:

$$\text{AVERAGE COST} = \frac{\$30,000}{1,000} + \frac{\$7,800}{1,000}$$

$$= \$30.00 + \$7.80$$

$$= \$37.80 \qquad \text{(when there are 1000 students)}$$

This is a rather high average cost per student per year, especially for a country in which the total cost of educating a student for a year may be no more than $100.

For comparison let us double the number of students. The annual utilization cost would not double because of economies of scale; let us suppose the utilization cost would be $10,600 for 2000 students. Then we would find an average cost as follows:

$$\text{AVERAGE COST} = \frac{\$30,000}{2,000} + \frac{\$10,600}{2,000}$$

$$= \$15.00 + \$5.30$$

$$= \$20.30$$

We have nearly halved the cost per student by doubling the number of students. And of course, if the number of students is again doubled there is an even lower average cost. For an overview of what happens to the cost as the number of students increases see Table 3-1, which shows the results of doubling and doubling again until the total number of students served per year becomes 256,000. At this point the cost is less than $3.00 per year for each student and will not become much lower regardless of how many students are served.

TABLE 3-1

Average Cost Per Student Per Year as a Function of the Number of Students

	Number of Students Served Per Year	(Annualized Development Cost) ÷ (Number of Students)		(Annual Utilization Cost) ÷ (Number of Students)						Average Cost Per Student Per Year
1)	1,000	$\frac{\$30,000}{1,000}$	+	$\frac{\$\ 7,800}{1,000}$	=	\$30.00	+	\$7.80	=	\$37.80
2)	2,000	$\frac{\$30,000}{2,000}$	+	$\frac{\$\ 10,600}{2,000}$	=	\$15.00	+	\$5.30	=	\$20.30
3)	4,000	$\frac{\$30,000}{4,000}$	+	$\frac{\$\ 16,200}{4,000}$	=	\$ 7.50	+	\$4.05	=	\$11.55
4)	8,000	$\frac{\$30,000}{8,000}$	+	$\frac{\$\ 27,360}{8,000}$	=	\$ 3.75	+	\$3.42	=	\$ 7.17
5)	16,000	$\frac{\$30,000}{16,000}$	+	$\frac{\$\ 49,760}{16,000}$	=	\$ 1.88	+	\$3.11	=	\$ 4.99
6)	32,000	$\frac{\$30,000}{32,000}$	+	$\frac{\$\ 94,720}{32,000}$	=	\$ .94	+	\$2.96	=	\$ 3.90
7)	64,000	$\frac{\$30,000}{64,000}$	+	$\frac{\$184,320}{64,000}$	=	\$ .47	+	\$2.88	=	\$ 3.35
8)	128,000	$\frac{\$30,000}{128,000}$	+	$\frac{\$363,520}{128,000}$	=	\$ .23	+	\$2.84	=	\$ 3.08
9)	256,000	$\frac{\$30,000}{256,000}$	+	$\frac{\$721,920}{256,000}$	=	\$ .12	+	\$2.82	=	\$ 2.94

Table 3-1 illustrates how the development cost per student decreases as the number of students increases. When there are only 1,000 students (Line 1) the development cost is over three-fourths of the total average cost. But when there are 16,000 students (Line 5) the development cost is less than one half of the total average cost. And by the time there are 256,000 students the development cost is only 5% of the total.

With a development cost as high as that postulated here ($1000 per lesson) it is probably never economically feasible to aim for an audience of less than 50,000 students annually. This would be a total of 300,000 students over the six-year life of the program.

As the number of students increases, the proportion of average cost attributable to development decreases, as we saw above. Conversely, the utilization costs become more and more important, relatively, as the number of students grows. When there are 64,000 students the utilization cost is 85% of the average cost per student. If there is to be a large audience, the only way to reduce average cost significantly is to reduce the utilization cost.

2. UTILIZATION COSTS

With a large audience the largest component of the average cost per student is the utilization cost. Utilization costs contain a number of components. Some are incurred for each student using the program, others for classrooms rather than individual students, and still others are shared by many classrooms.

Starting with the more global costs, we have first the cost of transmission. Each transmitter can serve a large number of students. The exact number depends upon the power of the transmitter and the population density of the area served. Small transmitters in rural areas might serve no more than 10,000 students in each grade whereas more powerful transmitters in thickly populated regions might be capable of reaching hundreds of thousands.

The cost per hour of broadcasting time also varies considerably. Large broadcasting stations with big audiences charge more than smaller stations in remote areas. As a rough estimate it may cost $4,000 to $7,000 per year to broadcast 180 half-hour programs. (In Table 3-1 we assumed $5,000.) To prorate this to individual students the figure must be divided by the number of students who are served each year by that transmitter.

There are also utilization costs that depend upon the number of classrooms being served. These costs include:

- the radio receiver
- maintenance of the radio
- power for the radio
- the teacher's guide
- posters and other materials that are used by the entire class rather than by individual students
- training of the teacher
- supervision of the teacher

Some of these costs are for materials or services that last more than one year. A radio receiver, for example, will serve for several years. Such costs must be annualized before the yearly cost per classroom can be computed.

Once the total yearly cost per classroom is computed the average cost per student per year is found by dividing by the average number of students per classroom. (In the following example, an average of 32 will be assumed.)

In addition to the cost for materials and services that are shared by all students in the classroom there are also materials that are used by individual students. These include worksheets, textbooks, rulers, etc. Here again, if there are some materials, such as textbooks that can be reused year after year, the cost must be annualized before summing.

The total average utilization cost per student per year is found by summing:

the average annual cost per student due to TRANSMISSION COSTS
the average annual cost per student due to CLASSROOM COSTS
the average annual cost per student of INDIVIDUAL MATERIALS

3. SOME SAMPLE CALCULATIONS

Table 3-2 is a form to be used for computing the average cost per student per year. This form is overly simplified but will serve for rough estimates, especially for comparison of the costs of different media designs or different utilization plans. Parts 1, 2, and 3 are for computation of utilization costs while Part 4 is for development cost.

Of the utilization costs only those shown in Part 1 and 2 can be directly affected by media designers. The transmission cost, in Part 3, would be considered in deciding what regions of the country to serve--these costs are outside the control of the program designers. Develop-

TABLE 3-2

Worksheet for Computing
Average Cost per Student per Year

Description of Costs				Average Cost Per Student Per Year
1) Annual costs for individual students':				
Worksheets				_____
2) Annual costs for each classroom:				
Teacher training	_____			
Supervision of teacher	_____			
Teacher's guides (annualized)	_____			
Radio receiver (annualized)	_____			
Maintenance of radio	_____			
Power	_____			
Posters, etc.	_____			
Total	_____	÷ 32	=	_____
3) Annual transmission cost:				
_____ (Cost of transmitting 180 lessons) × _____ (No. of transmitters) →	_____	÷ _____ (No. of students per year)	=	_____
4) Development cost:				
$180,000 ÷ _____ (Program life) →	_____ (Annualized cost)	÷ _____ (No. of students per year)	=	_____
TOTAL AVERAGE COST PER STUDENT PER YEAR				_____

ment costs shown in Part 4 are under the control of the program designer, and there may be decisions to make about tradeoffs between development costs and utilization costs. For example, it may cost more to develop lessons that teach effectively without using worksheets. If this added development cost can be estimated then the economic advantages of dispensing with worksheets can be computed.

TABLE 3-3

Worksheet for Computing Line (1) of Table 3-1
Average Cost per Student per Year When There are 1,000 Students

Description of Costs				Average Cost Per Student Per Year
1) Annual costs for individual students':				
Worksheets				$ 1.50
2) Annual costs for each classroom:				
Teacher training	$15.00			
Supervision of teacher	0			
Teacher's guides (annualized)	1.50			
Radio receiver (annualized)	11.00			
Maintenance of radio	1.50			
Power	12.60			
Posters, etc.	0			
Total	$41.60	÷ 32	=	$ 1.30
3) Annual transmission cost:				
$5,000 (Cost of transmitting 180 lessons) × 1 (No. of transmitters) → $5,000 ÷ 1,000 (No. of students per year) →				$ 5.00
4) Development cost:				
$180,000 ÷ 6 (Program life) → $30,000 (Annualized cost) ÷ 1,000 (No. of students per year) →				$30.00
TOTAL AVERAGE COST PER STUDENT PER YEAR				$37.80

TABLE 3-4

Worksheet for Computing Line (1) of Table 3-1
Average Cost per Student per Year When There are
256,000 Students

Description of Costs				Average Cost Per Student Per Year
1) Annual costs for individual students':				
Worksheets				$ 1.50
2) Annual costs for each classroom:				
Teacher training	$15.00			
Supervision of teacher	0			
Teacher's guides (annualized)	1.50			
Radio receiver (annualized)	11.00			
Maintenance of radio	1.50			
Power	12.60			
Posters, etc.	0			
Total	$41.60	÷ 32	=	$ 1.30

3) Annual transmission cost:

$5,000 (Cost of transmitting 180 lessons) × 1 (No. of transmitters) → $5,000 ÷ 256,000 (No. of students per year) → $ .02

4) Development cost:

$180,000 ÷ 6 (Program life) → $30,000 (Annualized cost) ÷ 256,000 (No. of students per year) → $ .12

TOTAL AVERAGE COST PER STUDENT PER YEAR $ 2.94

The computations resulting in Lines 1 and 9 of Table 3-1 are shown in Tables 3-3 and 3-4. The estimates used are for a hypothetical system of radio instruction that:

(1) provides 150 worksheets to each student every year at a cost of $.01 per page,

(2) provides two 3-hour teacher training sessions each year at a cost per teacher of $15,

(3) does not provide any supervision of teachers beyond that which is already provided by the existing school system,

(4) provides teacher's guides that cost $9.00 each for production and distribution, and have a life expectancy of 6 years (the same as the estimated life of the radio programs),

(5) provides one radio receiver for each classroom every 6 years at a cost of $66 for purchase and distribution,

(6) spends an average of $1.50 per year per receiver for maintenance,

(7) supplies batteries at a cost of $12.60 per year for purchase and distribution,

(8) provides no supplementary materials,

(9) transmits 180 radio programs per year via a single transmitter at a cost of $5,000 per year, and

(10) spends $1,000 per lesson for development of programs that have a six-year life expectancy.

Several of the above assumptions are questionable and it would be instructive for the reader to do similar computations with slightly different assumptions. For example, it was assumed in Table 3-4 that 256,000 students in the same grade could be reached by a single transmitter. In real life this is unlikely. What would happen to the average cost per student if two transmitters were needed? Five? Ten? What would happen to the cost if 36 hours of teacher training were given instead of the 6 hours assumed in Tables 3-3 and 3-4? What if the cost of the teacher's guide doubled? If the cost of the radio receiver doubled? What if no worksheets were used but the development cost increased by 50%? What if there are 50,000 students instead of 1,000 or 256,000?

4. SOME CAUTIONS ABOUT COST ESTIMATIONS

There are three rules to keep in mind when estimating costs:

(1) compute add-on costs only.

(2) consider hidden costs.

(3) compute costs to all contributors, not just to the government or project.

To use the radio lessons children need more than just a radio receiver and some worksheets. In most cases they also need a desk to work on, a chair to sit on, a roof, a chalkboard and chalk, and a teacher. None of these are cost-free. However, they are already part of the existing system and therefore their costs are not add-on costs and should not be considered. Although the cost of worksheets must be included, the cost of the pencils the children use to fill out these worksheets need not be considered since the children would ordinarily be expected to have pencils even without radio lessons.

Hidden costs are often difficult to detect. Among items that might be overlooked are administration costs--administration of the car pool, payroll division, purchasing and accounts payable. Similarly it is easy to forget personnel overhead costs such as vacation and sick leave benefits. These are most likely to be overlooked when the project works under the umbrella of some larger bureaucratic structure such as a Ministry of Education.

The costs that are easiest to miss are those that are paid by non-government sources. It is important to include the costs paid by all contributors, not just those that are paid directly by the project or by the government. The add-on costs to the local schools, to the teachers, and to the students must be included in order to get a realistic picture of the total costs of the project. If students, for example, are expected to provide some special kind of crayons that they would not otherwise purchase, then this is part of the add-on cost. If the teachers or the schools are expected to buy special materials then the cost of these must be included. If these are not included then the total add-on cost is being artificially lowered and the instructional system may be seen as inexpensive when in reality it is only shifting the financial burden from the government to the teachers or parents. If teachers are expected to put in more time preparing for the class than they would ordinarily, then they are contributing to the project and the monetary value of their contributed time must be estimated and included. Another cost that is often not paid directly by the project is broadcast time; the cost of broadcasting can be estimated by using the rates of commercial facilities that are comparable to the facility being used.

5. REDUCING UTILIZATION COSTS

Going back to Table 3-2, recall that, of the utilization costs, only those listed in Parts 1 and 2 are under the direct control of the program designers. Now look again at Tables 3-3 and 3-4, which are examples of the use of the form found in Table 3-2, and notice which costs do not change as the number of students increases from 1,000 to 256,000. The invariant per student cost are those in Parts 1 and 2, namely the costs for materials for individual students and the costs for materials and services that are supplied to each classroom. In Tables 3-3 and 3-4 the total of these two is $2.80. This invariant part of the average cost per student per year will not decrease no matter how many students are served. Even if the prorated costs of transmission and development approach zero, the average cost per student per year will never be less than $2.80. If we want to decrease the average cost below $2.80 per year we must directly tackle the invariant utilization costs.[2]

Since the invariant costs would not decrease if the coverage were extended, the only way to decrease the cost per student is to decrease the utilization costs--worksheets, teacher training and supervision, teachers' guide, etc. We will discuss each of these in order to see where costs can be decreased without significantly sacrificing quality.

6. WORKSHEETS AND OTHER INDIVIDUAL MATERIALS

In the computation in Tables 3-3 and 3-4 it was assumed that the students use worksheets. Worksheets are not the only possible individual material that could be used to support radio lessons. The Radio Mathematics Project has also distributed small cardboard rulers (in first grade) and reference tables for multiplication and division (in fourth grade). It was assumed that the life expectancy of both the rulers and the printed tables would be one year so these materials would be

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[2] One of the ways in which these sample computations was oversimplified was in not considering some cost breaks that would be obtained in actual cases; for instance, the cost per worksheet would decrease somewhat as the quantity increased--up to certain limits. The cost of producing teachers' guides is similarly lower in larger quantities. Also, if a large number of radio receivers are to be purchased it is quite likely that a discount could be obtained.

For making more accurate cost estimates these factors should be taken into account. Even though the computations presented here are not completely accurate it is still true that within certain ranges the cost of individual and classroom materials is essentially invariant.

distributed afresh every year. If more durable rulers and tables were used it is possible that they would serve for several years.

Printed materials likewise need not be throw-away items. If the students do not write on the worksheets but use them only for reading or as graphic illustrations then the sheets can be bound in textbook form and passed on to another child to use during next year. This is undoubtedly the easiest way to cut the cost of individual print support without sacrificing quality unduly. For very young children worksheets do enhance the quality of instruction greatly but for older children, say from third grade on, there will be only a slight reduction in quality if the printed materials are properly designed. A 150-page textbook designed to substitute for 150 worksheets can probably be produced in quantity for $2.00 per copy. If this book serves for even three years the cost per student per year will be reduced from $1.50 to 67¢, a significant reduction. If the textbooks last for six years or if two students share a single textbook the cost will go down to 33¢ per year, and if both of these happen the cost will be only 17¢. In fact, it is doubtful that such a cheap textbook would last so long, and there should be some provision for replacing lost and destroyed copies, so it is more reasonable to suppose that the lowest cost obtainable would be in the neighborhood of 50¢ per year. (If this alternative is under serious consideration an accurate cost estimate should be made.)

The cost of individual printed materials can be reduced further only by decreasing the number of pages. The extreme case would be to eliminate individual materials entirely, as was done by the Radio Mathematics Project in second, third, and fourth grades. This decision should not be taken lightly however since there is a real possibility that the quality of instruction would decline to unacceptable levels.

To get an estimate of the amount worksheets contribute to quality the Radio Mathematics Project conducted an experiment with parallel treatments of part of the first grade course. In one treatment the students received radio lessons that did not require worksheets. In the second treatment there were worksheets for about two lessons out of three. In all other ways the lessons were as similar as it was possible to make them. At the end of the experiment student achievement in the two groups was measured by a comprehensive posttest, and the results showed that there was no difference in quality between the programs that used worksheets and those that did not. This experiment was not conclusive since it involved only about one-third of the complete first grade program--during the first two-thirds of the year all students used lessons that required worksheets. Nevertheless, the results of the experiment have a profound implication for the design of radio-based instruction: well designed radio instruction can be effective without reliance on expensive supplementary materials.

In the case of mathematics it is quite clear that most topics can be taught well without worksheets if the instructional design is carefully thought out. The topics that can be successfully taught without worksheets include reading and writing numerals, addition, subtraction, multiplication, and application of all of these. The quality of instruction is most likely to decrease for topics that need more pictorial support: concept of fractions, equivalence of fractions, area, and other geometric topics. Strangely enough, the quality of instruction in addition and subtraction of fractions seems not to decrease even though the basic concept of fractions is more difficult to teach.

Eliminating, or reducing, individual print materials does not mean that supplementary visuals are not used. Most text and some pictorial illustrations can be put on the chalkboard by the teacher. In that case the project need supply only one copy of the material (in the teacher's guide) instead of supplying copies for each individual child. If the text is extensive or the drawings are complicated the teacher may spend an undue amount of time copying these onto the chalkboard, time that she could better spend teaching. In that case posters for classrooms could be supplied by the project. Posters should be used sparingly and with the due regard for cost, as they are expensive. Even though posters are used by 30 children at a time there may not be much cost savings.

The Radio Mathematics Project used posters in its second grade series as illustrations of fractions and area. Each poster was used for several lessons but even so it is estimated that it might have been cheaper to supply the same illustrations in the form of printed pages for each child.

Another substitute for printed pages that is frequently overlooked is plain paper. Since most children ordinarily buy small notebooks for their classroom use, this is not an add-on cost of radio instruction. If in a particular exercise the worksheet is being used only to provide space for the child to write then the transition to notebooks is straightforward. This happens in the mathematics programs, for example, in exercises where the child is asked to write the answer to some mental computation. In a language program it would occur with dictation of words or phrases for spelling practice.

In other types of exercises the transition may change the character of the task somewhat. In a multiple choice exercise in which the student is expected to underline the correct answer the alternatives might be written on the chalkboard (or printed in a reusable text) and the child asked to select and copy the correct answer. As another example, consider an exercise in which the child must count pictured objects and write the number below the picture. The picture could be put on the chalkboard or textbook and the child asked to write the number in

his notebook. A similar situation would occur in language if the child were asked to write the name of some pictured object.

In exercises in which there is a fixed relationship between the location of the printed matter and the location of the answer the elimination of worksheets changes the task significantly. In mathematics an example of this would be a printed exercise like:

$$\begin{array}{r} 23 \\ \underline{+\ 51} \end{array}$$

In this case the answer, 74, must be written in a specific location; it cannot be written above or to the side of the printed exercise. In language teaching a similar case would occur in an exercise in which the child must add punctuation marks to a printed sentence:

LETS PLAY BALL AFTER SCHOOL GEORGE SAID TO HARRY

The child's responses (quotation marks, apostrophe, comma, period) are not considered correct unless they are written in the correct places. In both of these cases the worksheet can be eliminated only if the student writes the exercises as well as his responses in his notebook. The Radio Mathematics Project solves this problem in two different ways. In second grade the exercises are written on the chalkboard by the teacher before the broadcast and copied by the children into their notebooks in anticipation of the radio instruction. In third grade the exercises are not copied in advance but are dictated by the radio teacher. In the case of the punctuation exercise cited above, one solution would be for the teacher to copy the unpunctuated sentence onto the chalkboard and then request the children to copy the sentence supplying the correct punctuation as they copied.

By using teaching strategies that take advantage of already available equipment and supplies, the add-on cost of radio-based instruction can be greatly reduced.

7. TEACHER TRAINING

In computing costs of teacher training one must include teachers' time, transportation, training materials, time of project staff, and possibly housing. Even if the teachers contribute their time and pay their own transportation the cost of these must be included if it is not something that is ordinarily expected of teachers. There may be some training materials, such as films, that can be used for several years; the cost of these must be annualized before summing. In computing the time of project staff members, include overhead and benefit costs.

For the Radio Mathematics Project it has been estimated that two 3-hour training sessions cost $15 per teacher. This is the estimate that was used in Tables 3-3 and 3-4. If you look at Part 2 of those tables you will see that the cost of teacher training is the largest component of the estimated classroom costs, and is a significant part of the total cost per student. If this cost can be halved or completely eliminated the cost saving will be considerable.

The Radio Mathematics Project has reduced teacher training to one 3-hour training session. Since the content varies little from year to year it is expected that only those teachers who have never used radio before will attend. When the children's programs are revised, after the six-year life has expired, teachers should return for a refresher session. By these means the cost of training can be reduced to about $1.50 per teacher per year.

To achieve such a drastic reduction in cost without reducing the quality of instruction puts great demands on the program designers. The radio lessons must be so easy to use that any teacher can use them effectively with essentially no training. The teachers' guides, too, must be simple, explicit, and completely self-explanatory since a single 3-hour session every 6 years is not sufficient for detailed explanations. To make radio lessons and teachers' guides completely self-contained is not an easy task and does increase the development cost. Even if the development cost increases by 50% there will be a net saving if there are 50,000 or more students per year. If the development cost increases by 20% (a more reasonable estimate) there will be a net saving with 10,000 students.

Another possibility for cost reduction is to use radio programs for teacher training. A short series of, say, six broadcasts could be prepared at a cost of $6,000; with a life expectancy of six years the annual cost would be $1,000. If there are 1500 teachers (about 50,000 students) the annual cost per teacher would be in the neighborhood of $2 per year. The same amount of time spent in traditional teacher training would be $8 or more, so there is a definite cost saving. (If special supplementary printed materials are required the cost of training by radio would be be greater.) It is not known whether radio training can be made as effective as face-to-face training sessions but it is an alternative well worth considering both because of its cost advantages and because of the logistic advantages--which are considerable for a widely-dispersed rural population.

8. SUPERVISION OF TEACHERS

Supervision of teachers, especially in nearly inaccessible rural schools, is quite expensive since it ordinarily entails classroom visits. There is little evidence that minimal supervision (two or three

visits a year) has much effect on the teachers' performance as a teacher. The greatest benefit that would likely be achieved would be an increase in usage of radio programs. To investigate this effect would involve a rigorously conducted study of usage with and without classroom visits.

Without such experimental evidence the Radio Mathematics Project took the stance that easy-to-use, obviously beneficial radio programs will probably be used fairly regularly even without supervision of teachers, and that any supervision beyond that already provided by the existing system would be prohibitively expensive.

We tried two methods of "supervision at a distance" with inconclusive but somewhat discouraging results. The first grade program was written to include embedded tests once a month beginning in about the fourth month of school. The tests were given by the radio teacher during the regular lesson and the children responded on a specially designed part of their worksheet. The teachers were requested to return these test worksheets to the district office. This system was designed to serve two purposes, as a pseudo-supervisory system and as a system for providing us with information that would lead to improvements in the instructional materials. There were no indications that the system acted as a "supervisory" system in the sense that it encouraged the teachers to use the radio more regularly than they would otherwise or that it helped them to adapt their teaching practices to the needs of the children.

We used another method of "supervision at a distance" in second grade. In this method the teachers were required to fill in a daily log that contained such questions as "Did your class use radio today?" and "Were there any problems with the radio receiver?". Most teachers filled in these logs and returned them monthly to the district office. A later study of this self-reported usage revealed no correlation with other indicators of usage. Although neither of these studies yielded conclusive results it was decided to abandon attempts to supervise at a distance.

9. TEACHERS' GUIDES

The Radio Mathematics Project supplies a separate guide for each grade in the form of a bound volume of about 200 pages.

The cost of reproducing and distributing this guide was about $9.00. Assuming a life of 6 years, the annualized cost is $1.50. (Realistically there should also be some allowance for replacement.) In computing the costs of teachers' guides it is necessary to allot one copy to every section of the grade, not one copy to every teacher since it may happen that a teacher has several grades in her room so she will need copies of the guides for each of those grades.

A cost of $9.00 is fairly high. It may be possible to reduce this when large quantities are required by using other means of reproduction and using cheaper paper. It is probably inadvisable to reduce the number of pages since there could be a significant reduction in the quality of instruction. Both the paper and the binding must be of sufficient quality to withstand six years of daily use.

Notice that the cost considered here is only the reproduction and distribution cost. The cost of writing the guide is included in development costs.

10. RADIO RECEIVERS

It is unlikely that a radio receiver of sufficient quality for use in a rather noisy classroom of 30 to 40 students can be purchased for much less than $50 or $60. In Tables 3-3 and 3-4 the cost for purchase and distribution was taken to be $66 and it was assumed that the life expectancy is six years. In regard to life expectancy very little is known of the average life of radio in regular classroom use. In Nicaragua it may well be that the life expectancy is more like four years since these radios are moved from place to place daily over dusty roads and in the rain. (There is no security in the schools so teachers must carry the radios home and back every day.)

Since the purchase price cannot be reduced much the greatest saving to be made in this area is to make provision for the sharing of radio receivers by several classrooms. In Nicaragua every receiver is used by as many as four classrooms during the day, being passed from one classroom to another between programs, etc. After each program there is a musical interlude of three minutes to allow for this activity. Note that here again the basic design of the radio programs is affected by cost considerations.

In large schools another possibility for cost saving is by using one receiver in one section of a grade with speakers in other sections of the same grade. The power requirements for such an installation would be more than for operating a single receiver but fortuitously the schools that are most likely to have several sections of each grade are exactly the schools that are likely to be wired for electricity, so batteries would not be needed.

11. MAINTENANCE OF RADIOS

The cost estimate used in Tables 3-3 and 3-4 for maintenance of radio receivers is based on an estimate made for the Radio Mathematics Project in which it was assumed that 10% of the radios are repaired every year at a cost of $15. Here again more field experience is needed to make

better estimates. Careful records should be kept to determine if any part of this cost stems from mishandling by teachers. If so, a reduction could be effected by including more instructions in the teacher training sessions or in the guides.

12. BATTERIES

The estimate of $12.60 for batteries for the year assumes 90 hours of use (180 half-hour programs). Thus even if radio receivers are shared by several classrooms each classroom will consume $12.60 of batteries.

If schools have electricity this cost can be cut to a few cents per year. If there are some schools that have electricity and others that haven't, the estimate must be made by using a weighted mean of these. Suppose, for example, that electricity cost 50 cents per year and that batteries cost $12.60, that there are 1000 classrooms with electricity and 2500 that need batteries. Then the weighted mean would be:

$$\frac{(.50 \times 1000) + (12.60 \times 2500)}{3500} = 9.14$$

In some cases schools have electricity that is used for lighting but do not have convenient outlets for the radio. It is usually well worth it to invest in extensions rather than use batteries in these schools.

13. POSTERS AND OTHER CLASSROOM MATERIALS

As mentioned before, posters are quite expensive so a careful cost analysis should be done before using them extensively. In Tables 3-3 and 3-4 we assumed there are no posters or other classroom materials.

14. SUMMARY OF UTILIZATION COST SAVINGS

Many of the components of the utilization cost can be controlled by the program designer. The components that are most susceptible to cost trimming are:

- materials for individual students
- teacher training
- supervision of teachers
- posters and other shared instructional materials

Some cost savings can also be made by sharing radio receivers and avoiding the use of batteries if at all possible.

In almost all cases cost savings are achieved only by reducing the quality of instruction to some extent, so tradeoffs must be seriously studied before decisions are made. Sometimes the utilization cost can be decreased without loss in instructional quality if more effort is put into the design and production of instructional materials; this can be done only by increasing the development cost, so again the tradeoff must be studied before the decision is made.

15. DEVELOPMENT COSTS

A complete analysis of the components of development cost will not be made. The interested reader is referred to a detailed study of the Radio Mathematics Project done by Wells and Klees (1978).

In general, the instructional quality of the programs is directly proportional to the development cost. Furthermore, many cost savings in utilization can be made by increasing development cost. If the target audience is sufficiently large, say 50,000 students or more, the prorated development cost is fairly low and it is generally feasible to consider increasing development cost to effect greater achievement or to reduce utilization costs.

Chapter 4

PLANNING THE CURRICULUM

Before beginning each year's production, there must be a complete and fairly detailed plan for the content of the course to be prepared during that year. This "master" plan should consist of a description of the topics to be taught, the level of performance the children are expected to reach in each topic, a list of prerequisites for each topic, a description of the way in which each topic is to be taught, a pool of exercises to use in teaching the topic, and a tentative time schedule.

For a year-long course, the development of the master plan requires two to three months of the curriculum designer's time along with perhaps five or six months' assistance from others in gathering baseline data--designing and producing tests, administering them in classrooms, analyzing the data, etc. Curriculum planning should start at least a year in advance of production because of the need to test both incoming and outgoing skills of children receiving conventional instruction.

1. DESCRIBING THE TOPICS

Each topic included in the master plan should be specified in behavioral terms. That is, the topic should be defined by giving a precise description of the kind of behavior one would expect as evidence that a child had mastered the topic. In skill subjects like arithmetic, one way to describe behavioral objectives is to list the exercises and problems the child will be able to do after learning the topic. For example, we might define a certain topic in numeration by giving the following description:

> The child will write from dictation any of the numbers 10, 20, 30, 40, 50, 60, 70, 80, and 90.

This kind of description is concise, describes the form in which the stimulus is to be cast (the examiner will orally instruct the child to write a specified number), and clearly defines the behavior of the child (he will write, not answer orally; he will not be expected to count; etc.).

One advantage of phrasing the description in behavioral terms is that test items can be easily produced. In fact, many topics can be described by simply listing all the test items that could be used to determine whether the child has learned the concept.

For some topics, the possible test items cannot be listed simply because there are too many of them. In arithmetic, this is less of a

problem than in other subjects since entire classes of exercises can be described quite well by specifying constraints on the numbers to be used in the exercises. For example, we might describe one topic in numeration in the following way:

> The child will write from dictation any number of the form <u>abc</u> where <u>a</u> is any digit from 1 to 9, <u>b</u> is any digit from 1 to 9, and <u>c</u> is any digit from 0 to 9.

This topic would then include numbers like 237, 230, and 517 but not numbers like 203, 401, or 700. As another example, again using small letters to stand for single digits, one of the topics in column addition could be described as follows:

> The child will be able to solve printed exercises of the form:

$$\begin{array}{r} ab \\ c \\ \underline{+\ d} \end{array} \quad \text{or} \quad \begin{array}{r} c \\ ab \\ \underline{+\ d} \end{array} \quad \text{or} \quad \begin{array}{r} c \\ d \\ \underline{+\ ab} \end{array}$$

> where <u>a</u> is any digit from 1 to 9;
> <u>b</u>, <u>c</u>, and <u>d</u> are any digits from 0 to 9; and
> <u>b</u> + <u>c</u> + <u>d</u> is 9 or less.

This method of specifying exercises is so precise that a computer can be programmed to generate entire classes of exercises.

Arithmetic is naturally more amenable to this kind of treatment than other subjects. Whenever natural language is involved, as in applications of arithmetic, in reading comprehension exercises, in grammar, or in language usage, the specifications of the exercises cannot be quite so precise. It is nevertheless of great importance to define the topic as precisely as possible. It may be necessary (and is usually very helpful to the script writers and test designers) to include lists of sample items. And sometimes it is even more important to describe and exemplify exercises that are to be excluded. How precisely descriptions must be written depends upon the subject and the experience of the team members. The purpose is to communicate the ideas from the curriculum designers to the script writers, studio directors, test designers, classroom observers, and others who are involved in the production and evaluation of the materials. We followed two rules of thumb that might be helpful to others: (1) Use clear, rather than "legalistic" language. You do not need to explicitly close all the loopholes if your team members understand your intent. (2) As a check on the clarity of the description, ask various team members to produce (without consultation) lists of sample exercises to be included and excluded; if these satisfy the curriculum designer, then it can be assumed that the description was adequate.

2. SCOPE OF OBJECTIVES

We have not yet dealt with the question of how broad a "topic" should be. A large part of the elementary school mathematics curriculum would be encompassed by an objective phrased as follows:

> The child will be able to read, write, order, add, subtract, multiply, or divide any numbers given in either oral or printed form, with or without being embedded in the context of a described or actual problem situation.

Clearly, this objective is too broad for the purposes of producing instructional materials. The following is more useful, but still not specific enough:

> The child will solve any column addition exercise with up to four addends and up to four columns.

At the other end of the scale, the following description indicates too fine a division of the curriculum:

The child will be able to solve these two exercises:

$$\begin{array}{r} 24 \\ \underline{+\ 13} \end{array} \qquad \begin{array}{r} 45 \\ \underline{+\ 33} \end{array}$$

There are two approaches to the problem of finding a suitable subdivision of the content. One, which I would call a "top down" approach, would proceed along the following lines: Write a very general description of the entire curriculum dividing it into some five or ten major topics (integer addition, measurement, etc.), subdivide each of these (column addition, addition equations, mental addition, etc.), and divide again (one-column addition, two-column addition without carrying, two-column addition with carrying, etc.) until each subdivision is small enough so that each topic corresponds to what you would think of as one clearly defined step in the teaching process. For a year-long course of instruction in a subject taught daily there might be 200 to 300 topics.

The other, or "bottom up," approach is to think not in terms of topics or even exercises but in terms of the skills that are required to do the exercises. In one sense, this is a more "educational" way of thinking since the purpose of most instruction is not to drill the children until they have memorized the answers to specific exercises, but rather to impart to them the mental skills that they will need in order

to solve the problems for themselves. We never need to teach children how to do the specific exercise

$$\begin{array}{r} 4872 \\ 3501 \\ \underline{+\ 789} \end{array}$$

Instead, our aim is to teach children the skills they would use to do that exercise if they ever needed to. The descriptions of the topics should still be in terms of exercises but the organizational emphasis would be on *skills*, not *exercises*.

3. DETERMINING THE NECESSARY SKILLS

In the "bottom up" approach the curriculum designer must identify the skills he wishes to impart, and then select suitable tasks to use as a vehicle for teaching those skills to the students. Although this sounds simple, in practice it is often remarkably difficult to determine precisely what skills are required for the completion of a specific task. Even analyzing something as seemingly simple as column addition has many pitfalls. Some experts advocate introspection as a means of analyzing a task to determine the component skills that are required. That is, they perform the task themselves, carefully auditing the mental processes they employ at each step. An introspective analysis of a task like

$$\begin{array}{r} 54 \\ \underline{+\ 29} \end{array}$$

might go something like this: "First I add 4 and 9 and get 13. I break 13 into two components, 1 and 3. The 3 is written below the line and the 1 is written above the next column ..." From this kind of introspective analysis the curriculum designer would derive a general description of the skills used in doing such exercises: adding two one-digit numbers, decomposing a two-digit number into its tens component and its ones component, recording the ones component, etc.

Introspective analysis is a useful first step but cannot be used as the only tool for determining the underlying skills. One disadvantage of relying completely on introspective analysis is that a person who is quite competent at a particular task may have such complete, unconscious mastery of some skills that he is unable to articulate them. These completely internalized skills can never be revealed by introspection. In the addition example above, several critical skills were not mentioned: the decision to start with the column 4 + 9 rather than the column 3 + 1, how to determine the sum of 4 and 9, the decision to carry. If this same exercise were done by children in first and second grade, some of them would start with the column 3 + 1, some would add 4 and 9 incorrectly, and some would not carry but would simply write both digits

of the number 13 in the same column:

$$\begin{array}{r} 5\ 4 \\ +\ 2\ 9 \\ \hline 713 \end{array}$$

This kind of evidence illustrates that there are skills in column addition that may not be revealed by introspection.

The above remarks motivate four points I want to make about task analysis. First, although introspective analysis is valuable, it serves only as a springboard by helping to formulate some initial hypotheses about the kinds of skills involved in a task. Second, the skills most often overlooked in introspective analysis are decision-making skills rather than the more straightforward operational skills. Third, the best--and, as far as I know, only--way to test the hypotheses generated by introspective analysis and to identify skills not revealed by introspective analysis is to gather performance data from students who are in the process of acquiring the skills in question. Fourth, the most informative kind of performance data to gather is the actual errors made by children, for it is often only by studying the errors that one can infer the nature of the skills required.

It was mentioned above that in introspective analysis important skills may be overlooked. The opposite is also true: it is easy to postulate skills that are not important for the purposes of designing the curriculum. The skill of adding a single column in a multicolumn exercise, for instance, requires that the student focus on each digit, perceive its distinguishing characteristics, and mentally associate the correct numeric concept with that numeral; he must also be able to grasp a pencil correctly, have the hand-eye coordination needed to write the answer, etc. While it is true that all of these skills enter into column addition, any of them that have already been acquired by all students who will take the lessons need not be considered. The curriculum designer should be concerned only with those skills that are needed *and* that the children have not already acquired. The set of skills that need be considered depends on the aptitudes and experiences of the children to be taught.

Also, there is no need to be overly concerned with the underlying psychological mechanism of skills; in many cases, one can teach skills quite well without being able to give a precise description of the skill that is being taught. Instead of using a psychological definition of skills, the curriculum designer can rely on operational definitions. These operational definitions are derived from analysis of the errors children make. The reasoning is as follows. A child who consistently uses some incorrect strategy has a misconception--or "missing conception." It is this "missing conception" that is the skill to be defined. We do not have to say what the skill is, but only what it is not.

The kinds of errors that give rise to these operational definitions of skills are the systematic errors, that is, the errors that have a pattern that is so well-defined that the exact error a child will make can be predicted. A first grader, for example, might write 402 for forty-two, 705 for seventy-five, and 207 for twenty-seven, and we could accurately predict that he will write 302 for thirty-two and 901 for ninety-one. Note that we are not simply predicting that he will make an incorrect response when asked to write 32 or 91; we are predicting exactly what form this incorrect response will take. Since the error consists of writing a zero where it is not needed, the operational definition of the lacking skill is phrased negatively: the skill of *not* writing a zero between the digits of a two-digit number.

An advantage of this kind of operational definition of a skill is that, if we look only at the errors committed by children in the group for whom the instruction is intended, we will consider only those skills that are pertinent to the group of children we intend to instruct.

To use this approach to skill definition, the curriculum designer needs a great deal of data on how children respond to the kinds of tasks contained in the curriculum. These data must be collected from children who are involved in the process of learning to do the tasks in question, since children who have already mastered the topics will not make the kinds of errors that will help identify the skills to be taught. In analyzing errors, it is necessary to have data on a number of similar exercises so that similarities in incorrect responses can be detected. In order to develop sets of exercises that require the same skills, some preliminary definition of skills must be used. This preliminary definition might be derived from introspective analysis. If it turns out that there are many skills that were not anticipated, it may be necessary to revise the list of hypothesized skills and use the revised hypotheses as a basis for revising the test.

Even after several rounds of testing, it is unlikely that all errors will be successfully categorized. Detecting systematic errors is difficult. Even in arithmetic where errors are relatively easy to classify, experienced researchers have succeeded in identifying the misconceptions in only about half the incorrect answers given by children. It would be easy to say that the unclassified incorrect answers are the result of "random" errors, but for the fact that there is experimental evidence of consistency in many of those incorrect answers even though the researchers still cannot describe them well enough to predict the errors children will make on other similar exercises.

4. GROUPING EXERCISES

Continuing with the bottom-up, or "skill referenced," approach to curriculum design, the next job of the curriculum designer, after the

relevant skills have been determined, is to specify appropriate tasks to be used in teaching and testing these skills. Ideally, one would like to start the teaching of each skill in the simplest possible context, with tasks requiring that one skill and no others. In practice, such tasks rarely exist. Almost every kind of meaningful exercise or task that could be included in a curriculum will require two, three, or even a dozen component skills. There is no exercise that requires carrying that does not also require the ability to read and write numerals, the ability to add two one-digit numbers, etc.

It is at this point that the top-down and bottom-up approaches to curriculum design converge. Previously, in talking about the top-down approach, I suggested dividing and subdividing the entire curriculum until a suitably fine subdivision was reached. However, I gave no guidelines for classifying exercises nor for knowing when to stop subdividing. Now, with the idea of a skill as being the underlying organizational device, we can see that the process of subdividing the tasks and exercises encompassed by the curriculum becomes a process of grouping tasks in accordance with the skills required. If two tasks require exactly the same skills, they should fall into the same class of exercises. Thus, we see why it is ridiculous to have a class of exercises consisting only of

$$\begin{array}{r} 24 \\ \underline{+\ 13} \end{array} \quad \text{and} \quad \begin{array}{r} 45 \\ \underline{+\ 33} \end{array}$$

There are many, many other addition exercises that require the same skills as these two. All of these exercises should be grouped together.

After the skills have been enumerated, the entire set of exercises should be divided so that all exercises that require exactly the same skills would be grouped together. Each such set of exercises would correspond to a "type" of exercise. The exercises of each type would all be of the same level of difficulty since each would require exactly the same skills. This characteristic of exercise types provides the curriculum designer with a basis for determining empirically whether he has defined the skills appropriately: if a group of children are given a random sampling of exercises of the same type, one would expect that the proportion of correct responses would be about the same for all exercises. Furthermore, one would expect the distribution of types of incorrect responses to be about the same.

5. DETERMINING PREREQUISITE RELATIONSHIPS

In designing a curriculum, it is not enough simply to list the topics to be included. One also needs to know how these topics are to be ordered. The most important factor in sequencing topics is the prerequisite relationships among them.

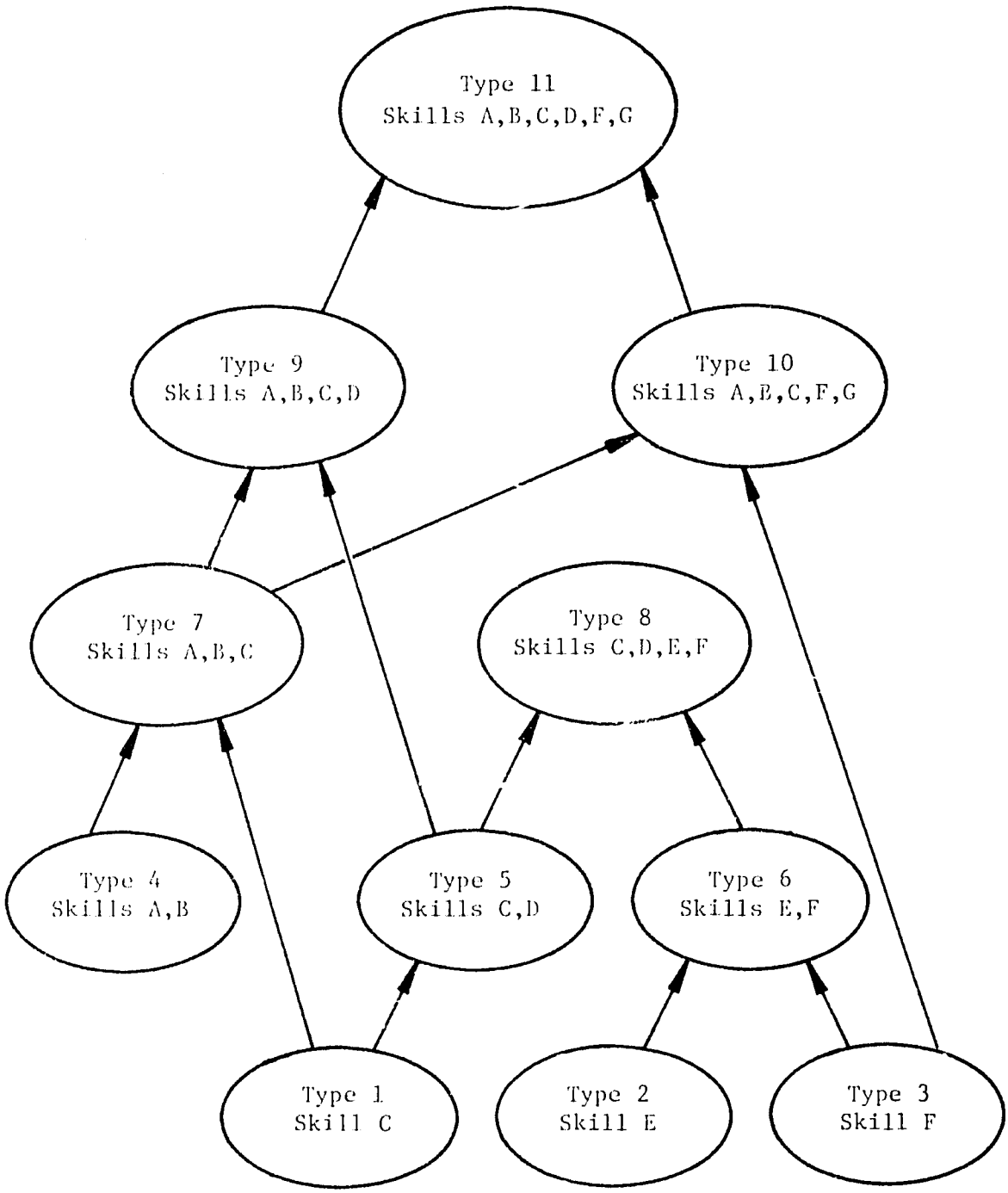

FIGURE 4-1.
An Example of a Prerequisite Hierarchy of Curriculum Topics

The prerequisite relationship among different types of exercises is determined by the skills involved in those exercises. Exercise types can be arranged into a prerequisite hierarchy by using the following rule: Type X is prerequisite to Type Y if and only if the set of skills required by exercises of Type X is a subset of the set of skills required by exercises of Type Y. An example of such a prerequisite hierarchy is shown in Figure 4-1. The circles represent exercise types. The arrows between circles represent the prerequisite relationship; Type 1 is prerequisite to Type 5, Type 2 and 3 are prerequisites to Type 6, etc. Note that although Types 5 and 7 have some skills in common, neither is prerequisite to the other since each has a skill that is not required by the other.

Viewing the prerequisite relationships in this way provides the curriculum designer with yet another tool for empirical investigation of the postulated skill structure. The implication of a prerequisite connection between two types of exercises is that if a child has mastered some type of exercise, then he has necessarily also mastered all prerequisites. By testing, one could find out which children had mastered Type 8 from Figure 4-1, for instance; if those children were further tested, it should turn out that they have also mastered Types 5 and 6 (and, of course, the even more fundamental Types 1, 2, and 3). The converse is also true: a child who has not mastered Type 5 would be expected to fail with Type 8.

In practice, one cannot expect complete mastery so what test results would show would be steadily declined performance on exercises from higher and higher branches on the prerequisite tree. If a number of exercises of each type were given to one child, that child might score 90% on Types 1, 2, 3, and 4; 80% on Types 5 and 7; 70% on Type 6; and 0% on higher types.

There is another implication of this kind of hierarchical structure that is not captured by the tree diagram of Figure 4-1; if a student has mastered all of the component skills for a specific task, then he can do the task even though he has received no specific instruction using exactly that kind of exercise. For example, if a child has mastered exercise Types 2 and 3, it can be inferred that he has acquired the relevant skills E and F. Since he has both of those skills, he should then be able to do exercises of Type 6 since those exercises require only those two skills. If, on investigation, it is found that such transfer of learning does not occur, this indicates a deficiency in the postulated skill structure; there must be some previously unsuspected skill that is entering into exercises of Type 6.

Other places where such transfer would be expected would be with Type 8 (transfer from Types 5 and 6), with Type 7 (transfer from Types 1 and 4), with Type 9 (transfer from Types 7 and 5), and Type 11 (transfer from Types 9 and 10). The implication, then, is that Exercise Types 6,

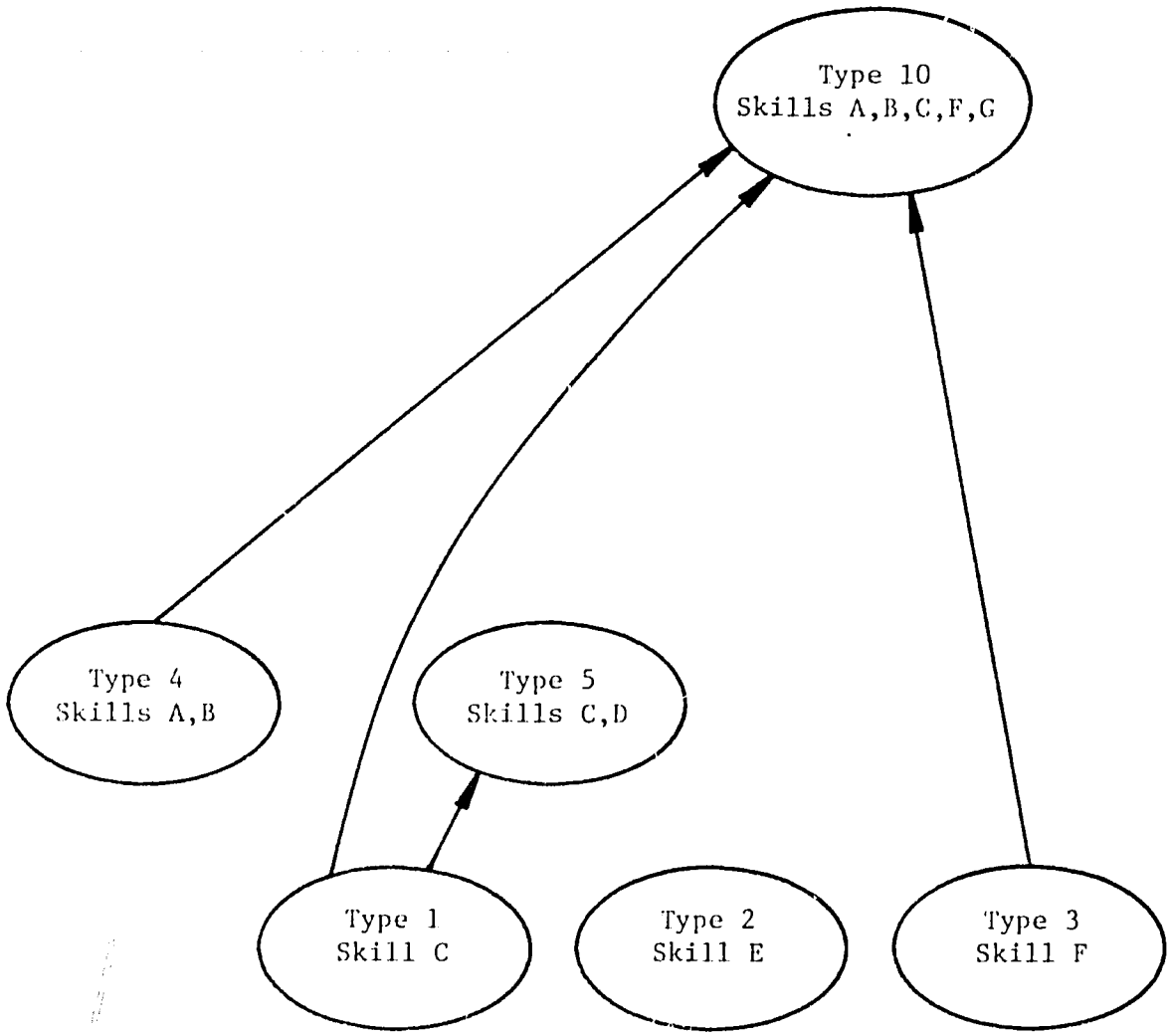

FIGURE 4-2.
An Example of a Pruned Prerequisite Hierarchy of Curriculum Topics

7, 8, 9, and 11 are redundant; they will be learned without being directly taught. This sort of thing does in fact happen. Although there are around 200 types of column addition exercises (with up to four addends and three columns), students can be taught all of the component skills by using fewer than 40 of these types.

If the prerequisite hierarchy is reduced by eliminating the redundant exercise types, the structure becomes the much simpler one shown in Figure 4-2. Generally, practical considerations about the difficulty of teaching each skill and the amount of practice the children will need will temper the decision about how severely to prune the tree. If it is anticipated that Skill C, for instance, will be particularly difficult for the children, then one might want to leave in exercises of Type 7 to provide more practice and to make the transition to Type 10 somewhat easier. Also, for practice that is provided for retention of skills after initial instruction, exercises might be drawn from Types 6, 8, 9, and 11 in order to offer some variety to the children.

6. DECIDING ON TEACHING STRATEGIES

After topics are described and ordered into a hierarchy such as that shown in Figure 4-2, the curriculum designer should turn to pedagogical concerns. Generally, there are many ways in which to teach any given topic and it is the task of the curriculum designer to determine which shall be used. It is here that consideration of the constraints described in Chapter 3 enter in. A teaching strategy that would be ideal for a small group of students in a well-equipped classroom may be quite impossible in overcrowded and under-equipped classes. A method that involves the use of a quantity of expensive printed materials cannot be chosen if there are severe cost constraints, and so on. After a teaching strategy has been determined, the precise nature of the tasks (exercise formats and content) must be specified. These tasks must then be studied to determine if they will require prerequisite knowledge that is not already included in the curriculum. As an example, in the radio mathematics lessons, one of the tasks used in teaching ordinal numbers required the children to circle the first (or second or third) of a group of pictures printed on their worksheets. To accomplish this task, the children had to understand the instruction "Circle the..." and had to perform the physical action of circling a specified picture. Hence, as a prerequisite to this activity, the children had to learn to circle a picture following instructions from the radio teacher. Although this activity is not part of the mathematics curriculum per se it had to be included as an "interim" objective. Other interim objectives might be understanding the language to be used in instructions, identifying pictured objects, or recognizing certain sound effects. These interim objectives form a small but essential (and often overlooked) part of the curriculum.

Besides adding new topics to the curriculum, pedagogical considerations might also cause the addition of new links between existing topics. One example from the radio mathematics lessons concerns two topics: solving arithmetic exercises given in column format, and writing the same kind of exercises from dictation. Ordinarily, children would learn to do arithmetic exercises by practicing on exercises that are already printed for them. Only after they learned how to do the exercises would they be expected to write the exercise as well as solve it. This is partly because writing exercises is a time-consuming and tedious task, and partly because some exercises, like this one:

```
   4
  25
 601
+  3
```

are extraordinarily difficult for children to write because of the problem of aligning the columns correctly. It is not unusual to find children who can solve such exercises without difficulty but who can still not transcribe them correctly. In the radio mathematics lessons, because of cost considerations we wanted to dispense with printed materials in second, third and fourth grades, so we could not supply the children with worksheets of printed exercises. As an alternative, we used a method of instruction in which the children would transcribe such exercises from dictation. This meant we had to view the transcription of these exercises as a prerequisite to their solution. This added a prerequisite link between two topics that would ordinarily be viewed as independent.

7. SETTING MINIMAL PROFICIENCY STANDARDS

After the interim objectives are added to the instructional hierarchy, the next task is to determine for each topic in the hierarchy the level of achievement to be attained by children. A common error made by curriculum designers is to assume that all children will attain complete mastery of all topics. This is a quite unrealistic goal: students seldom attain complete mastery of all skills. (Even after years of practice I still make mistakes in balancing my checkbook and spelling certain words.) Performance criteria could, of course, be set arbitrarily, and in the absence of more information, you may have to resort to this. The reason it is important to set some criteria rather than simply assume the children will learn as much as they can is because these criteria will be the basis for making decisions during the feedback phase of production. As an example, suppose that two topics, A and B, have been taught. The children are tested to find out how well they have learned these, and the results show that their performance on A is 80% correct but on B it is only 70% correct. There is time left in the school year to provide more practice in one topic but not both. Which topic

should be reviewed? That depends on the performance criteria set for the two topics. If the criterion for Topic A is 90% and the criterion for Topic B is 70%, then the correct choice is Topic A. Unless specific minimum values are given by the curriculum designer there will be no basis for making such decisions at a later time.

One way to set performance goals is to determine how much children learn under a different system of instruction for the same subject. In the case of the Radio Mathematics Project, our goals could be directly compared to the goals of conventional instruction. What we wanted, then, was to determine how well children performed in the conventional system and set our *minimum* goals to this level. We tested children in conventional classrooms at the end of the school year, and used these results to guide us in setting criteria of performance for the radio-based curriculum.

8. DETERMINING THE SCOPE OF THE COURSE

If the minimum proficiency standards are set by testing children in conventional schools, one of the outcomes may be that the criteria of performance for some topics may be so close to zero that it is not worthwhile to include any instruction on that topic. It is often the case that official curriculum guidelines are too ambitious, asking more of the children than they are able to achieve. It is not desirable to try to teach topics that are beyond the abilities of the students, both because they will become frustrated and also because such instruction will take time that could better have been spent in providing the children opportunities to consolidate their understanding of more basic topics.

Thus, the amount children learn from conventional instruction can influence decisions about the scope of the curriculum. At the other end of the scale, the amount children know at the beginning of the year may also affect the scope of the course. Children may not have the prerequisite skills needed to cope with the topics on the lowest level of the hierarchy, so instruction in prerequisite skills will need to be added. In other cases, the level of incoming skills may be higher than expected, so some of the lower-level topics can be eliminated from the curriculum. In Nicaragua, we found that incoming first graders already have the concept of number, can count quite well up to 5 or 6, and can count by rote far beyond that. They also understand such concepts as larger and smaller, above and below. As a result, we could start the instruction for first grade from a higher level than we had anticipated.

9. PRODUCING A TIME SCHEDULE

At this point in the curriculum design, an instructional hierarchy has been developed and pruned (or augmented) to fit the needs

and abilities of the students for whom the curriculum is being designed. For each topic in the hierarchy, an instructional strategy has been determined, and minimum criteria for performance have been established. The next step is to establish a tentative time schedule for instruction. This schedule is tentative because the amount of instruction needed for each topic cannot be precisely predicted but must be determined by feedback obtained later in the year. In making a preliminary time allocation, you will need estimates of both the total time to be used for instruction and the time period over which the instruction is to be distributed. The total time for instruction can be estimated in terms of the number of instructional segments needed if all instructional segments are to be roughly the same length. For the radio mathematics programs we assumed that instruction would be broken into small segments of two to six minutes and that a lesson would not ordinarily have more than one segment on the same topic. We planned for five to ten segments per topic on the average, although this varied widely depending upon the difficulty of the topic. The instruction would be spread over one week if five or fewer segments were planned, two weeks for six to ten segments, etc.

The prerequisite relationship, as depicted in the instructional hierarchy, imposes strong constraints on the sequence in which topics can be taught, and these constraints, together with the time constraints, must be taken into account when making up a time schedule. Usually a great deal of juggling is necessary before all of these constraints are satisfied and an acceptable preliminary plan is established.

10. PRODUCING POOLS OF EXERCISES

If possible, it is best to have a pool of already prepared exercises for each topic. This puts less demand on the lesson planner to invent appropriate examples at a time when he may be under considerable time pressure to produce outlines on schedule. Exercise pools made at leisure--well before the continuous pressure of keeping up a daily production schedule begins--are generally more carefully thought out, contain fewer ambiguities, and more nearly cover the intended scope of the rules and principles to be taught. Such exercise pools have the added advantage of providing items for weekly tests.

For mathematics, we relied heavily on pools of exercises that were generated by computer. These exercises, whose formats were carefully thought out in advance, were made up of randomly generated digits, thus assuring us that we were not neglecting any of the possible number combinations. Most curriculum writers and teachers have "number prejudices", that is, they tend to prefer certain combinations and neglect others when making up arithmetic exercises for children. Zeros, for example, are commonly neglected. And some people have a tendency to overuse doubles like 4 + 4 and 6 + 6, or to use even numbers more often than odd. There are also order preferences--exercises like:

$$\begin{array}{r} 42 \\ \underline{+\ 3} \end{array} \quad \text{and} \quad \begin{array}{r} 540 \\ \underline{+\ 26} \end{array}$$

are much more common than:

$$\begin{array}{r} 3 \\ \underline{+\ 42} \end{array} \quad \text{and} \quad \begin{array}{r} 26 \\ \underline{+\ 540} \end{array}$$

In language arts and other subject areas there are also prejudices toward certain vocabulary and types of sentences. Although it would be difficult to use a computer to generate exercises written in natural language, there are other measures that can be taken to produce a wider range of exercises. One is to prepare pools of exercises over a period of time, making an effort to diversify. Another is to have several people work independently on the same exercise pools. Discussion also generates ideas that a person working alone will not have.

Besides the content, the exercise specifications must also define the format of the exercise and the kind of response expected of the children. An exercise like 5 + 8 can be given in several forms, with different kinds of responses. It can, for example, be given orally using a question like:

How much is 5 plus 8?

The exercise could also be given as a deferred oral response, using instructions like the following:

Think quietly, without saying anything, about 5 plus 8...

(PAUSE:10 SECONDS)

Tell me: how much is it?

The exercise could also be given orally but with a request for a written response:

Write the answer to 5 plus 8.

Or the exercise can be given in written form as:

5 + 8 = _____

or as:

$$\begin{array}{r} 5 \\ \underline{+\ 8} \end{array}$$

These written exercises could be printed on a worksheet, they could be

copied by the children from the chalkboard into their notebooks before the radio broadcast began, they could be copied from the chalkboard during the broadcast, or they could be dictated to the children by the radio teacher.

Since each of these forms of the exercise requires different skills, they will probably be in different exercise pools. The above mentioned exercises would have been divided into classes like:

- Oral addition, with concrete material
- Oral addition, sums to 9 or less
- Horizontal addition, sums to 9 or less
- Column addition, printed exercises, sums to 9 or less
- Column addition, dictated, sums to 9 or less

Even with this division of exercises into different exercises pools, there will still be slight differences between exercises in the same pool. All variants that are to be used should be specified. In the above example, the topic "Oral addition, sums to 9" would include oral exercises with immediate oral response, oral exercises with deferred oral response, and oral exercises with written response; all of these variants would be included in the same exercise pool.

Another part of the exercise specification is the definition of what constitutes a correct answer. For exercises in mathematics, it is usually clear what the correct answer will be. In other subjects, correct answers for each exercise must be specified if there is any chance of misinterpretation. Suppose children are asked to write the answer to a question like:

What day comes before Thursday?

It must be specified whether the answer must be a complete sentence, whether misspellings of "Wednesday" will be accepted, and so on.

Chapter 5

PLANNING A LESSON

1. THE PRODUCTION CYCLE

The feedback system of producing curriculum materials requires that design of new materials be based on feedback collected in the classrooms. The more rapidly these data can be fed back into the production system the more responsive the curriculum will be to the current needs of the children being served. Although the time needed to prepare radio programs and to prepare and distribute printed materials is likely to be several weeks, it is imperative to keep production time as short as possible. One way to save time is to do tasks concurrently whenever possible. For example, production of broadcast lessons and production of printed materials can be done in parallel, as shown in the simplified production cycle depicted in Figure 5-1. The time needed to produce a lesson can be decreased even more by dividing the tasks even more finely. Several script writers can work on the same script, for example; instructional segments on different topics can be done by different script writers, while still another writer is preparing entertainment segments for the same lesson. At the same time, other team members can be writing the teachers' guide and still others can be designing the worksheet.

Shortening the production cycle by using parallel production is one of the means by which the curriculum is made more responsive to the needs of the students. But parallel production is not without cost. The more people there are working on the same lesson, the greater the probability of inconsistencies. Scripts may refer to a worksheet that the children won't have because the guide didn't advise the teachers to distribute them, a script may instruct the children to circle a picture of a horse when the worksheet contains a picture of a cow, and so on. To avoid such inconsistencies, the lesson must be planned in greater detail than would be necessary if only one person were to produce all parts of the lesson. Also, the lesson must be edited more carefully not only to check the quality of each part but also to ensure that the parts are properly articulated. A schema for a production cycle with editorial checks is shown in Figure 5-2.

2. THE LESSON PLAN

The plan for each lesson should contain enough detail so that several people can work on the same lesson without introducing inconsistencies between the parts. The plan should contain a list of topics to be included in the radio broadcast and in the postbroadcast

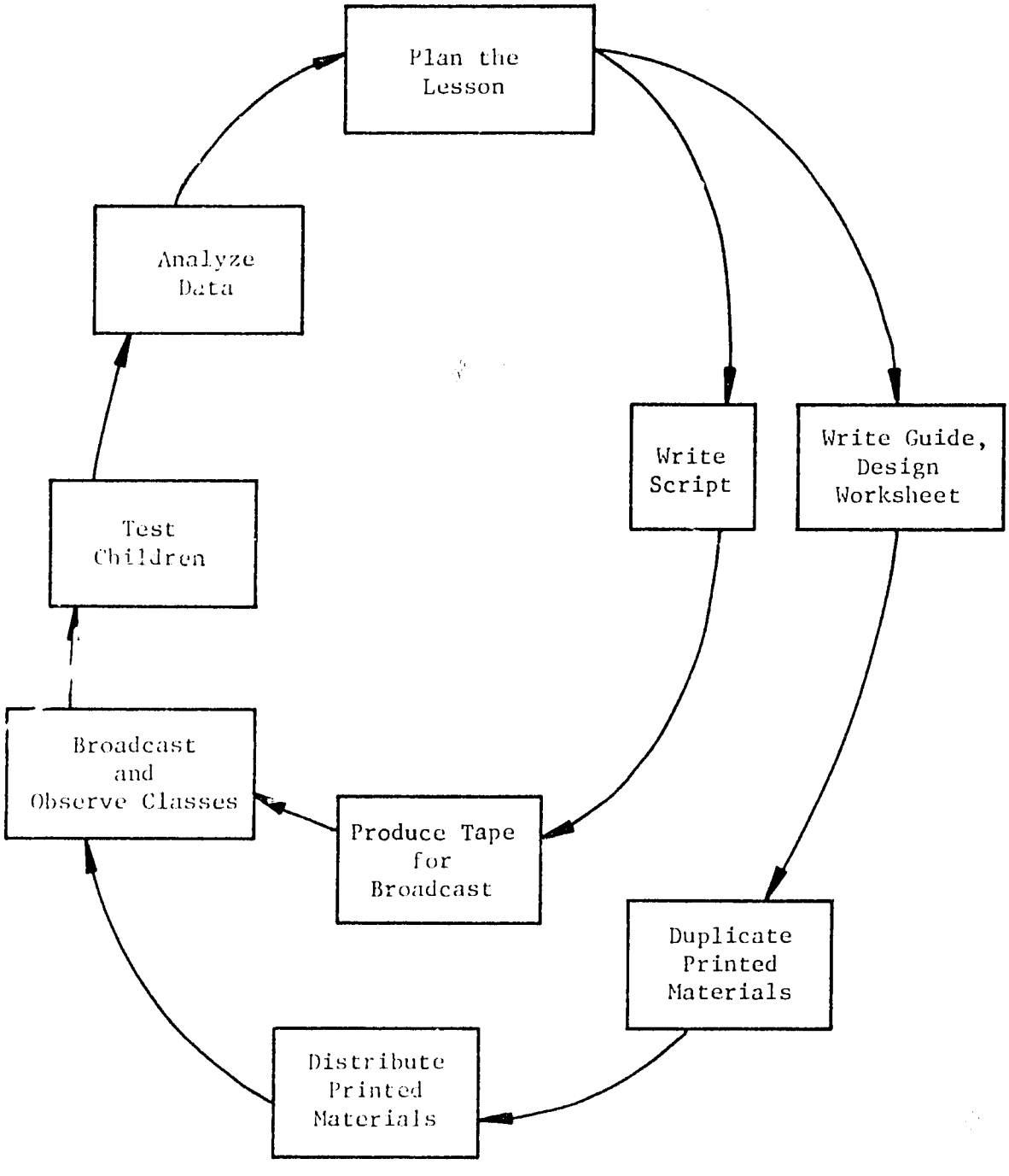

FIGURE 5-1.
Production Cycle

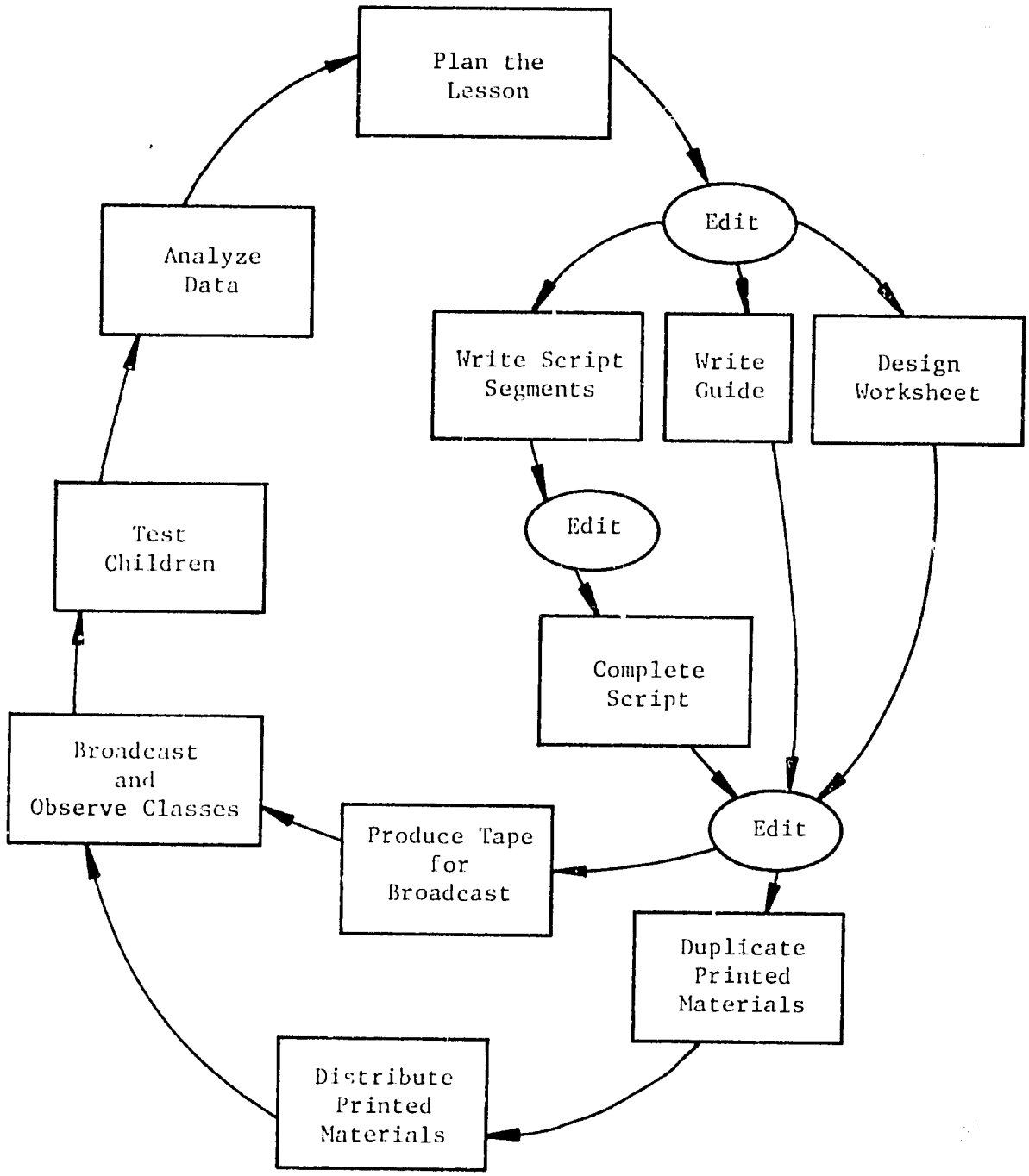

FIGURE 5-2.
Production Cycle with Editorial Checks

Grade 1 Lesson 47 Version 1 Date 5/5/75

Materials, broadcast: Worksheet #47
Materials, postbroadcast: For each child, 20-30 objects for counting

DESCRIPTION OF SEGMENT	TAUGHT BY	MATERIALS	TYPE OF RESPONSE	TIME	EXERCISES
APL 9.3 Applications of Addition and Subtraction	Radio	None	Oral	3 sec.	5 + 1, 3 - 2, 1 + 4
NUM 113.1 Greater and Less	Radio	None	Oral	3 sec.	Greater: 2, 4 Less: 3, 1 Less: 2, 5 Greater: 5, 1 Greater: 6, 2
ADD 23.1 Oral Addition	Radio	None	Oral	3 sec.	5 + 1, 1 + 2, 2 + 1, 4 + 3, 5 + 3
NUM 108.2 Successors	Radio	None	Oral	3 sec.	9, 19, 29, 39 49
NUM 110.2 Reading Numerals	Radio	Work-sheet, Part 1	Multiple Choice	8 sec.	13, 10, 12, 11, 14
NUM 114.1 Writing Numerals	Radio	Work-sheet, Part 2	Written Numeral	10 sec.	9, 15, 6, 13, 12
APL 12.1 Money Indentifi-cation of Bills	Radio	Work-sheet, Part 3	Multiple Choice	5 sec.	$10, $5, $1, $10, $2
NUM 115.1 Counting	Radio/ Teacher	Work-sheet, Part 4	Written Numeral	15 sec.	(see worksheet)
ADD 18.8 Column Addition	Teacher	Work-sheet, Part 5	Written Numeral	-	(see worksheet)
NUM 115.2 Counting	Teacher	Objects to Count	Oral	-	8, 15, 23, 7, 11
NUM 117.1 Rote Counting	Teacher	None	Oral	-	20 to 30, 50 to 60, 10 to 20, 40 to 50

FIGURE 5-3. Lesson Outline

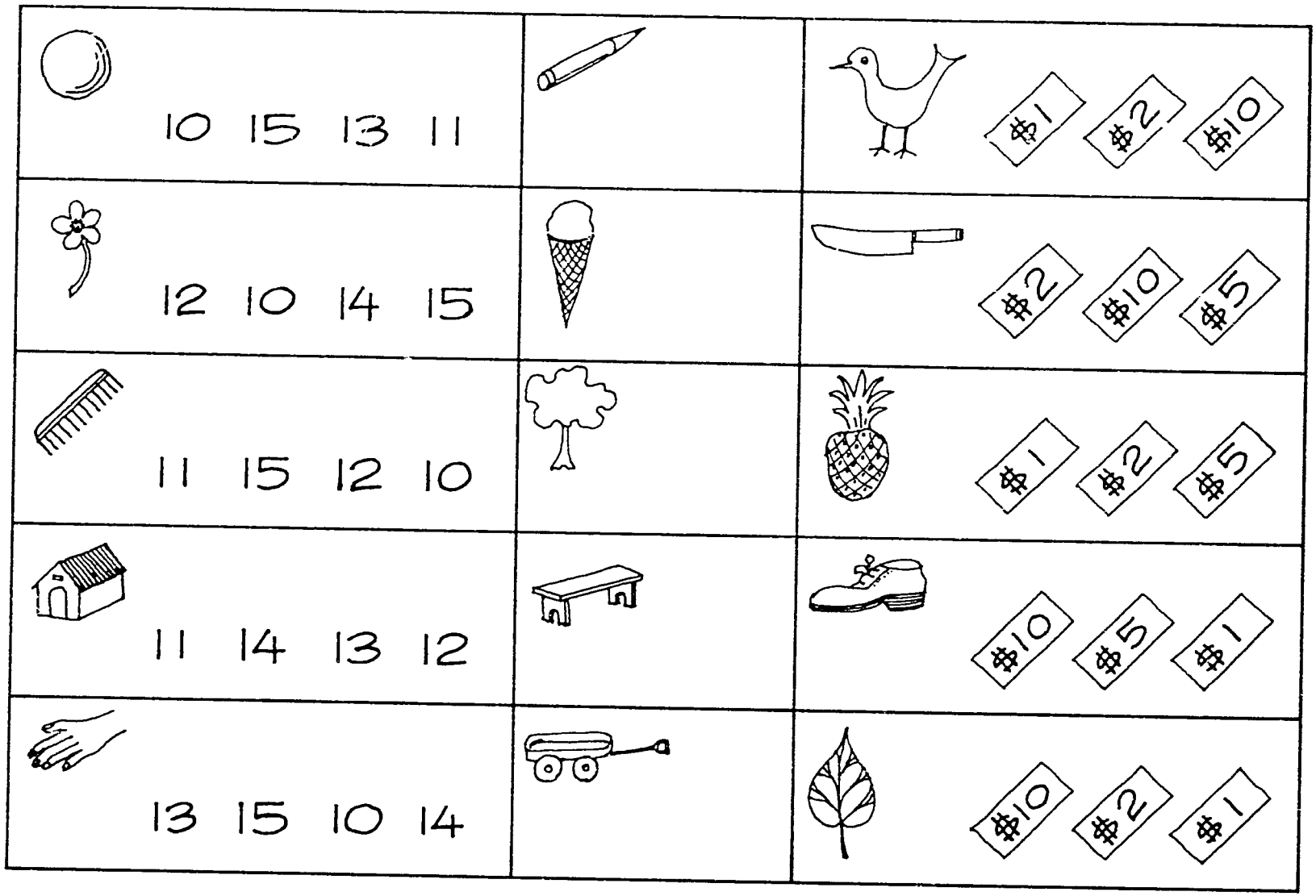

Figure 5-4
Sketch for Worksheet (Front)

NOTES FOR LESSON 47

1) APL 9.3 Applications of addition and subtraction. Use dramatized story problems similar to those in Lesson 45, Segment 4.

2) NUM 113.1 Greater and Less. This is the first time "greater" and "less" have appeared together. Warn the children to listen carefully for the words "greater" and "less."

3) ADD 23.1 Oral Addition. Use questions like "What is the sum of five and one?" This is the first time the word "sum" is used, so explain to the children that "What is the sum" means "how much altogether."

4) NUM 108.2 Successors. Use quick drill similar to that in Lesson 46, Segment 2.

5) NUM 110.2 Reading numerals. See Lesson 45, Segment 3.

6) NUM 114.1 Writing numerals. See Lesson 46, Segment 4.

7) APL 12.1 Money, identifying bills. This is the first time the $10 bill has been included. See Lesson 44, Segment 4.

8) NUM 115.1 Counting. This segment will be started by radio and finished by the classroom teacher. Have the children do one exercise, then tell them to do the other exercises by themselves. The teacher should check their work when they are finished.

9) ADD 18.8 Column addition. The children should be able to do these without help from the teacher.

10) NUM 115.2 Counting. See Lesson 46, Segment 9.

11) NUM 117.1 Rote counting. When the children are counting from 20 to 30, they may not know when to stop. Tell the teachers to stop the children when they reach 30. Do the other exercises in a similar way.

FIGURE 5-5. Notes to Accompany Lesson Outline

part of the lesson. For each of the topics listed there should be:

- A description of the topic
- A description of the materials to be used by the children
- If pertinent, a sketch of the worksheet, including the exercise identifiers (pictures, numbers) that will be referred to by the scripts
- A list of the exercises
- The format of the exercises
- The kind of responses to be given by the children
- The time to allow for each response
- Notes on how to teach the topic, possibly referring to previous lessons that include segments on the same topic and on prerequisite topics

One way to distribute the above information is in the form of a lesson outline together with a sketch of the worksheet and a set of notes on how to teach each topic. Figures 5-3 to 5-5 illustrate the kind of lesson plan used for the radio mathematics lessons.

3. LISTING THE TOPICS

The first step in planning the lesson is selecting the topics to be included. The design of each lesson is based on both the proposed time schedule for topics (part of the master plan described in the preceding chapter) and the feedback data that have been collected by observing classes and testing children. The data might show, for example, that the children's skills in a once-mastered subject are deteriorating and that further review needs to be scheduled. On occasion, children may exhibit competence in some skill that has not yet been taught, either because of instruction from some other source or, more commonly, because of transfer of learning from a closely related subject taught in previous lessons; when this occurs, planned instruction in the topic can be eliminated, or decreased. All of these affect the lesson outlines themselves. In order to take full advantage of this kind of feedback, lesson outlines should not be prepared too far in advance.

4. ASSIGNING TOPICS TO RADIO OR CLASSROOM TEACHER

After the topics to be included in a lesson are determined, each topic must be assigned to either the radio portion or the postbroadcast portion of the lesson.

Decisions about which topics to teach by radio and which to delegate to the classroom teacher are frequently quite difficult. Some topics can be taught in their entirety by radio. Others are best introduced by radio with follow-up by the classroom teacher. Some topics

might be introduced by the teacher and later practiced during the radio broadcast. In fact, most topics could be taught in any one of these ways so the decision will hinge on time constraints and on judgments about the relative efficiency of instruction. A major consideration is the capability of the average teacher balanced against the limitations of radio. Most topics in mathematics are best taught by a teacher--if that teacher is a master of the content, well trained in instructional strategies, and sensitive to the needs of the children. Such teachers are rare, even in developed countries. However, even a poorly trained teacher is capable of doing a satisfactory job of teaching certain parts of the curriculum. We found Nicaraguan teachers, for example, to be quite competent in teaching children to read and write numerals, do column addition, and memorize basic facts such as the multiplication tables. Their deficiencies tended to be more in the area of abstract mathematical notions, such as the concepts of fractions and the measurement of area of irregularly shaped figures.

Another consideration in deciding whether to assign a topic to radio or to the teachers is the kind of supplementary materials to use. If complicated materials are necessary, radio is usually a poor choice because of the difficulty of giving instructions and because too much time must be spent in organizing and manipulating the materials. Simple materials such as worksheets or seeds and stones can be used quite well in conjunction with radio instruction but tasks like measuring common objects, pouring liquids, and weighing things are best left to the teacher.

For topics that could be taught either by radio or by the teacher, time is often a deciding factor. Teachers spend more of their time on classroom management and on discipline. If we want two minutes of quick drill on addition facts, it may be best to do it by radio where it can be inserted between two other topics with little loss of time in making a transition from one subject to another.

If precision of language is needed, radio is clearly the better choice since the content of instructional messages can be closely controlled. This was a major consideration in the design of the radio mathematics lessons, and would perhaps be of even greater importance in reading or foreign languages. At times, when we wanted to control the instructional language quite carefully, we used radio entirely; other times we used radio to introduce the topic and to serve as a model for the teacher.

5. SELECTING EXERCISES

The lesson outline should also list the specific exercises to be used in each segment. Exercises for instruction must be chosen with great care, for the basic concepts formed by the children often depend

more on the nature of the exercises themselves than on the accompanying explanations. Many teachers believe that it is their explanations of concepts and rules that convey the ideas to the children. In fact, children--whose verbal abilities may be inadequate--often do not listen to or even misunderstand such instruction. They form concepts from the examples given them, internalizing the principles without necessarily being able to express them, or expressing them in language poorly reflecting that used by the teacher. When a particular rule is to be taught, it is necessary to choose exercises that will exemplify the full scope of the rule without misleading the children into either overgeneralizing or undergeneralizing the rule. It is rare that one can teach the full extent of a rule and all of the exceptions to the rule in a single lesson. Thus, the examples must be ordered to bring in further extensions and exceptions at a timely rate, neither so fast that the children cannot assimilate them nor so slowly that they have time to solidify initial, immature versions of the rule.

Examples of the acquisition of immature rules are numerous in mathematics. In some cases these incomplete understandings are almost unavoidable and are readily overcome at a later time, but always at some cost in time lost. An example is the overgeneralization formed by many children that numbers with more digits are always larger. This conclusion is certainly true of whole numbers (101 *is* greater than 99) and is reinforced in the child's mind over years of experience with such numbers. It is not true of decimal numbers (1.01 is not greater than 9.9) but the misconception is difficult to dispel. I am not, of course, advising that decimal numbers be introduced at the same time as whole numbers; such a decision would be folly. I am, though, recommending that the person who teaches decimal numbers be aware that a child may correctly say that 9.3 is greater than 1.8 and may also believe that 1.79 is greater than 9.3. (Worse yet, he may think that 3.50 is greater than 3.51!) Thus, if one were preparing a lesson to teach the children how to determine the greater of two given decimal numbers, one would be well advised to use exercises like 2.35 vs. 22.1 as well as 2.35 vs. 2.21.

Another pitfall in selecting exercises is to choose those that will lead to ambiguous instructions. For example, instructions about exercises with duplicated digits may cause confusion. Suppose we are trying to teach the multiplication algorithm and we use the exercise:

$$\begin{array}{r} 434 \\ \underline{\times\ \ 2} \end{array}$$

Our instruction might be: "First, we multiply four times two..." If the child thinks we mean the four on the left we have started him along the wrong path from the very beginning. We could have said "the last four" but some children will think "last" means "last in the order in which we usually do arithmetic," whereas others will think "last in the order in which I wrote the number 434". The obvious solution is to say "the four

on the right"...except that a certain number of children consistently confuse left and right. Best of all would be to change the exercise to something like:

$$\begin{array}{r} 134 \\ \underline{\times\ \ 2} \end{array}$$

6. SPECIFYING THE TIME FOR RESPONSE

Besides specifying the type of response expected, the outline must also specify the amount of time to be allowed for each response. The duration of pauses will depend upon the complexity of the response as well as the experience of the children. For example, it takes children longer to write a two-digit number than to write a one-digit number--though not twice as long. We usually used a formula that included a start-up constant plus a multiple of the number of digits to be written. Thus, for example, the pause allowed for writing a number at the beginning of second grade was calculated from a formula like:

$$4 \text{ seconds} + (3 \times \text{number of digits})$$

From this, we could calculate 7 seconds for a one-digit number, 10 seconds for a two-digit number, etc. We used similar formulas for determining the pauses for drawing the tally marks, circles, or boxes used in teaching counting and arithmetic operations. As children gain skill, the formulas must change to reflect their increasing speed. The above formula, which would be applicable at the beginning of second grade, would be changed to:

$$3 \text{ seconds} + (2 \times \text{number of digits})$$

by the end of the same year. The exact formula that is used would, of course, be determined by classroom observations.

Pauses for simpler actions such as picking up a pencil, standing up or sitting down, etc., would not be calculated by formula but would similarly change as the children become more adept. To maintain consistency, a list of standard pauses should be made and updated as new information comes in from the classroom observers.

7. SPECIFYING SUPPLEMENTARY MATERIALS

Another item to include in outlines is a description of the kinds of supplementary materials to be used during each instructional segment. These might be seeds, stones, bottle tops, rulers, notebooks, or worksheets. This information is needed both by the script writer, who will write the instructions for children, and the writer of the teachers'

guide, who must list the materials the teacher is to hand out to the children before the broadcast begins. Also, if posters are to be used or if the teacher is to write exercises on the chalkboard before the broadcast, this must be specified in the teachers' guide. Script writers and teachers will also have to know if children are expected to copy exercises from the chalkboard before or during the broadcast.

In order for the script writer to write exact instructions for exercises that appear on a worksheet, the worksheet must be designed, in rough form, at the same time the outline is written. This is best done on a separate page accompanying the outline. Details such as the symbols (numbers, letters, or pictures) that will be used as exercise identifiers must be included in this rough layout.

Another useful accompaniment to the outline is notes to the writers of scripts and guides containing suggestions for teaching the topics, the kind of phrasing to use in instructions, the rate at which instruction can be faded, etc. These kinds of suggestions need not be written for every segment but are especially useful when a completely new topic or response mode is introduced.

Chapter 6

PRODUCING LESSONS

The completed lesson plan is copied and distributed to the artist and to the writers of scripts and teacher's guides. Two to three script writers may be needed to produce the instructional segments for five lessons per week. One other person can edit the instructional segments, write entertainment segments, assemble the parts into complete scripts, and produce the radio programs. With several people working on scripts, the work can be assigned by subject rather than by lesson. Thus, for example, one script writer could be responsible for all addition and subtraction segments, while others could write instruction for multiplication, division, and other topics. Greater consistency across lessons results from delegating responsibility by subject. Consistency within a lesson can be maintained by having one person responsible for editing all segments and assembling segments from various writers into a single script.

1. INSTRUCTIONAL SEGMENTS

The first task of the instructional script writer is to orient himself with regard to the topic for which he is to write a segment. Is this the first time the topic has appeared in the lessons? If not, how far has the instruction progressed? Will the children need a great deal of detailed instructions? Or very little? Have the prerequisites been completely mastered or will the instruction have to include review of old material as well as instruction in new concepts? To answer these questions, the script writer should look at previously written segments in the same topics and also study the feedback reported by the formative evaluation department. He should refer to the master plan to identify the prerequisites of the topic and look at previously written instructional segments and feedback results for those prerequisites.

If the topic is new or has only recently been introduced and has not yet reached the classroom there may be no feedback to rely on. However, if it is an important topic it will have been pretested enough ahead of time so the children's incoming skills could have been analyzed and reported by the formative evaluation department. When starting instruction on a new topic it is necessary to know if the children--or some sizable portion of them--already know something about the subject. It is a maxim of instructional design that good teaching must start children from where they are and move them ahead from there. Much seemingly good instructional material has been totally ineffectual in practice because it started at the wrong place; either the children already knew much of the material and didn't need the instruction or they had not yet mastered the prerequisites and could not profit from the instruction which was aimed over their heads. Two common failings of

teachers and curriculum designers are to assume that children know nothing about a topic before it is explicitly taught, and that children will achieve complete mastery in a short time if the instruction is well prepared. Often children know a great deal about the topic even before it is taught, having learned from their teacher, their parents, or their peers, or because of transfer of learning from related topics. And, in general, children learn more slowly than many people expect. Even after they have grasped a basic concept they will need much practice and review to achieve mastery; furthermore many skills deteriorate quite rapidly if sufficient, well-spaced review is not provided. The net result is that the learning curve for any particular topic generally starts higher than expected and climbs very slowly. A gain in achievement test scores of even a few percentage points may indicate relatively successful instruction.

With this in mind, the script writer will plan the instruction to begin at an appropriate level, with a sufficient amount of detail, and very gradually reduce the amount of instruction until the children are capable of performing the task without help. The rate at which instruction is faded will depend greatly on the topic and may take as much as five or ten lessons. Thus, each segment in a topic must be planned in relation to other preceding and succeeding segments in the same topic.

Although the amount of instruction given per exercise fades gradually over time, this fading is not continuous. That is, in segment 1 there will be abundant instruction with the first exercise, considerably less with the second exercise, and a slightly smaller amount with the third and subsequent exercises. In segment 2, which may be one or more days later, the instruction does not take up exactly where it left off, but will provide a brief review of segment 1; this is needed because the children may have lost the thread of instruction during the elapsed time and because some individual children may have been absent the first day. Within segment 2 the instruction is faded quite rapidly until by the third exercise there is even less instruction than there was at the end of the first segment. By the last segment (which may be five to ten lessons later), the children should be receiving no more instruction, even in the first exercise, than they would be given in a test of the same topic.

2. STRUCTURE OF INSTRUCTIONAL SEGMENTS

Each instructional segment follows a fairly standard format. First, there is an introduction, then a sequence of exercises, and finally an ending. The introduction should be short and specific, not a lecture on the concept or rules to be taught. All that is needed is a short announcement of the topic and the kind of response expected; if special materials are needed, the children should be advised to get those

materials ready. Typical introductions would be like this:

> Now we'll do some oral addition.
> Everyone get ready to think--and to answer aloud.
>
> Get your notebooks and pencils ready.
> You're going to do some division exercises.
>
> Now you're going to do some more work on your worksheets.
> Look at the next part of your worksheet, the part with
> the pictures of the animals.

Following this introduction there would be a set of exercises; there might be anywhere from two to twenty exercises in a set. After the exercises have been completed, there would be a terminating message that would be as brief as the introduction to the segment:

> That's all of the oral addition exercises for today.
>
> Now you've finished all the division exercises so put
> your notebooks and pencils away.
>
> Now you're through with your worksheets.
> Put your worksheets and pencils away.

3. STRUCTURE OF EXERCISES

Between these two brief statements the exercises would all have very nearly the same formats, varying somewhat according to topic. The simplest exercise consists of an instruction or question, followed by a response from the children, and ending with an announcement of the correct answer. The shortest kind of exercise of this type is exemplified by a multiplication drill:

TEACHER:	How much is five times seven?	(Instruction part)
CHILDREN:	Thirty-five.	(Response part)
TEACHER:	Thirty-five. Five times seven is thirty-five.	(Reinforcement part)

The instruction part of an exercise may on occasion be longer and more complex than the above example. It may contain explanations or other supplementary messages, and might even include dialogues between radio personalities. Story problems, for example, are a form of instruction-response-reinforcement exercise, even though the instruction part is quite long and complex; we frequently presented problems in dramatized form with several voices, appropriate sound effects, music,

etc. Each of these mini-dramas terminated with a question to the children in the classroom. Their response, ordinarily given orally, was followed by an announcement of the correct answer. Even though the script for these exercises would be considerably longer and more complex than a simple multiplication drill, the basic form is the same.

Some exercises require several responses from the children. Here, for example, is the script from an early exercise in addition:

TEACHER: Look at the next exercise on your worksheet . . . . Let's read this exercise together.

TEACHER AND CHILDREN: Forty-three plus twenty-five.

TEACHER: Forty-three plus twenty-five. Look again at the sign of this exercise. See if it's a plus sign or a minus sign . . . . Which is it?

CHILDREN: A plus sign.

TEACHER: A plus sign. So, are you going to add or subtract?

CHILDREN: Add.

TEACHER: Add. The plus sign means add. In this exercise, we're going to add by *columns*. One column is four plus two. The other column is three plus five. Which column do we start with?

CHILDREN: Three plus five.

TEACHER: Three plus five is where we start. Now, think about three plus five . . . . How much is it?

CHILDREN: Eight.

TEACHER: Eight. Three plus five is eight. So you will write eight. Write the eight under the line.

(PAUSE:06 SECONDS)

Now let's go on to the next column, the one that says four plus two. Think about four plus two . . . . How much is it?

CHILDREN: Six.

TEACHER: Six. Four plus two is six. Under the four plus two, write a six.

(PAUSE:06 SECONDS)

Now, you've finished. Under the line you wrote a six and an eight. And that's the complete answer to the problem. Tell me, a six and an eight together is what number?

CHILDREN: Sixty-eight.

TEACHER: Sixty-eight. The answer to the problem is sixty-eight.

This rather lengthy piece of script includes only one exercise although there are a total of nine explicit responses, seven oral and two written. Each of these responses is part of a "subexercise." The seven oral subexercises all have the standard instruction-response-reinforcement form of a full exercise. The two written responses include instruction and response but have no reinforcement. Besides these nine explicit subexercises there is also an implicit subexercise, in the initial instruction, "Look at the next exercise on your worksheet . . . ." Although there is neither an oral response nor a pause for a written response, we do indeed expect the children to attend and respond to the instruction. Since the time needed is so short no timed pause is necessary; there is only a short hesitation, indicated by ellipses in the script (. . .), before the next instruction is given. This implicit subexercise, which is as important to successful execution of the task as any of the following instruction, also has the shortened instruction-response form.

4. INSTRUCTIONAL PART OF EXERCISE

The instructional part of an exercise can be cast either as an imperative or as a question, and may or may not contain additional information. The most important characteristics of good instructional messages are brevity and clarity.

Brevity is needed to keep the pace of the interaction fast. Children lose interest when instructions are overly verbose, often because there is more content than they can readily assimilate at one time. As a general rule, an instructional message should take less than sixty seconds; messages that are longer than this frequently indicate that the teaching strategy has not been well thought out. In the radio mathematics lessons, the average instruction was less than 20 seconds long and many instructions were no more than four or five seconds long. The script writer should keep in mind the principle that children learn by doing. Any time the radio characters are talking the children are not

actively engaged in the task and are not making as much progress as they could. If script writers think of the radio program only as a means of stimulating the children to action, their scripts are more successful. This concept is very difficult for many script writers, who tend to think more of what the radio is saying than what the children are doing. It is natural to think of the radio in this way since radio has so often been used to convey information in only one direction--from the radio to the listener. However, if the main goal of instruction is acquisition of skills rather than of knowledge, the emphasis needs to be on the learner and not on the teacher.

Clarity of instruction is also essential. In writing instruction for young children the language must be simple and direct. Use words that the children themselves would ordinarily use in describing the same situation. For example, instead of saying "Underline the correct result," it would be better to say "Draw a line under the right answer." Unfortunately the former phrasing comes readily to mind for most beginning script writers who are more accustomed to writing for adults.

One of the greatest difficulties in writing scripts is writing "spoken" language instead of "written" language. Every language has at least two variants, one spoken and one written. Written language tends to be formal, employing words that the writer would not ordinarily use in casual conversation. In fact, many times the words we all use in everyday speech are felt to be somehow inferior to the written parallels. In speech, we might say "the same" but write "similar". Or we might say "not good enough" but write "substandard". "Nice" becomes "likeable," "okay" becomes "acceptable," "a man I know" becomes "an acquaintance," "he is going to do that" becomes "he will do that," and so on.

Also, written language tends to be more complex syntactically with many more subordinate phrases, qualifying adjectives, and other kinds of modifiers. Even when read aloud, this kind of language does not become spoken language. In writing scripts we want to use spoken language so that the radio programs will sound natural and spontaneous, and so that they will be completely understandable to the children in the audience. Beginning script writers have great difficulty with this since they are so accustomed to writing written language. For some, the best training is to start by using a cassette recorder to record the script which is later transcribed onto paper. If one can imagine talking directly to a group of children the speech will ordinarily be appropriate for scripts. This is not a cure-all by any means since some people suffer so much from "mike fright" that even their spoken language becomes very stilted. Another training device that works quite well is to ask a colleague to read aloud the script you have written; if it does not sound natural and conversational, you need to revise.

There are a few rules of thumb that can help a script writer produce spoken language instead of written (these rules apply to English but there are similar rules for other languages):

(1) Use contractions. Spoken language abounds with words like "you're" and "can't" and "I'm."

(2) Use short sentences without subordinate phrases or clauses. Even though several short sentences may contain more words, the ideas will be more clearly conveyed than by a lengthy, complex single sentence.

(3) Use the active voice instead of passive. Say "The boy opened the window" rather than "The window was opened by the boy."

(4) Do not use descriptive adjectives in noun phrases. You should use adjectives only when they are necessary to qualify the meaning of a noun. For example, you would not say "the playful kitten" unless you wanted to distinguish between a playful kitten and some other kind of (unplayful) kitten.

The order of multiple instructions within the instructional part of an exercise is critical. When giving instructions to children, think first of the physical and mental steps the child will have to take to comply with the instruction, then phrase your instructions in that order. For example, the instruction, "Circle the sixth animal in Part 4 of your worksheet" requires the child to do these things:

(1) Attend to his worksheet

(2) Locate Part 4

(3) Count to find the sixth animal in the row

(4) Circle that animal

Thus, the instruction would be more easily followed if it were written as "Look at your worksheet . . . at Part 4. Find the sixth animal in that row . . . . Circle that animal." Although the instructions are somewhat more wordy, the memory load is significantly reduced, partly because the child can be performing each simple task immediately after he hears the instruction and will not need to hold the entire instruction in memory, and partly because he will not have to do the mental processing necessary to reorder the tasks into the sequence he will have to use to complete the exercise.

Be specific about the form of the response you expect from the children. Do not say "mark the black cat" unless the meaning of "mark" has already been clearly defined; it would be better to say "circle the cat" or "write an X beside the cat" or some such. Also, do not ask a question that would ordinarily be answered orally if what you want is a written answer; use "Write the number that comes after 24" rather than "What number comes after 24?"

Generally, you will use questions when you expect an oral response. It must be established in the first lesson that the children are expected to respond orally when a question is asked. To avoid confusion, never ask a question that you do not expect the children to answer. Children do not understand, for example, that they are not expected to answer rhetorical questions. Also, questions like "Is everybody ready?" might be intended by a script writer simply as device for calling the children's attention, but the children who do not perceive this intent tend to answer aloud if they are accustomed to answering other questions aloud. If such questions are used very often without provision (pauses) for children's responses, the children will learn that they are not really expected to answer aloud and will not answer even when the script writer intends that they should.

Group responses are effective only when all children are giving the same answer simultaneously. It is only when there is a single correct response that reinforcement messages from the radio are appropriate. Thus, questions that have more than one correct answer should be avoided. Do not, for example, ask the children for a number between one and one hundred or ask them to tell you a kind of fruit whose name starts with a P. Even questions whose answers may be cast in different forms should be avoided unless the children are taught to answer in a standard form. If you ask children how many objects there are in an empty box, their answers might include "zero" and "none" and "There aren't any;" although these answers may appear equivalent to an adult, that equivalence is not always obvious to young children.

Another type of question to avoid is the question that implies a different question. An example of this is "Do you know how much eight times seven is?"; the syntactic form of this question would lead many children into answering either yes or no, whereas other children--and most adults--would answer the implied question "How much is eight times seven?"

Also avoid questions whose initial part is also a well formed question. When children are participating fully in the radio lessons they will eagerly answer questions as soon as they are asked. This sometimes results in the children answering a question before it is fully formed and drowning out the remainder of the question; this can cause considerable confusion, especially when the subsequent reinforcement message is not congruous. Consider the following exercise.

TEACHER: Look at the next animal on your worksheet.
Is that animal a cow or a dog?

(PAUSE:03 SECONDS)

A cow.

As soon as the children hear "Is that animal a cow . . . " some will immediately answer "yes" and not hear the remainder of the question. They will hear the reinforcing message, "a cow", which is then somewhat incongruous. An even greater incongruity between the children's response and the correct answer would occur with a question like "How much is eight plus three plus five?" Some children may answer eleven (having heard the question "How much is eight plus three?") and will then hear the radio teacher tell them that the correct answer is sixteen. Such situations can be avoided by rephrasing the questions:

Look at the next animal on your worksheet.
What animal is it?

Think about eight plus three plus five . . . .
How much is it?

5. RESPONSE PART OF EXERCISE

The script writer must plan for what the children are to say and do as well as for what the radio is to say and do. The children may be asked to respond orally. They may be asked to write or to draw, either on a worksheet or in a notebook. They may be asked to work with concrete materials. Or they may be asked to perform some physical activity that does not require special materials. In any case, the script writer must provide for the right amount of time for the children to complete the required task. Frequently, the time to allow in a pause for children's responses will already have been specified in the lesson outline. But in some cases, the script writer will have to make the decisions. The pause needed might be so short that the actors need not pause at all; this happens when children who are already quite accustomed to the style of the radio lessons are asked to focus their attention on another part of a worksheet that they already have in front of them. In similar situations, the children might need a bit more time---to pick up their pencils, for example; for a pause of less than two seconds, it is usually sufficient to use ellipses in the script; the actor will then pause only a little longer than he would naturally pause at a full stop like a period or exclamation point. Timing for many physical actions is usually left to the script writers since the situations do not arise often enough for standards to be set (as they would be for writing numerals or writing words). Usually, a script writer can simply time himself performing the same action and allow just a little more for children to do the same

thing. Another useful way to time scripts in the absence of data from the classrooms is to read the script to others who play the role of children in a classroom.

In addition to deciding on the time to be allowed for responses, the script writer must also provide models when appropriate. Since radio is an oral medium of communication, the only places meaningful models can be provided is with oral responses or with other kinds of responses (like clapping) that produce distinctive sounds. Modeling is done by writing a part for children into the scripts. Child actors in the studio read this part and the children in the classroom are expected to respond in chorus along with them. Oral responses do not have to be modeled, but the educational effectiveness of the lessons will be enhanced if they are. Using children adds to the cost of producing recordings, however, since children are more difficult to train and to manage in the studio than adults.

6. REINFORCEMENT PART OF EXERCISE

In most of the examples shown so far, only the oral responses were reinforced. Written responses cannot usually be directly reinforced because the reinforcement message would only be a repetition of the information given in the preceding instruction. Another kind of response that cannot be reinforced with an oral message is a physical response. If, for example, we ask a child to hold up three fingers there is no way to provide further information. We can tell him he should have held up three fingers but if he confused between three and four, this message will serve no useful purpose. It is almost a general rule that only oral responses can be reinforced when the medium of communication is oral (as with radio). Since reinforcement is such an important stimulus to learning, this is one of the reasons oral exercises must play such a large role in radio instruction.

With written responses, one of the most effective ways of providing information about the correct answer is by means of an oral bridge. For example, if a child is expected to write a three-digit number from dictation, the reinforcement can be provided in the context of asking him to read the digits aloud, in this fashion:

TEACHER: On the next line in your notebooks, write the number two hundred six.

(PAUSE:07 SECONDS)

Look at the number you just wrote. Read me the digits in that number.

CHILDREN: Two, zero, six.

TEACHER: Two, zero, six. That's how two hundred six is written.

Technically the reinforcement in this example is a reply to the oral response "Two, zero, six", not the written response 206. It might seem that a more natural way to reinforce the written response would be to read the digits to the child so he could read his own work:

TEACHER: On the next line in your notebook, write the number two hundred six.

(PAUSE:07 SECONDS)

Check the number you just wrote. It should be written: two, zero, six.

Although this is more concise and more direct, it is less effective as reinforcement because the children are less actively involved in the correction process.

The reinforcement given by the radio teacher should usually repeat the exact words expected from the children. In some cases this leads to a rather stilted dialogue but we found it to be the best formula for the reinforcement. It is important that the answer given by the teacher be as close in time as possible to the answer given by the children, so that they can do an immediate mental comparison of the two answers. For this same reason, the answer should not be paraphrased or imbedded in a longer speech, for the child would then have to do some mental processing before he could make the comparison. A reinforcement message like "two hundred six is written two, zero, six" would be unsatisfactory because the child would have to sort the phrase "two, zero, six" out of a fairly complex utterance that also contains a severe distracting influence, the spoken "two hundred six". By the time he has done this, his own response has faded somewhat--or completely--from his memory.

Some writers tend to produce reinforcement messages that start with phrases like "That's right . . ." or "Good . . ." or "Correct . . ." Although these phrases make the script sound more natural, they are not desirable for several reasons. First, they separate the child's response in time from the announced correct response. Second, they are additional verbiage that the child must process before he can sort out the part of the message that he must compare to his own previously spoken response, thus adding to his mental load. And third, they carry a judgmental connotation that should not be part of a factual reinforcement message. Finally, these judgmental messages are sometimes embarrassingly inappropriate; nothing is quite as ridiculous as a radio teacher who enthusiastically praises a class of children who have just unanimously shouted out the incorrect answer.

A script in which the radio teacher repeatedly mimics the words just spoken by a chorus of child actors may seem unduly repetitious. Why must the correct answer be given twice, once by the children and again by the teacher? The reason for this is not apparent when reading the script but is quite obvious when observing a lesson in the classroom. The child actors, serving as a model, are heard only when the children in the classroom do not respond since a group response of twenty or thirty voices is sufficient to drown out any radio message. Thus, the usefulness of the children's voice in the radio program is limited to those times when the classroom students are not participating--at the beginning of the year when children are still somewhat shy about answering aloud, when the radio teacher's instruction is not adequate to explain the kind of response expected, when it is not clear to the classroom students that they are expected to respond, or on those occasions when only a few of the children know the correct response. During those times, some of them unanticipated by the script writer, the children's voices on the radio serve as a direct instructional device. But when the classroom students are responding enthusiastically, as is usual, they cannot hear the child actors and thus cannot use their utterances to provide reinforcement.

7. ASSEMBLING THE INSTRUCTIONAL SEGMENTS

After all instructional segments for a lesson are written they can be put into order. Since the segments are usually on quite different topics, the order in which these segments occur within the lesson will not depend on considerations of content.

One consideration will be the kind of activity used. To provide the variety that is needed to hold the children's attention and to keep them from tiring of an activity, it is best to separate segments that are similar in exercise format and response mode. If there are two segments with oral drill, one on addition and one on subtraction, these segments should be separated by some written exercises or work with other physical materials.

In our experience in Nicaragua, we found that some teachers occasionally tuned into the broadcast a few minutes late. This was usually not due to irresponsibility but to circumstances that could not easily be controlled. They might not have accurate means of telling time, and even if they did, the broadcasting station itself might not have held to a strict time schedule. Since this does happen, it is best for the radio program to begin with an activity that can be taken up by the children in midstream. Worksheet activities, dictated exercises, and dramatized problems are poor choices since essential information may be given in the first few seconds of the segment and not repeated. An ideal activity for the beginning of the lesson would be oral work in which each exercise is a self-contained activity that does not take more than about 30 seconds to complete.

If there are any transition segments, they will occur last. Transition segments usually start with one exercise that is done by the children with the help of the radio teacher, then the children are left working on the remaining exercises as the radio program signs off. The work is later checked by the classroom teacher as the first postbroadcast activity.

Worksheet activities should be done in the order in which they appear on the worksheet. If a worksheet is divided into three parts, for instance, the children would find it confusing to start with part 2 or 3, then return to part 1 later. Since the physical layout of the worksheet cannot be changed at this time (the artist has probably already completed his work) the order of these segments is fixed. Of course, worksheet activities can be separated from one another by other activities.

At this time, the total length of the script must be calculated. There should be a total of about 18 to 20 minutes of instructional scripting (to leave time for entertainment segments, etc.). It often happens that there is either more or less than this amount and segments must be shortened by reducing instruction or deleting exercises, or they must be lengthened by adding exercises. These decisions must be made in consultation with the curriculum department who can decide the instructional implication of such changes. In the worst case, entire segments have to be moved from one lesson to another, which means the original outlines must be revised. Usually the segments can be moved around within the same week; to facilitate this it helps to undertake the job of assembling scripts a week at a time rather than a lesson at a time. In rare cases, segments from the last lesson of the week may have to be held over the next week's lessons (we rarely found that segments needed to be moved up). Because of the strand/segment nature of the radio lessons such changes can be made without violating the instructional integrity of the curriculum package. If each lesson were devoted to a single unifying topic it would not be possible to make such rearrangements of pieces of script.

To fill a 30-minute broadcast time slot we used a 27-minute program. The remaining three minutes (filled by a musical selection) was used in the schools to carry radio receivers from one classroom to another. This was a cost saving device to allow each receiver to be used by as many as four classrooms in the same school. Using this system the total number of receivers that need to be purchased is the same as the maximum number of sections in any one grade.

8. ENTERTAINMENT SEGMENTS

If 18 minutes out of 27 are filled with instruction, there are left about eight minutes of programming time to be filled by entertainment segments and about one minute for introduction and sign-off messages. The entertainment segments can be written quite independently

of the instructional segments and put together later.

We used entertainment segments almost solely to provide diversion for the children, rather than to reinforce learning of mathematics. On occasion, songs and riddles did have some mathematical content but this was incidental to the true purpose of the entertainment segments. Our criterion for the success of an entertainment segment was the enjoyment evinced by the children rather than any increase in mathematical competency. Over the years we experimented with many kinds of entertainment: songs, riddles, games with physical activities, jokes, stories, music for listening, guessing games, calisthenics, quiz shows, and poems. At first we tried to integrate these activities with the mathematical exercises and also relied heavily on dramatized adventure stories but found that neither of these strategies was satisfactory. Eventually we developed a format in which entertainment segments were entirely independent of mathematical activities and we almost totally eliminated stories as a means of enlivening the lessons. We found that the most successful forms of entertainment had two attributes. They required active participation by the children. And they were usually non-verbal. Songs, active games and calisthenics were the most popular diversions. Jokes, poems, and stories were least popular. Riddles and guessing games varied somewhat in popularity; those that had the most sophisticated verbal content (puns, for example) were usually unsuccessful but some of the simpler riddles, especially those that incorporated comical sound effects, were well received.

Because of the popularity of songs and physical activities, we incorporated at least one of each in every lesson. Some kinds of entertainment, such as most jokes and stories, cannot be repeated since their appeal often depends on novelty. Songs, in contrast, seem to become more enjoyable with repetition. For the songs to be effective, the children must be taught the words; when teaching songs, we asked the children to repeat the words one line at a time before asking them to sing. We used both traditional songs and specially composed songs. Composing music for children requires a knack that not all musicians have. Factors to consider are the words, which should be simple and repetitious; the range, which needs to be adapted to children's voices; the melody line, which cannot be very complex; and the pace, which should be lively but not so fast that the children's tongues will trip over the words. If songs are used as devices to teach language, especially foreign languages, the natural intonation pattern that would be used in speech must be preserved. Thus, the melody line and musical phrasing should arise from the natural language intonation; to do this, the words should be written first, and then the music fitted to them.

Besides songs, we also occasionally used other kinds of participatory music. Children do not much enjoy music for listening

only, but do like music without words if they can participate by clapping, marching, tapping their toes, or imitating the musical instrument being played. We also tried asking the children to dance but they seemed to find this embarrassing.

Physical activities like stretching and bending exercises are also popular with children. At first we tried to embed such activities in games but soon found that a game context was not necessary. The children enjoy simple calisthenics without window dressing. However, writing instructions for even the simplest physical exercise can be quite tricky. The meaning of standard phrases like "touch your toes" is not known to most children. In an ordinary classroom the teacher would teach physical exercises by example but with radio the instruction must be much more carefully thought out. Some exercises can be done by the children in their seats (head rolling, facial movements, arm stretching) but others can only be done in standing position. For these exercises there must be explicit instructions, and sufficient time, for putting away instructional materials, standing up, and sitting down again. The physical constraints of the typical classroom must be taken into consideration. Will there be enough room for the children to swing their arms about? To jump? To run? Some of these activities become quite noisy, so noisy that children cannot hear spoken instructions; we used a rather loud drum roll to terminate such activities and signal the children that they were to stop what they were doing so they could hear the next instruction. Calisthenics, like songs, can be repeated many times with perhaps slight variants and still retain their appeal.

9. ADDING TRANSITIONS BETWEEN SEGMENTS

After assembling all segments, both instructional and entertainment, into the order desired, transitions between segments need to be added. A natural impulse is to add verbal transitions between the segments to provide some kind of conceptual bridge between disparate subjects. This is not necessary, and in fact is undesirable. Children are not disconcerted by a radio program with rapid changes of topic and are often uninterested in the kind of verbal interchanges between radio characters that might seem to an adult to be the most natural transition. We ordinarily used a short musical transition. Frequently this music was a clue to the nature of the upcoming activity. For each year we chose a particular piece of music to signal worksheet activities, another to signal physical exercises, another to denote mental arithmetic, etc. Gradually the children came to recognize these signals, even without our telling them the significance. When the worksheet theme began, you could see the children begin to arrange their worksheet in front of them and pick up their pencils even before the radio teacher instructed them to do so.

10. FINISHING TOUCHES

The script also has to be checked for an equitable distribution of voices. Two or three radio teachers with easily distinguishable voices should be used to prevent boredom, and there should be frequent change of voice. For very short segments, one of these teachers can do the whole script but there should be a different voice in the next segment, and long segments should use more than one voice. The change within a segment can be after a certain number of exercises have been given, or the voices can be alternated within an exercise with one voice giving the initial instruction and another giving the reinforcement message. Introductions to segments and closing remarks can be made by a different voice.

Another thing to be checked in the completed script is possible discrepancies between segments that may occur because the segments were written by different people without collaboration. It may be that one segment ends with an instruction to the children to put their worksheets aside, and the next segment begins with an instruction to get the worksheet out so the next set of exercises can be done. Both statements should simply be deleted. (But it is better to have them than for everyone to forget to tell the children when to get materials ready and when to put them away!)

Finally, the introductory and closing parts of the script are added. Both of these should include the lesson number and name of the series, and it may be desirable to add other information or credits to the introduction. This information is primarily for teachers and other adults, not for children; it should be kept as short as possible so as not to take time that could be used for the children. After the identification, we usually included something in the introduction for the children. Every year we used a specially composed "sing-along" song as the theme song for the series, and in second grade we included a count-down to the lesson time that the children could count along with the radio: ten, nine, eight,...

11. STUDIO PRODUCTION

One last check by the curriculum department and the script is ready to go to the studio for production. Production of educational programs need not be an elaborate affair. Clarity is much more important than artistic value. Good, intelligible voices are a must. "Cartoon" voices, as frequently heard in American television animated cartoons, must be avoided as they are quite unintelligible to children. Any out-of-the-ordinary speech characteristics--exceptionally low voices, strange intonation patterns, etc.--must also be avoided; even when they are intelligible, they are so distracting that the children pay more attention to the quality of the voice than to the content of the message.

The speed of speech should be somewhat slower than normal, especially for very young children. If the language used is not the first language of the children, speech must be even slower and there should be exaggerated pauses after each phrase and sentence to allow the children time to mentally process the content and put it into a semantic framework. To achieve natural sounding speech under these constraints, professional actors should be used.

Sound effects should be chosen carefully, and may have to be tested with children before they are used, since children have not yet developed the "auditory literacy" to identify sounds that are readily recognizable by adults who have learned many sound effect conventions from years of exposure to commercial radio and television. It is an enlightening experience for a radio director to take a sound effect record into an ordinary classroom and ask the children what they hear. If there is any questions about the children's ability to interpret the sounds that are to be used, they can be subtly instructed in very natural ways. The sound of footsteps, for instance, could be interrupted by an actor saying "Who's coming? Oh, it's you, John." Rain on the roof could be preceded by someone commenting on the possibility of rain. Usually children learn these sound conventions very rapidly, so such hints need not be repeated very many times.

One aspect of educational radio programs is more controlled than in commercial radio: the timing. Timing in commercial production is usually done by ear, relying on the directors' and actors' intuition. In educational radio, much of the timing will actually be done with a stop watch. Pauses that are not timed in the script also have to be carefully controlled. One trouble spot is with oral responses that are being given by child actors. These utterances must be made to coincide exactly with the choral response that will be made by the children in the classroom. Choral responses given by 20 or 30 children are slower than responses given by only two or three children in a studio. The speech itself is slower and there is also a noticeable hesitation before the response is given. Children who are reading from a script tend to speak too fast and to start too soon; they must be directed to slow down, and should be cued to begin by the director rather than taking their cue from the preceding speaker.

12. PRODUCING SUPPLEMENTARY MATERIALS

Materials to supplement the radio lessons may include worksheets or textbooks for the children, guides for the teacher, posters, and other printed materials. There may also be other concrete materials such as pebbles or rulers. The choice of materials will have been made before scripts and guides are written, and will be specified in the lesson outlines. Because of cost and logistic factors, the radio math lessons rarely used concrete materials other than those that the teacher and

children could acquire for themselves at little or no cost. The only materials we produced regularly were teachers' guides; for first grade, we also used children's worksheets.

13. PRODUCING WORKSHEETS

Usually a single 8 1/2 by 11 worksheet printed on both sides will have enough room for all the exercises a child can do in an hour. We found the best format was a division of the worksheet into parts, one for each separate segment that used worksheet activities. Each of the three to seven parts contained four to ten exercises. For older children there could be more parts and more exercises per worksheet.

In designing a worksheet, the layout should be as clean as possible. Extraneous information such as credits to the authors or funding agency should be left off. Information that is necessary to adults but not important for the children should be printed in small print at the bottom or on the back; this might include the name of the project, version number of the worksheet, etc.

One of the most difficult tasks young children face when using a worksheet is simply finding the correct place on the page. You will need to use some system of uniquely identifying each exercise using symbols that all children can readily comprehend and that will not be confused with any of the symbols used in the exercises themselves. If it is certain that the children can read letters and numbers, these can be used. Generally, if the exercises themselves contain numbers it is best to use letters as exercise identifiers, and vice versa. With first graders, who do not acquire facility in reading letters and numbers until quite late in the school year, pictures can be used as identifiers--but only if they are easily distinguishable from pictures that are part of the exercise itself. The system we followed was to enclose the identifier pictures within another object; we used flags, blocks, and balloons as "carriers" for the picture identifiers, and instructed the children to find "the flag with the picture of a tree," etc.

The pictures that are used as exercises identifiers must be carefully chosen to be sure that all children can recognize both the picture and the name that will be used in giving instructions. We found it necessary to field test all of the identifier pictures before use.

Drawing pictures for children--both those used as identifiers and those used in exercises--requires a kind of skill that has little to do with artistic creativity. Liberties of form and style that might be appreciated by adults are not acceptable when the purpose is to produce instructional materials for children. This is not to say that the aim is to produce realistic drawings. Simple line drawings are preferable to

shaded drawings, both for easy identification and because they are easier to reproduce. Caricatures are preferable to realistic pictures providing the exaggeration is in the direction of emphasizing the features that the children find most relevant in helping them to identify the object. In drawing an ox, for instance, the horns should be drawn proportionately larger than in real life since they are important in the child's schema of what an ox is.

Some cartoon conventions should be avoided since their significance is learned only through experience and is not yet understood by young children. The use of wavy lines to denote heat rising, for example, is a cartoon convention not understood by most children. Motion is generally hard to portray in a drawing without resorting to conventions like extra lines that are meaningless to the child. A wagging tail on a dog, a person shivering, a nodding head--all are ordinarily portrayed with symbols that are meaningless to a child.

14. TEACHERS' GUIDES

The main thing to keep in mind when writing teachers' guides is that the teacher, especially in large or multigrade classrooms, is always overworked. The goal of the guide should be to simplify the teacher's work as much as possible without depriving the children of valuable education experiences. The guide for each lesson should be self-contained and limited to a single page. Instructions should be clear and concise, without needless explanatory text, and the format should be such that the teacher can immediately find important information. At the top of each page there should be a list of the materials the teacher will need to gather together before the lesson starts. Instructions about when to distribute these materials to the children should be explicit. If the teacher is to put exercises and drawings on the blackboard before the radio lesson, the guide should contain an illustration that can be easily copied. It should also state whether or not the children are to copy these exercises into their notebooks. Different activities for the children should be in clearly demarked sections. If an activity is optional or is one for special groups of children, that should be clearly stated. If teachers are to grade children's papers, correct answers should be given.

Chapter 7

FIELD TESTING THE LESSONS

In the feedback method of producing educational materials, the production of materials such as radio tapes, worksheets, and teachers' guides is only the beginning. To complete the cycle, the materials must be field tested, data must be collected, and the course of future work must be planned with this information as a basis.

1. SELECTION OF FIELD-TEST CLASSROOMS

The aim of formative evaluation is to tailor the curriculum materials to the needs of the children who will use the radio lessons after they are completely developed. To find out what those needs are and how to adapt to them, the lessons must be tried out with children from the target population. If the programs are aimed primarily at rural public schools, then the children should be from public schools in rural areas. If most schools have only one classroom for several grades, few text-books, teachers without credentials, and no equipment beyond desks, chairs, and chalkboards, then the classes chosen as field-test classes should have similar characteristics. Other factors to consider when choosing classrooms are the number of children in a classroom, the drop-out rate, the failure rate, the ages of the children, the experience of the teacher, the nature of the community, the distance of the school from paved roads and from nearby towns, the population density of the neighborhood, the availability of radio batteries, notebooks, and pencils, the regularity of mail service, the distance to the school district office, and the strength of the radio signal. Unless field-test classrooms are chosen with all these factors in mind, the project may succeed in tailoring the curriculum to a group of children who are unlike the children for whom the materials were mainly intended.

It is *not* necessary, and in fact not desirable, to use a random sampling technique for selecting the schools in which the formative evaluation is carried out. One reason is that a large sample is not needed: ten to twenty classrooms will usually suffice. If chosen randomly, a sample of this size might not contain any classrooms with the characteristics that might influence the results the most. For example, if only 10% of the rural schools are one-room schools, a random selection of a dozen classes might not contain any of these, which would leave the project staff unaware of the serious and complex problems of designing a curriculum for maximum effectiveness in a situation where the teacher's attention must be divided among several disparate groups of children. Neither must the classrooms be self-selected. Sampling by soliciting volunteers is almost certain to lead to a biased sample. Thus, the selection should be made by the project staff, taking care to ensure

that the selected classrooms are representative of the diversity of the entire target population.

2. INTERVENTION IN FIELD-TEST CLASSROOMS

Even though classrooms are chosen to be representative of the intended audience, they may not remain representative if they are provided with special services or privileges that will not later be available to all classes that use radio. Care must be taken to ensure that the field-test classes remain representative during the school year. If they are provided with expensive equipment, if the teachers are given extensive assistance in the classroom, or if they are closely supervised by enthusiastic project personnel, the characteristics of these classes may change enough so that they can no longer be considered representative of the target audience. The treatment of the field-test classes should be as close as possible to the treatment that will be provided on a larger scale at some future date. If special equipment will be used in all schools when the program is fully implemented, then it can be used in the field-test classrooms, but not otherwise. If, in the future, classrooms will be supplied with $50 radio receivers, then that same kind of equipment should be used in field-test classrooms. Similarly, if teacher training in the future will be limited to, say, twenty hours, then there should not be more teacher training for the field-test classes. If you cannot realistically expect a great deal of teacher supervision in the future, then supervision should be likewise limited during the developmental year.

The danger, of course, in exceeding planned levels of intervention is that the children's and teachers' interest and participation will be artificially increased to the point where the effects will be seen in achievement tests and other measures of the impact of the curriculum materials on the children's abilities and attitudes. Should there be a significant improvement due to excessive intervention, then the feedback obtained from these classrooms will mislead the production team into believing that the planned (minimum) intervention will be more successful than it actually will be.

Unfortunately, no matter how carefully factors such as equipment and teacher training are controlled, the level of additional intervention in field-test classrooms will still be high enough to have a significant indirect effect on achievement and attitude. This arises because of the nature of the formative evaluation process. Project personnel will have a noticeable presence in the classroom as they observe lessons in progress, test the children, and perhaps even interview teachers and children. This active attention, which is properly part of the formative developmental process used for producing educational materials and not part of the planned intervention itself, will have many indirect effects. Participation will be higher; the teacher, knowing her class will be

observed while using the radio lessons, will be more likely to use the lessons regularly, and children who are being observed will put out a little extra effort. Interest will also be higher; the teacher especially may be quite enthusiastic about having been chosen to participate in the new project. Because of frequent testing, the children's test taking skills may increase. Perhaps more importantly, the tests will serve to focus their attention on important concepts and facts that are included in the lesson programs. Because of the nature of the feedback process, this so-called Hawthorne effect cannot be completely eliminated, but it must be minimized as much as possible.

3. TEACHER TRAINING

The Radio Mathematics Project had as one of its goals the production of materials that required a minimum of teacher training and supervision. This did not arise from any feeling that training and supervision would not increase the educational effectiveness of the programs; good teacher training would undoubtedly enhance the value of the programs. But there were other factors that were an overriding concern. One of these factors was cost. Teacher training and supervision are expensive. With limited resources for implementation, the extent of the implementation might be severely curtailed if extensive training were to be an essential ingredient. Another factor was the logistic and bureaucratic difficulty of ensuring adequate training and supervision for all teachers nationwide. In countries like Nicaragua, teachers from remote, sometimes nearly inaccessible, rural areas cannot easily get to teacher training centers, nor can supervisors, who may not have adequate transportation at their disposal, travel to the schools.

Because of these difficulties, the Radio Mathematics Project restricted teacher training to a single three-hour session just before the school year began. During this session necessary materials such as radios, teachers' guides, worksheets, and transmission schedules were distributed to the teachers. General information about the project was given, usually by means of a short film or a slide-tape show. The tape for a typical lesson was played to illustrate the nature of the broadcast lessons, and the teacher's role before, during, and after the lesson was explained. The purpose of the teachers' guides was discussed, using as an example the guide for the lesson they had just heard. About an hour was allowed for questions from the audience. (See Table 7-1 for a list of topics that were included in teacher training sessions.) There was no additional training nor any special supervision of teachers during the school year.

Other projects might want to plan more extensive teacher training, especially if the curriculum they are preparing is quite different in content from what teachers are accustomed to. A note of caution is to be sure to provide no more teacher training in the field-

TABLE 7-1

Topics and Guidelines Discussed in Teacher Training

1. Have a broadcast schedule and use the radio lessons every day that they are broadcast.

2. Read the teachers' guide for each lesson the day before the lesson is broadcast so that you can prepare the materials that will be needed.

3. Be sure to have the necessary materials ready on time. Materials that the children will need during the broadcast must be distributed to them before you turn the radio on. If the children are to copy exercises from the chalkboard, be sure to allow enough time so you can write them on the chalkboard and the children can copy them before the lesson begins.

4. Turn on the radio on time. Tune it in carefully so there will be no distortion of the sound. Adjust the volume so the children in the back of the room can hear.

5. During the broadcast, encourage the children to participate. They should answer aloud when the radio teacher asks them a question. All children should do all of the written exercises. Children who listen but don't participate do not learn as much.

6. To develop listening skills, encourage the children to listen to the instructions given by the radio teacher. Do not repeat or paraphrase the instructions; the children should learn to listen and understand without additional help.

7. If you have more than one grade in your classroom, work with the grade that is not taking the radio lesson. That way, you can use the radio as a teaching assistant to teach the children in one grade while you are teaching the children in another grade.

8. Occasionally there may be one or two children who cannot keep up with the radio lessons. During the radio lesson you can sit with these few children and give them the extra help they need without distracting the other children who do not need special help.

9. Do the postbroadcast activities every day. Do not skip some days and try to do two days' activities in one day. Children learn best when they are taught a little bit each day.

10. In the postbroadcast activities, do not mimic the teaching style of the radio lessons. Encourage more small group work so the children can learn to work together. Also allow the children to ask more questions and to discuss ideas. Use activities

(TABLE 7-1, cont.)

with concrete materials and encourage the children to experiment and to speculate. The emphasis should be less on getting a correct answer and more on exploratory behavior that gives rise to questions rather than answers.

11. Adapt the postbroadcast activities to your own situation. If you don't have exactly the kind of materials suggested in the guide, find something similar that you can use for the same purpose. If you have special equipment or supplies that could be used in a better kind of activity, use them.

12. Try to make up activities of your own. After you understand the intent of an activity described in the teachers' guide, try to think of a similar activity that would teach the same concepts. The activities that you devise yourself are usually more interesting to the children and they will learn more from them.

13. Children learn a great amount from working with concrete materials like yardsticks, rulers, measuring tapes, scales, cups, pints, quarts, liters, and clocks. Try to gather together or make as many of these things as you can, and use them when appropriate. If you gather a few at a time and save them, you will soon have enough material and equipment to make your mathematics classes interesting.

14. Do not use more than 50 minutes for mathematics class even if the children seem very interested in the activities. The official time allotment for mathematics is 50 minutes. And remember: reading, writing, and other subjects are just as important for the children as mathematics.

15. Try not to "teach ahead" of the radio, even if you feel your class is ready for more difficult material. You may go too fast for some children. The pace of instruction used by the radio has been carefully researched to find the pace that will produce the most learning. Children need to be taught in small steps with ample repetition.

16. Do not introduce new methods or shortcuts. If the radio teacher uses one method for teaching a topic, use the same method when you work with the children, even if you know a method that seems to you to be better. Children can easily become confused if they are shown two different ways to do the same thing. Remember, the approach used by the radio was selected after careful thought and research; it is the approach that is best for most children.

test schools than would be provided later to all teachers who will use the completed set of materials.

4. DELIVERY OF MATERIALS

During the developmental year, most supplementary materials will not be ready for distribution to the teachers at the beginning of the year. Worksheets, teachers' guides, and other materials that are prepared during that year must be distributed regularly to the teachers in the field-test classrooms.

We delivered materials once a week during the developmental year. Delivering materials less frequently--once a month, perhaps--would mean that lessons would have to be prepared so far in advance that feedback from the classrooms could not be effectively used in planning and producing future lessons. This weekly delivery of materials is one way in which the treatment of classrooms during the developmental year differs from the treatment that would be given at a later time, and is one of the contributing factors toward a Hawthorne effect. Teachers may perceive these regular deliveries as something akin to a supervisory system; at the very least, they will be constantly reminded that the radio lessons are available and that they are expected to use them. It is best not to use these visits as a pretext for communicating with teachers. The person who delivers the materials should not discuss with the teacher any aspects of the radio lessons, nor offer advice on how to conduct the lessons. One way to avoid such surrogate supervision and in-service training is to have the materials delivered by a driver or clerk who is not acquainted with the educational aims of the project.

5. SUPERVISION

Of course, teachers may sometimes have questions that must be answered, so there must be some line of communication with the project staff. We anticipated that in a large-scale implementation, it would be too difficult logistically and too costly to provide on-going supervision beyond the level that was already being used in the public educational system. We planned, then, that the regular channel of communication in the future would be through the existing district offices. Even during the developmental year, it would be best to use this channel. For both administrative and pedagogical questions, we found it effective to have the teachers--or their principals--communicate with the district administrator, who could help them with problems of radio repair or replacement, obtaining teachers' guides, and getting additional worksheets, as well as answer questions about broadcast schedules, course content, and the way to conduct classes.

We found that district administrators could be trained in two to

three days of intensive seminars at our offices. Much of this time was spent on administrative matters: what do do about radio maintenance, how and when to distribute batteries, where to obtain more copies of printed materials, and so on. A large part of the time was also spent in discussing the nature and content of the curriculum and the teacher's role when using broadcast lessons.

6. THE USE OF CASSETTES

It is often suggested that for preliminary field testing of the curriculum materials, the radio lessons could be delivered by means of cassette tapes rather than by radio. Since so few classrooms are involved, this may seem the best approach. However, the differences between using radios and using cassette tapes in the classroom are so great that the feedback obtained might be greatly misleading.

One of the greatest differences between cassettes and radios is that the cassette is much more under the control of the teacher (which, incidentally, makes it a more effective though more costly medium of instruction in many circumstances). With cassettes, the daily lesson can start when the teacher wants, which means that prebroadcast activities need not be timed to end at exactly the time the broadcast begins. The teacher may allow the class more--or less--time to get ready; as much time as necessary may be spent on preparatory activities of all kinds. Some kinds of prebroadcast activities may take widely different amounts of time in different classrooms. If the teacher's guide suggests such activities, this weakness will not be uncovered by using cassette tapes.

Another result of having the lesson starting time controlled by the teacher is that the children never miss any part of the lesson. If a teacher starts the cassette player at 9:10 instead of 9:00, the children do not miss part of the lesson, which they would if the lesson broadcast had started at 9:00. Valuable information about the likelihood of tuning in late and the resulting decrease in learning would be lost.

Use of a cassette player also allows the teacher the option of stopping the tape at any time. If the pauses allowed for the children's responses are too short, the teacher can stop the tape until the children are ready to go on. If the teacher perceives--rightly or wrongly--that some concept needs elaboration, the tape can be stopped while the class is given further instruction. The net result of these actions may well be better instruction for the specific group of children, but the information about deficiencies in the taped lessons will not get back to the curriculum developers who could make changes that would benefit the children who will later take the lessons by radio.

Part or all of a cassette tape can be replayed; if the teacher believes that the children need more practice or need to review material

from preceding lessons, the tapes can be played as often as desired either for the entire class or for selected individual students. If the additional instruction was indeed necessary, the children's achievement scores will improve--an improvement that would not have occurred had the lessons been broadcast only once.

Cassette tapes also lend themselves to "stockpiling." For a variety of reasons a few lessons may be missed and the teacher may try to make up the lost time by giving several lessons in one day. In later years, when the lessons are broadcast, make-up lessons will not be possible; during the developmental year it is necessary to determine just how much review must be incorporated in the lessons to compensate for missed lessons.

Another feature of cassettes is that the teachers can preview lessons. This may result in additional prebroadcast activities if the teacher sees the need for special preparation. Also, the teacher may be able to play a more effective role during the taped lesson, rephrasing ambiguous questions, giving demonstrations that weren't requested by the teacher's guide, etc. In cases like this, the information gleaned from observing the class in action is more about the teacher's perception of the lesson than about the children's reactions to it.

Because cassettes do have many advantages over radio, lessons that are designed to broadcast cannot be effectively field-tested by using cassettes.

Chapter 8

TESTING THE CHILDREN

The most accurate way to measure the effectiveness of the curriculum materials is to test the students regularly to determine whether or not they are learning at the desired rate. Gains in learning should be measured by comparing the children's abilities before and after instruction. Retention of acquired skills should also be measured by follow-up tests to ensure that the curriculum includes adequate practice and review. If a lack of knowledge of prerequisite skills or concepts could seriously interfere with learning a topic, then prerequisites should be tested before the new topic is introduced; if necessary, plans can then be made to review them.

Tests for formative evaluation differ from tests used for evaluating individual children in that the aim of the former is to collect information that will lead to improvements in the curriculum materials rather than to collect information that will allow a judgment about an individual student's abilities. Most classroom tests, including standardized tests, aim at evaluating the individual student--to ascertain the extent of the student's knowledge, to determine whether he should pass or fail, or to find out what kind of remedial lessons he needs. Generally, tests that are used for evaluating individual students cannot adequately test every topic in the curriculum since such a test would be too long. Usually only a sample of the most important topics are included, under the assumption that a student's overall knowledge can be judged by his performance on some subset of the skills and concepts included in the curriculum. Also, tests used for evaluating individual students must be given to every student; individual decisions about grade placement or remediation for individuals cannot be made by testing a random sample of students.

When evaluating curriculum materials rather than students, the aims are quite different. It is important to evaluate how well topics are taught in the curriculum. But it is not important to evaluate individual students. Since the stress is on topics rather than students, it is not necessary to give the same test to all students. One group of students can be tested to determine the efficacy of the instruction in, say, ten topics; a different group of students can be tested in another ten topics; and so on. By breaking the tests up in this fashion it is possible to collect accurate information on many topics without requiring any one student to take an overly long test.

1. YEARLY PLAN

The first step in planning tests for the year is to decide which topics to test. Theoretically, if a topic is important enough to include

in the curriculum, it is important enough to test. In practice, it is impossible to test all topics, usually because of financial limitations which may cause the testing program to be somewhat curtailed; it may be that the amount of information gathered by testing certain topics is not worth the expense of gathering the information. In the Radio Mathematics Project, we tested only one third to one half of the total number of topics included in the curriculum; we omitted topics that could not be well tested in a paper-and-pencil test, topics that were not directly related to essential objectives, and topics that were quite similar to others that were tested.

Once the topics for testing have been chosen, the next step is to make up a tentative time schedule for testing the topics. The plan for the testing program must be keyed to the teaching schedule, since topics should be tested immediately after they are taught. To measure achievement *gains*, a topic must be tested before it is taught as well as after. This pretesting cannot be done by a general test at the beginning of the year but must be done just before teaching the topic. The reason for this is that there may be a great deal of transfer of learning from related topics that are taught earlier in the year. The Radio Mathematics Project has seen cases of learning gains of as much as 25% *before* a topic was taught. If such gains are sizeable then the outcome of the formative evaluation may be a recommendation to eliminate the topic from the curriculum. If this recommendation results from a pretest the week before teaching, it is probably too late to change the teaching schedule for this topic. Pretest results are needed while there is still time to make changes. If the production cycle is four weeks long, then pretest results collected five weeks before teaching can have an effect. Thus, pretesting of each topic should be done at least twice: one production cycle before teaching is scheduled, and just before teaching will start. Additional pretesting will provide further information about the influence of prerequisite topics and other related topics.

Pretesting is done to establish a baseline against which to measure learning gains and to determine if a topic needs to be taught at all. Posttesting is done to measure the effectiveness of instruction and to measure retention. A test immediately after teaching measures short term gains due to instruction. Long-term as well as short-term gains must be measured since children may not retain the knowledge and skills they have gained from the instruction. For most topics regular practice will be included after the initial instruction. To determine whether sufficient practice is provided the topic should be tested again a few weeks later and perhaps several more times during the year.

One possible scheme for scheduling is to pretest one, five, and ten weeks before teaching, and to posttest one, five, and ten weeks after teaching. Of course, this sequence would be truncated at one end or the other for topics that are taught near the beginning or end of the school year. This is a very heavy testing schedule, and it is not necessary to

test all topics so often. If there are several closely related topics, it may be sufficient to use the suggested scheme for only one of them, and test the others only twice, just before and just after teaching.

The testing schedule, which can be made up tentatively at the beginning of the year, should be flexible enough to allow for contingencies that arise during the year. There may be feedback from classroom observations, from teachers, or from test results for related topics that indicate a need to test a topic not originally scheduled for testing or to test more extensively in some topic that has already been tested.

TABLE 8-1

Typical Testing Schedule

	Topics						
Weeks	1	2	3	4	5	6	7
1	TEACH				Test		
2	Test			Test			
3		Test	Test				
4		TEACH					TEACH
5		Test					
6	Test			Test	Test		
7			Test	TEACH		Test	
8			TEACH	Test		TEACH	
9		Test	TEACH			Test	
10			Test		Test		
11	Test				TEACH		

A typical test schedule is shown in Table 8-1. In this schedule Topics 1, 2, 3, 4, and 5 are all on a heavy testing schedule; Topic 6 is on a light testing schedule; and Topic 7 is not tested at all. Notice that even though Topic 1 is on a heavy testing schedule, it is not pre-tested because it is taught too early in the year; pretesting for Topics

2, 3, and 4 is also curtailed for the same reason.

If at any time during the year the teaching schedule is changed (usually as a result of feedback from the tests or from classroom observations) the testing schedule must also be changed since the tests are keyed to the teaching sequence. Thus, if it is decided to teach Topic 6 in Week 12 rather than Week 8, the tests for Topic 6 must be changed from Weeks 7 and 9 to Weeks 11 and 13.

2. ITEM POOLS

As soon as the topics to be tested have been selected, item pools for each topic can be prepared. It is best to prepare the item pools at the beginning of the year so as to obtain consistency; if items are written as needed, there may be a gradual change over time in the wording of instructions, the formatting of the graphic display, and other characteristics that might invalidate direct comparisons of test results obtained at different times during the year. It is also wise to try out items in advance to establish validity and reliability.

To get accurate estimates of the children's performance, each topic should be tested by three or four or even more items each time the topic is tested. The number of items needed depends greatly on how well the behavioral objective is defined. Ideally, every behavioral objective would correspond to a universe of test items that was perfectly homogeneous in content, knowledge requirements, skills, and difficulty; in such an ideal situation, any test item selected at random would be sufficient since it would be perfectly representative of the entire universe of test items. In some of the better defined areas of arithmetic it is nearly possible to achieve this ideal, although even in arithmetic such a complete characterization of all skills has not been achieved. In mathematical topics outside the realm of simple arithmetic, it is difficult to define such clear behavioral objectives, and in subjects like natural languages it may well be impossible, given our current state of knowledge of these subjects and how they are learned. Furthermore, skill objectives, such as addition and punctuation, lend themselves more readily to this kind of definition than do other kinds of objectives; if the objective is to learn a certain list of unrelated vocabulary items, then no single item, or small set of items, would be completely representative since a child could have learned some words without any increase in understanding of the other words in the list. For these reasons compromise is necessary in deciding the number of test items. If the relative difficulty of items varies greatly, or if the variation is not known, it may be necessary to use eight or ten items to get an acceptable measure of performance on the topic.

Another consideration in deciding the size of the initial item pool is whether or not the same items are to be used when the topic is

retested. If the behavioral objectives are sufficiently clear so that there is no problem in selecting equivalent test items, then every test could use completely different items. However, if there is doubt about the definition of the behavioral objectives, then it is necessary to use exactly the same items in every test to ensure comparability. The only disadvantage of using the same items over and over is that some children might remember especially striking items and do better in subsequent tests. In general, the best solution is to use the same items but to test different, but comparable children. If this strategy is used then the size of each item pool will be just the number of items to be used on any one test.

To select items for the initial item pools, you should try out two to three times as many items as you will need in order to weed out items with ambiguous instructions, items that prove to require skills not included in the topic, and items whose difficulty is atypical. Work on item pools should begin early enough to allow for two or more trial-and-revision cycles; usually this means that the work must begin in the preceding school year.

3. WRITING TEST ITEMS

Test items for each topic should be written in conjunction with the specific behavioral objective for that topic. In fact, in many cases it is nearly impossible to completely clarify a behavioral objective for a topic without listing representative test items. If it is difficult to phrase the objective precisely, some thought about test items may help to clarify the concept.

Much has been written about the desirable properties of tests: validity, reliability, discriminatory power, etc. Most of these properties apply only to tests that are intended to evaluate individuals, not to tests designed for formative evaluation of a curriculum. The two characteristics desired for curriculum evaluation tests are content validity and item reliability. Reliability can be ascertained by simple test/retest procedures; validity is more difficult to attain and to verify. Since items with the kind of content validity described below generally have high reliability, the main concern of the item writer will be validity.

Basically, an item has content validity if it tests exactly the knowledge or skills that it is purported to test. To prove validity we must show (1) that correct answers are given by those students who have the ability in question and (2) that wrong answers are given by students who do not have the ability.

There are many ways in which children can correctly answer a test item even though they lack the ability specified in the behavioral

objective. They can guess--a common response to multiple-choice items; thus, no matter how carefully written a multiple-choice item may be it is always invalid to some extent because some proportion of the correct responses will be given by children who do not have the desired ability.

Sometimes an item contains unintentional clues. Consider this item:

Select the phrase that is closest in meaning to the underlined word.

<u>Typhoons</u> occur most frequently in June.

(a) Large sailing ships
(b) Bad storms
(c) Ancient fortresses
(d) Japanese warlords

Ostensibly this item tests the child's understanding of the word *typhoons*. However, since only *storms* can *occur* (ships, fortresses, and warlords do not occur), some children can select the correct answer without understanding the word *typhoons*. (The item can be improved by changing "Typhoons occur most frequently in June." to "What are typhoons?")

A more elusive variant of the same fault is found when unintentional clues are given by *other* items in the same test. The best check on this is to do each test, as a student would, in its entirety. Thus, content validity is not just a characteristic of isolated test items but a characteristic of items in a specific test context.

Some children who lack the ability being tested may copy answers from a fellow student's paper. Thus, it is not just the test context of an item that may cause invalidity but the entire testing environment. Copying may be controlled by close monitoring during examinations, by penalizing students, etc. A better method is to give different tests to different students so that they are not doing the same test items; even with only five or six tests distributed randomly in each classroom the chances are very slight that two neighboring children will have the same test. This will not in itself reduce copying unless the children are told they are taking different tests. However, even if there is copying we can be reasonably sure that correct answers are not the result of copying.

In summary, we can never be absolutely certain that correct responses are given only by those children who have the ability being

tested, but reasonable care and awareness of the problems help to improve the validity of the test.

The other aspect of content validity concerns the incorrect responses. We want to be certain that incorrect responses will be given only by those children who do *not* have the desired ability. That is, we do not want children who have the ability to fail because they did not understand where and how to write their answer or because they were confused by the wording of the test instructions. This aspect of validity can often be verified by a study of the incorrect responses actually given by children; that is, we can offer data-based evidence that, for a particular group of students, the item has high content validity as far as the "incorrectness" aspect is concerned.

Suppose that an item has been written and we wish to verify its validity through an error analysis. First we administer the item to a sizable sample of students and look at the incorrect responses. To show validity we must be able to explain the incorrect responses in terms of a deficiency in the knowledge or skills specified by the behavioral objective. Many times incorrect responses are clearly the result of a student misinterpreting some administrative instruction; he puts his answer in the wrong place, or enters it in the wrong form. These are evidence of an invalid item. Suppose a child is asked to "write a synonym of *erroneous*" and he writes "correct." If the behavioral objective specifies that the child was to know a synonym of "erroneous" but not that he was to understand the word "synonym," then this response indicates invalidity; it seems that the child knows the meaning of the word "erroneous" and could probably produce a synonym (since he produced an antonym), but he does not understand the word "synonym." Thus, his incorrect response is caused by a lack of an ability that is outside the scope of the specific objective.

One possible result of such an analysis may well be a change in the statement of the behavioral objective. Reformulating the objective is not an underhanded way of assuring content validity of test items; validity is a characteristic of the relationship between an item and an objective; it is not an inherent characteristic of items.

The above example indicates that we need to know what part of an item contains the essence of the idea to be tested and what part is an instruction whose wording could be altered. It is useful to consider the *form* of an item as distinct from its *substance*. Consider the following items:

Write the sum of 7 and 5.

Write the sum of 2 and 9.

Write the sum of 5 and 8.

These three items all stem from the same objective (add two one-digit numbers whose sum is between 10 and 18, inclusive), and all three items have the same form, although they differ in substance:

Form: Write the sum of _____ and _____.

Substance, Item 1: 7, 5

Substance, Item 2: 2, 9

Substance, Item 3: 5, 8

The substance is determined by the objective and cannot be changed. The form, however, can be altered if desired. Alternate forms for the above items include:

Write the total of _____ and _____.

Add _____ and _____ and write your answer.

How much is _____ plus _____?

Since we assume the substance of an item to be immutable, investigations of content validity center on an investigation of item form. If we have several alternate forms at our disposal, as in the above example, we can determine which form is the most valid by trying them out, using the same substance in each one. The form that yields the highest percentage of correct responses is generally the most valid form. Notice that this argument applies only to the forms that can be used with a wide range of substances; it is not generally true that the easier of two items is the more valid (as we saw in the "typhoons" example given previously).

Sometimes there is only one form that seems reasonable to use. In this case we cannot choose the most valid of several alternatives, but we may still want to obtain some information about the validity of the form, since if it is quite invalid we may not wish to use it at all. A fairly good idea of the validity of the form can be gotten by trying out the same form with a number of different items varying the substance so as to obtain items of different difficulty levels, using some a priori judgment about relative difficulty. For example, the form "Write the sum of _____ and _____." can be used for a wide variety of items of differing levels of difficulty, taken from closely related topics:

Write the sum of 2 and 3.

Write the sum of 7 and 9.

Write the sum of 20 and 6.

Write the sum of 48 and 5.

The relative difficulty of these items as determined by actual testing of children should correspond quite closely to our intuitive idea of difficulty. That is, we would expect children to find the first item above the easiest, the second item a bit more difficult, etc. If the results do *not* correspond quite closely to our a priori ranking the form is probably invalid.

4. ASSEMBLING WEEKLY TESTS

Weekly tests cannot be assembled ahead of time since the list of topics to be tested may change due to changes in the teaching schedule or because previous tests or classroom observations indicate a need to test topics that were not included in the original test schedule. Thus, test construction like lesson preparation must be a part of the weekly production schedule.

One thing that can be done in advance, however, is to lay out the format of the test worksheets and to establish the style of the general instructions so that these common elements of the tests will be the same throughout the year. Factors that can be specified in advance are the kind of header (name, date, etc.) to use on the printed worksheet, the conventions to use for identifying the test items (are they to be identified by letter, number, or picture? are they to be separated from one another by lines?), the wording of initial instructions, and the phrasing of the instructions on where and how to write responses. These elements of a complete test are independent of the specific items to use in the test but also affect the validity of items. They should be field tested in advance and not changed during the year.

If the general form of the test and the specific item pools are all designed and tested before the year begins, the task of producing weekly tests is fairly simple. First, the list of topics to be tested is modified according to the needs of the moment. Then the items for all topics are assembled into a single list. If there are 20 to 30 topics to be tested, there may be 100 or more items. This would be too long a test for any individual child to take. It must, therefore, be broken into a number of smaller tests. You might allow anywhere from 10 to 50 items per student depending on the ages of the children and the average difficulty of the items. Ordinarily, the test should not take more than about 20 minutes to administer since more than this is an undue imposition on both the students and the teachers. The time allowed, however, should be sufficient for all children to complete the tests since missing data leads to faulty analysis and faulty conclusions. It is best to divide the items so that each test in the weekly battery of tests is of about the same length and difficulty so that there will not be a wide variation in the time needed by the children to complete the tests.

5. TEST ADMINISTRATION

The first step in administering the weekly tests is to decide which children to test. The decision about how many children to test should be made at the beginning of the year before the experimental classes are selected. This decision depends on the following factors:

(1) The number of topics to be tested during the year.

(2) The number of items to be used in testing each topic.

(3) The number of times each topic is to be tested.

(4) The size of the student sample that is needed to establish statistical significance of any differences.

(5) The number of items to be used in each test in the weekly battery.

If there are, say, 200 topics to be tested an average of four times during the year, and there is an average of five items per topic, then 4000 items will be given during the year. Assuming that the items are spread over 25 weeks, then there will be about 160 items in each weekly battery. If each child is to be given abut 20 items and each item should be taken by 30 students, then the total number of children to be tested would be:

$$\frac{160}{20} \times 30 = 240$$

If there are, say, 25 students per classroom on the average, then 10 classrooms would suffice for the weekly testing component of the formative evaluation.

If each weekly test battery contains five tests, it is natural to think that Test 1 should be given in two classrooms, Test 2 should be given in another two classrooms, and so on. This is not the optimal distribution of tests for several reasons. First, a given topic might be tested in different classrooms in different weeks; since classrooms may differ greatly from one another on any number of dimensions the results from the different weeks will not be comparable so you will not obtain a good measure of the effect of instruction on the average student. Second, if all children have the same test, it is more difficult to control copying. Random distribution of tests over all children is much better. In each classroom, give Test 1 to the first child, Test 2 to the second child, etc.; this ensures that all field-test classrooms are represented in the statistics for each test item, and reduces the copying of answers to an insignificant level.

To ensure that tests are administered consistently, the test administrator should adhere strictly to a set of written instructions. The time allowed for the tests should be the same in all classrooms. The oral instructions for the children should be identically worded; for greatest control, the test administrator should read these instructions from a prepared script. The introductory instructions for the children may include instructions not to copy or talk, instruction on where to write their names, and advice to use pencils instead of pens. In Nicaragua, we supplied pencils with erasers and collected them at the end of the testing session.

Because the administration of tests needs to be so tightly controlled, the tests should be given by trained project personnel, if resources permit, rather than by classroom teachers. If possible, classroom teachers should not be in the classroom during testing since they may give inadvertent clues or even intentional help to the children, and also since a knowledge of the test content may influence the emphasis of instruction in upcoming lessons.

6. TESTS WITH ORAL INSTRUCTIONS

The scheme described above for the design and administration of the tests is adequate if the instructions for the individual items are printed on the test worksheets. For young children who have not yet learned to read with facility, the instructions for many items should be given orally. A first-grader, for example, might be able to find and circle the largest of 12, 41, and 20, but might not be able to read the instruction, "Circle the largest of these numbers."

When oral instructions are used but different children within the same classroom are taking different tests, a serious problem of test design arises. Items must be distributed among the tests in such a way that all items in corresponding positions require the same oral instruction. This generally means that items in the same position on different tests are similar to one another; they may be testing the same behavioral objective or very similar behavioral objectives. This is not always the case, however; some kinds of items require only the most general kind of instruction--or none at all.

Table 8-2 demonstrates how this works in practice. It shows a 3 × 3-item test (3 tests and 3 items per test) with common oral instructions. Item 3 in Table 8-2 requires no instruction; all essential information is contained in the printed component of the item, and most children would know what to do with these items even if no oral instruction were given. In Items 1 and 2 some essential part of the information is contained in the oral component. Although some children

TABLE 8-2

Three Tests with Common Oral Instructions

Oral Instruction	Worksheet		
	Test A	Test B	Test C
1. "Write the number that goes between these two numbers."	4 ___ 6	972 ___ 974	49 ___ 51
2. "Circle the greatest number."	8 10 15	362 326 289	3.2 3.02 10.1
3. "Solve this exercise."	3.2 - 1.58	5 x 2	$\frac{5}{7} - \frac{2}{5} =$

could do Item 1, Item 2 is completely unsolvable without the information contained in the oral component; the instruction that goes with a printed item like:

8 10 15

could be "Circle the least number" or "Circle the one-digit number" or "Circle the odd number."

If tests contain items with oral instructions, the distribution of items across tests will depend partly upon the oral instruction. Items in the same location on different test worksheets must have the same oral instruction. The easiest way to do this is to plan for exactly the same number of tests per battery as there are items per topic: If there were, for example, five tests and five items per topic, the first item on each test would be for topic 1, the second item for topic 2, etc. The disadvantages of this kind of parallel testing is that the number of items per topic is fixed regardless of the nature of the topic, and the total number of topics that can be tested in one week is exactly the same as the number of items that can be given to any one child. Limiting the number of topics to the number of items that can be given to an individual may be a very severe restraint. One way to get around this is to use two, or even three, batteries of tests each week. Of course, the more batteries of tests there are, the greater the total number of children needed in the experimental group.

If much of the test is oral, there arise variations in administration that must be controlled in order to get reliable results. As mentioned above, a script for all instructions should be supplied to each test administrator so that the wording of item instructions will be the same in all classrooms. However, because different people read at different speeds, use different intonation patterns, make different gestures, and allow differing amounts of time for students to write their answers, there is still considerable variation. This variation can be significantly reduced by using taped test instructions. For other subject areas, taped tests might be even more desirable than they are for mathematics; in teaching second languages the validity of test results would be much higher with taped tests.

If there are oral instructions with each item, a problem of timing also arises. The time allowed for responses should be enough so that all children can complete each item. This timing can be better controlled on a tape than if instructions are read from a script.

7. COMPLETELY ORAL ITEMS

In the oral items exemplified above, there was a printed component that contained essential information. For many topics, it may be desirable to use test items that are completely oral, using the worksheet only as a convenient place to write the answer. You might, for example, want to ask the children to write a number from dictation or to spell a word. In those cases the substance of the item as well as the item instruction is given orally. This means that all children in a classroom will be doing the same task at the same time, so the sample of students who are contributing to the performance data is four or five times the size of the sample on items that have varying printed components. This will give a larger sample than is needed for statistical reasons. There is, however, no reason to give the same oral item in every class to which the same battery of tests is administered. The completely oral items must be the same for every child in the *same* classroom but they can vary from classroom to classroom. We can design a test with two different sets of oral instructions for completely oral items but with the same oral instruction for partly printed items, as shown in Table 8-3.

In this test Items 1 and 2 are partly printed, and Item 3 is completely oral. Note that for completely oral items, unlike partly printed items, there need be no relationship whatsoever between items in corresponding positions. Oral instructions of Form I are to be used in half the classrooms tested and oral instructions of Form II in the other half.

By designing a test with two different forms of oral instructions and four different forms of worksheets we effectively end up with eight

TABLE 8-3

Tests with Two Forms of Oral Instructions
for Completely Oral Items

Oral Instruction		Worksheet			
Form I	Form II	Test A	Test B	Test C	Test D
1. "Write the successor of this number."		5 ___	19 ___	309 ___	251 ___
2. "Complete this equation by writing the missing number on the line."		4 + __ = 7	25 + 17 = __	__ × 7 = 56	__ + 12 = 30
3. "Write the sum of 17 and 12."	"Write all the prime factors of 105."				

different tests and a 2 x 4 split of the sample population. The total number of items for which we will obtain information depends upon how many items there are on each test worksheet and how many of these are completely oral. If there are, say, 30 items and half of them are completely oral there will be:

15 × 4 = 60	partly printed items
15 × 2 = 30	completely oral items
90	total items

If only 10 of the 30 items are completely oral then we have:

20 × 4 = 80	partly printed items
10 × 2 = 20	completely oral items
100	total items

Chapter 9

GATHERING OTHER INFORMATION

Test data are the most reliable source of information about the efficacy of the curriculum materials. From paper-and-pencil tests, the children's abilities in most topics can be quite accurately measured. However, group tests do not yield answers to many of the questions of curriculum designers, script writers and other members of the production team. Some topics cannot be tested by means of paper-and-pencil tests. Also, test data generally tell how much learning occurred but not how that learning came about; if the children do not learn as rapidly as desired or give inexplicable erroneous responses, test data usually do not help in determining why the children had these particular problems. Did the children misunderstand some particular phrase used in the instruction? Were they not allowed enough time to complete tasks? Did the radio actors speak too fast? Was the instruction so explicit that the children never had the opportunity to develop the kind of independent problem solving skills that would be tested by a paper-and-pencil test? Were the examples poorly chosen? Answers to these kinds of questions must come from sources other than group tests. Information about the learning process itself rather than just the end results of learning comes from sources such as classroom observations, individual testing of children, and suggestions from teachers and supervisors.

1. CLASSROOM OBSERVATION

Classroom observations are one of the most fruitful sources of information about the process of learning. At the beginning of a school year and whenever new instructional techniques are used, the information from classroom observations will be more useful to the curriculum designers and script writers than any other kind of data gathered.

Unfortunately, classroom observations produce an even greater Hawthorne effect than group testing. The presence of observers in classrooms almost ensures that the teachers will use the radio lessons every day, that they will start classes on time, and they will devote both more time and more effort to the subject than they would if unobserved. The children, also, will put forth more effort when observed by a stranger in the classroom. If the observers actually assist the teachers by making suggestions or working with individual children, then the teachers may be receiving assistance that would not be offered as part of the curriculum package in the future. The net result of these effects would be that the children's performance and interest would be markedly higher in classes that are regularly observed.

The Hawthorne effect can be controlled to some extent by observing as unobtrusively as possible and by making sure that the

teachers are convinced that the observers are in the classrooms for the purpose of finding out how the children react to the curriculum materials rather than for the purpose of training, supervising, or assisting the teachers. It is not enough simply to *tell* the teachers the purpose of the observations; the conduct of the observers must also convey the message that the purpose of their visits is to investigate the effects of the instruction on the children. The observers must obviously focus on the children, not the teachers, and must not offer either advice to the teachers or help to the children. Even if teachers solicit suggestions or assistance, observers should politely decline. Since teachers are so likely to perceive observations as a form of teacher supervision, it is important that the observers not be people who have held supervisory or training positions; if they come from the same district, teachers will already know them in that role, but even if they come from other districts and are personally unacquainted with the teachers, they will have difficulty in changing their attitudes and behaviors vis-à-vis the teachers. In connection with this it is frequently assumed that the best classroom observers would be people with previous experience in classroom observation. This is often not true, however, since most classroom observation is undertaken for the purpose of upgrading teacher skills, and the focus is on the teacher rather than the students.

Despite these objections to classroom observation as excessive intervention, the benefits outweigh the disadvantages. In the first months of production, formative information from observations will have a greater impact on curriculum design than any other source of information, even tests. The kinds of design parameters that might be changed as a result of observational data include:

- Length of radio programs
- Lengths of instructional segments
- Mix of instructional and entertainment segments
- Frequency and duration of dialogues between radio personalities
- Frequency of student responses
- Kinds of student responses
- Amount of instruction for new topics
- Rate at which prompting is faded
- Length of instructional messages
- Vocabulary

- Style and timing of announcement of correct answer
- Amount of time allowed for children's responses
- Kind of background sounds used during pauses for children's responses
- Signals used to indicate the ends of pauses
- Mix of voices
- Speed of speech
- Use of juvenile voices for cuing student responses
- Kinds of sound effects
- Type of entertainment
- Format of worksheets
- Style of artwork
- Selection of auxiliary concrete materials
- Number of activities in post broadcast period

2. TRAINING OBSERVERS

The first step in training observers is to explain to them that the goal of classroom observations is solely the improvement of instructional materials. There are many interesting things to observe in a classroom: the social development of the children, reactions of individual children to praise from the teacher, the physical surroundings and how they influence intragroup communication, etc. Most of these things are not of interest to the curriculum developers since they will not affect the design of the instructional package. Observers need to be fully acquainted with the instructional materials and the goals of instruction, and they must also know enough about the production of materials to have a good understanding of what factors are under the control of the production team and what factors cannot be changed. It is important for the production team to know, for instance, that the children cannot identify a certain sound effect, since sound effects can be changed. It is not informative to suggest that class size be limited to twenty students, since class size is beyond the control of the production team. The entire production process, from the design of the curriculum master plan to the delivery of materials to the classroom, should be explained to the observers, stressing the kinds of decisions

that must be made at each step. In making the master plan, for example, the critical decisions are how much material to include in the course, how finely to divide the curriculum into topics, and how to sequence these topics. In making the lesson outlines, some of the critical decisions are how long the radio programs should be, what topics to include in the radio broadcasts and what to put in the postbroadcast period, how many instructional segments there should be, how many exercises to put in each segment, and what kinds of supplementary materials to use. In writing instructional segments, there are decisions to be made about the length and phrasing of instructional messages, the timing, the rate of fading prompts, etc. Writing teacher's guides, producing radio programs, and designing worksheets similarly involve innumerable decisions about factors that will influence the amount children learn from the materials. Although each of these decisions is made from the best information available, that information is frequently inadequate, and changes based on data gathered from the classroom can lead to significant improvements.

Besides teaching observers where and how their comments can be incorporated into the curriculum package, they should also be given advice on how to conduct themselves in the classroom. The first rule is to observe the children, not the teacher, since the main concern is the impact of the instructional materials on the children. Initially, almost every observer focuses more on the teacher, a natural result of the fact that teachers generally tend to dominate the classroom by placing themselves physically in the most visible position in the room and by taking the lead in all activities. A concerted effort must be made to focus on the children rather than the teacher.

To avoid distracting the children, the observer should begin each session by standing quietly in the back of the room or where the children cannot easily see him. He should not make obtrusive gestures or noises. After the children have become involved in the lesson, the observer should circulate quietly among them so he can observe individual responses, especially written responses that cannot be seen from a distance. Care should be taken when observing the work of any individual child, since the child may become distracted and uncomfortable if he feels himself subject to prolonged or critical scrutiny. No assistance should be offered to the children. If a child requests assistance, he should be told to ask his teacher. One way to discourage such involvement with individual children is to avoid eye contact and to be continually occupied with note taking.

Involvement with the teacher should also be avoided. Advice or comments should not be volunteered. If the teacher asks for suggestions on how to conduct a certain activity or how to deal with an individual child, the observer should reply as noncommittally as possible. If the teacher seems unusually anxious to receive advice, the observer may give diffuse praise in the form of comments like, "Everything seems to be

going very well. Thank you for letting me observe in your classroom."

When observers are beginning their training, a good procedure to follow is to send two observers to the same classroom so they can compare notes and help one another to sharpen their skills. It is best if one of these is an already trained observer, but even two untrained people working together can effectively train themselves, especially if they later confer with script writers and curriculum people to find out which of their observations are helpful for the production of instructional materials.

3. THE OBSERVATION FORM

Notes made by observers should refer to specific activities that occur during the lesson. General comments are usually of little help to the production team. For example, the observation that some of the exercises did not allow the children enough time to write their answers is not specific enough when a lesson may consist of ten different kinds of exercises, with widely varying lengths of pauses. Instead, the observer should note specifically that the response pause was too short in the first three exercises of the fourth instructional segment.

To assist the observer in keeping his comments to specific points of the lesson, an observation form should be used. This form need not be elaborate but must be specific to the lesson being observed; general observation forms yield little useful information.

The ideal observation form is one that serves to orient the observer in the briefest possible way. An example of the kind of observation form used by the Radio Mathematics Project is shown in Figure 9-1. Each segment of the radio program should be identified by printing the first exercise of the segment, writing the name of the song, or describing in a few words the kind of game or other physical activity that the children will be participating in It is best not to use a single short phrase that will be spoken only once by one of the radio characters since the observers may be momentarily distracted and miss this cue. What he needs to be able to do is to determine the correct section of the radio lesson by observing the actions of the children or the exercises they are doing in the notebooks.

For most lessons there will be some segments about which the curriculum designers or script writers have specific questions. These questions, written in the simplest, briefest form possible, should be inserted into the observation form at the appropriate points, and reviewed by the observers before the lesson starts.

In many cases the observers will see something that is entirely unanticipated. These observations do not fit neatly into a pre-planned

OBSERVATION SHEET

Lesson 171, Second Grade Date _____

School _____ Teacher _____

No. of Students _____

SEGMENT	COMMENTS
Song: Good Morning	
Song: Monday a Baby Girl was Born	How many children know the words?
Oral problems, time	
Oral problems, addition 40+8, 60+3,...	
Addition of fractions, from chalkboard	How many children had difficulty writing 2/3? ____ 3/5? ____ 5/10? ____ 3/4? ____
Joke: The Candy Man	Did the children laugh?
Oral subtraction, 12-4, 17-8,...	Were the pauses for calculating the answers long enough?
Column exercises, from chalkboard	
Game: Simon Says	Did most children participate?
Comparison of numbers, from chalkboard	
Division, drawing circles	
Riddle: The Drum	How many children guessed the answer?
Problems, The Race	
Multiplication, dictated	How many children had difficulty writing the exercises? What kind of problems did they have?

FIGURE 9-1.
Observation Form for Lesson 171

form so there must be enough room on the form, perhaps at the end or on the back, for comments that do not seem to belong in another place. Unexpected occurrences are usually more important than more ordinary observations but may be missed by an observer who is restricted by an overly detailed observation form. One of the reasons observers fail to note the unexpected is that they have too many mandatory notes to write. To avoid this problem, do not put too many specific questions on the observation forms.

It is best not to design a fixed format for the observation forms since a little experience will provide ideas for improvement of the forms. And the forms need not be elaborately produced. Photocopies of neatly hand-printed forms are usually sufficient.

During the radio lessons, the observer should write comments for each segment of the radio program. Specific questions should be answered if possible. The main concern is with the cognitive aspects of the lessons. The children should be watched closely to see if they seem to understand the instructions being given and if they can do what is expected. If there are any specific symptoms of misconceptions these should be noted. The best guide to determining whether or not the children understand the concepts being taught is their participation. If they perform the tasks requested without hesitation it should be assumed that they understand. If not, the observer should try to determine if the source of the trouble is the phrasing of instructions, the task itself, the time allotted, or some lack of necessary background, making note of specific errors committed by the children. In many cases the observers will not be able to make a definitive statement as to the source of the problem but should nevertheless record their best guesses for later discussion with other observers, script writers and other project personnel.

A second concern is the interest and attitude of the children. Do they seem attentive and interested? Do they participate willingly, or grudgingly? Or not at all? During entertainment segments do they respond with enthusiasm? Do they sing, hum, keep time with the music? Do they laugh at the jokes, or at least smile? Even a groan at puns may be an indication of interest, whereas a far-away look is an indication of material that is not satisfactory. During games that require physical participation do they seem to anticipate the opportunity to participate or are they embarrassed and ill-at-ease?

4. INDIVIDUAL INTERVIEWS AND TESTS

Group tests yield the most reliable information about the results of learning. Classroom observations, in contrast, yield information about the learning process rather than the end results. An even more fruitful source of information on children's thought processes is the individual interview.

To investigate cognitive thinking processes that are affected by the instructional devices and content of the curriculum, interviews must be highly structured and content oriented. Children can be asked to solve problems and do exercises as the interviewer watches and records the sequence in which operations are performed and the places where the children hesitate or seem unsure of themselves. The children can also be asked to report their thinking as they do the task. Some children are remarkably communicative and provide valuable insights into their conceptions and misconceptions. If the children are hesitant they can be prompted to some extent, but the interviewer should be sensitive to the child's attitude toward extensive questioning and skip on to other tasks if the child is unwilling, or unable, to supply more details about his cognitive processes. Also, care must be taken not to ask leading questions for a child will frequently agree that, yes, he did think what the interviewer suggests.

Young children are sometimes quite shy with interviewers. One device that seems to overcome the communication barrier in these cases is a play situation in which the interviewer assumes the role of student while the child plays the part of a teacher who is explaining the task to the student/interviewer.

Structured interviews of the kind suggested above have the goal of exploring in depth the thinking processes of the children. Another kind of interview is more like an individual test in which the goal is simply to determine whether or not the child can do the task, but not how he does it. This kind of individual testing is useful for measuring performance on topics that cannot be tested by a group paper-and-pencil test. To find whether young children can read numerals like 84 or 78, for example, the best method is ask them individually to read the numbers aloud.

Individual interviews and tests are a time consuming and therefore expensive way of collecting data. To ensure that the time is spent as efficiently as possible, the children to be interviewed must be carefully selected. For exploratory studies or to estimate group performance on objectives that cannot be group tested, the children can be selected at random. But for in-depth studies of misconceptions and error patterns, the children should be selected by means of a screening test; for example, if you want to investigate the kinds of errors children make when solving certain kinds of arithmetic exercises, a group test can be given to identify the children who are having problems so that just those children can be interviewed.

5. SUGGESTIONS FROM TEACHERS

Many projects have relied heavily on the classroom teacher to supply suggestions that will lead to improvements in curriculum

materials. If teachers are treated openly and frankly, they can be a source of many excellent ideas and criticisms. For a project that is just getting underway, comments from the teachers who are using the curriculum materials are invaluable. For best results, the teachers should be well informed about the project and its goals; as with observers, the more the teachers know about the production process, the more pertinent their comments will be.

There are, however, a number of disadvantages of using teachers as a source of information, and in no case should they be used as the sole source. One disadvantage is that this kind of cooperative effort is a great imposition on the teacher's time. If possible, teachers should be reimbursed or compensated in other ways for the time they devote to these extra duties.

Another disadvantage is a greatly increased Hawthorne effect. Teachers who are better informed about the project and who are asked to contribute to the curriculum design will become so involved in the project that their enthusiasm will be a direct cause of increases in children's abilities. It would generally be best not to rely on test and observational data on children who are taught by these highly involved teachers.

If teachers are relied on as one of the primary sources of information, their comments should be interpreted with care. Many teachers are poor judges of students' abilities. There are several reasons for this. One is that the most vocal, and hence most noticeable, students in a classroom tend to be those with greater than average ability. Another reason for misjudgements about children's abilities is the conviction, sometimes subconscious, that teaching and learning are opposite sides of the same coin, that children know nothing until they are given explicit instruction and that once they have received such instruction they will have learned what was taught.

The input of experienced teachers into the curriculum design and production is an absolute necessity. However, the amount of input that is needed is far too great to rely entirely on teachers who are already engaged full time in teaching activities. Instead, experienced teachers should be hired as full-time members of the staff.

6. CHILDREN'S WRITTEN WORK

Some information about children's errors and misconceptions can be gleaned from studies of their written work. Worksheets, notebooks, and homework papers may be collected and inspected for clues about conceptual difficulties. In doing arithmetic, for example, children frequently use written "crutches" like tally marks or rough sketches. Generally, the information obtained from children's written work is not

sufficient to justify as much effort as group testing and observation but occasional surveys of small samples of children's work are well worth while. One word of caution in analyzing such samples is not to rely on such written work as an indication of children's true abilities since they may receive much help from teachers, other students, and family members.

Chapter 10

DATA ANALYSIS FOR DECISION MAKING

Feedback from tests and classroom observations may affect various stages of the production process. Feedback that indicates a change in the planned content of lessons will affect the lesson planning and every step thereafter. Feedback that indicates a change in the speed of speech will affect studio production but not script writing or lesson planning. Thus, there are several feedback loops, not just one. The different points at which feedback may enter into the production process are shown in Figure 10-1. Because the feedback enters in at different points, the time it takes for the effects to be felt in the classroom varies. If the change affects only studio production, and nothing before that point, the effect will reach the classroom in a very short time. But if the change is in the lesson content itself it will not reach the classroom for several weeks.

The faster information is fed back into the production process the better the curriculum materials will be. For this reason, it is unlikely that there will be time to perform complex statistical analyses of the type often reported in statistical evaluations of formal experiments. Also, the style of reporting results will be less formal since the audience for the analysis of formative data is within the project, rather than a wider audience who might demand more precision than will be needed for making rapid decisions about the style or content of instructional materials. Results need to be reported as fast as possible in language that is easily comprehended by curriculum designers, script writers, artists, writers of teacher's guides, and other staff members.

To keep information flowing, it is helpful to release reports to the production team in several stages. Results of classroom observation will usually be obtained first because there are no papers to grade or statistical analyses to be done. Gross analysis of test results would be reported next. If a more detailed analysis of errors on test papers is done, that information would be contained in yet another report. And finally, if further individualized testing or interviewing is needed, there might be a fourth report. Each report should be organized by topic. The recommendations for each topic should be (1) no change in plans is necessary, (2) a specific change is recommended, or (3) no recommendation is made pending further study of already collected data or collection of new data. If there are more data to be collected, the mechanism for collection must be decided. It may be that the usual channels of testing or classroom observation can be used to obtain the information needed. Or it may be that special methods of collecting information are needed. (Note that if the result of feedback is a recommendation that more feedback data are needed then the feedback is

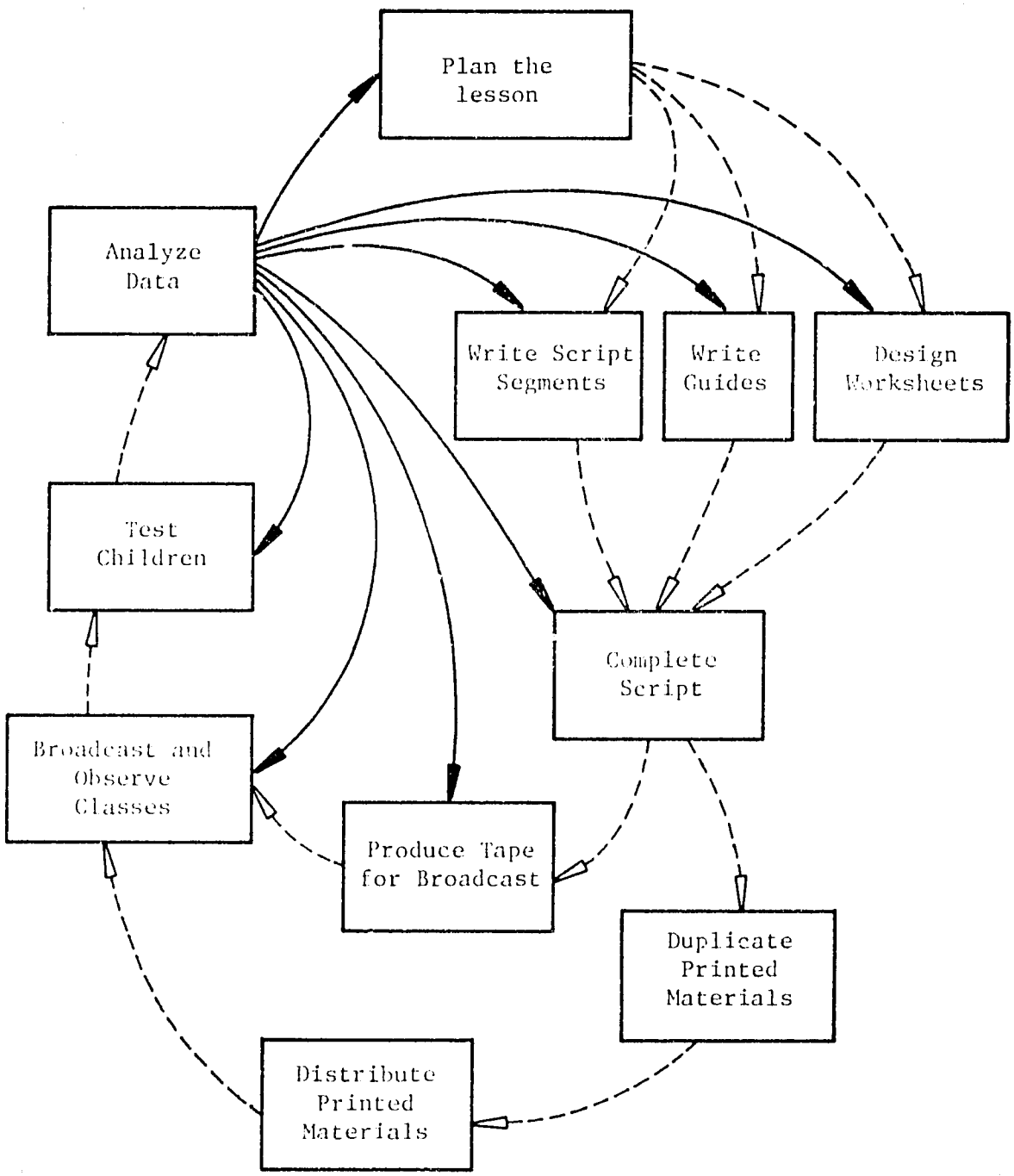

FIGURE 10-1.
Feedback into the Production Process

affecting the feedback mechanism itself, as shown by the smallest loop in Figure 10-1.)

1. ANALYZING CLASSROOM OBSERVATIONS

Information from classroom observations is sometimes referred to as "soft" data in contrast to the "hard" data obtained from paper-and-pencil tests. It is "soft" in the sense that it is less reliable since it is a report of the observers' perceptions, and is quite open to interpretation. Even though less reliable, observational data are often the only information about some aspects of the curriculum's effects on the children. To discard this information entirely would be as shortsighted as to rely on it as the only source of information.

Since observational data are colored by the observer's preconceptions, it is best to have observations by several people, and to form recommendations by consensus. It is also best for each observer to observe a sequence of lessons, preferably in different classrooms, before forming conclusions. In Nicaragua, we found the best way to interpret observations was to hold a meeting of all observers once a week. With notes covering the last five lessons in hand, the observers would discuss each topic covered during that period of time, and agree on a recommendation that would be included in a joint report. If no consensus could be reached, the report would call for further investigation, usually either further observation or more extensive testing.

2. FIRST ANALYSIS OF TEST DATA

The first step in analyzing data from group paper-and-pencil tests is to calculate, for each test item, the proportion of children who gave a correct answer. If there are several items testing the same objective, the average of the percentages correct for this objective should also be computed. These results can be reported in a form, like that in Figure 10-2, that shows both the test items and the results.

In reading that figure you will note the low performance in the multiplication items (Topic MC4) compared to the performance on comparisons of decimals (Topic CD3). However, the results shown do not mean much in isolation. It is only when they are compared with previous test results and with performance goals that conclusions can be drawn. An easy way to compare test results of different weeks is to graph the results for each objective, as shown in Figure 10-3. In that figure, the test results (average percentage correct) are shown in comparison to the amount of instruction and to the desired year-end performance. The topic was introduced in weeks five and six, and further practice was provided in weeks seven, seventeen and eighteen. The topic was tested in weeks one, four, six, seven, twelve, and thirty. Notice that at the beginning

Report of Weekly Test Results

Grade: 4 Subject: Math Dates of test: April 17-18, 1981

Lessons given on those dates: 31-32

Number of classes tested: 4 Total number of children: 128

Teaching Objective	Test Item	Sub Test	No. of Children	% Correct	Average
CD3	"Circle the largest number"				
	3.11 4.23 6.98	1	48	96%	
	6.32 6.23 6.30	2	44	95%	93%
	0.03 0.30 3.00	3	36	86%	
MC4	3800 × 4	1	48	42%	
	6800 × 9	2	44	32%	38%
	8064 × 2	3	36	39%	

FIGURE 10-2.
Example of Report of Weekly Test Results

of the year, the children already had some ability, as shown by the 27% average on the first weekly test. By week four, the proportion of correct answers had already risen to 38% even in the absence of direct instruction; this phenomenon is attributable to transfer of learning from related topics in multiplication. There is then a sharp rise in achievement between weeks four and six, due to the instruction that started in week five. Thereafter, the achievement is more or less constant, with learning due to additional practice almost exactly balancing the forgetting that occurs over time. The criterion level, shown by a dotted horizontal line, was surpassed slightly in week 6; had this not been the case, further practice and perhaps more explicit instruction would have been provided in the period between weeks seven and seventeen. The additional practice in weeks seventeen and eighteen was a direct result of the test results in week twelve which showed a slight decline in skills.

Teaching Objective: MC4 MULTIPLICATION IN COLUMN FORM, WITH CARRYING, 4-DIGIT MULTIPLICARD WITH ZEROS, 1-DIGIT MULTIPLIER, 5-DIGIT PRODUCT.

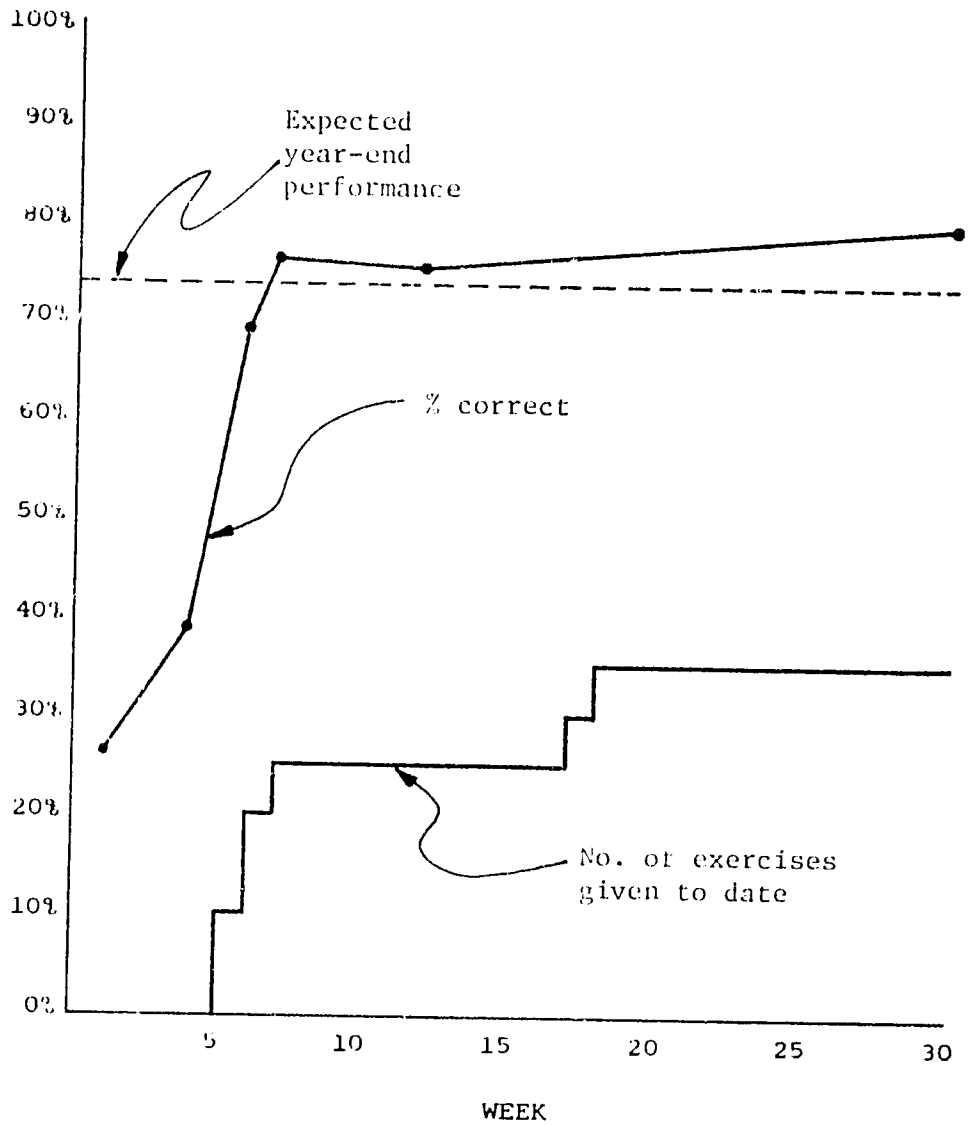

FIGURE 10-3.
Test Results and Number of Exercises Given

With this overall view of what happened with the topic MC4 over the year, we can now look back at the results of the test in week four (reported in Figure 10-2) to see how they would have been analyzed at that point in time. Although the performance on MC4 was low at that time (38%) we can see from Figure 10-3 that it was in fact higher than one might expect since no instruction had yet been given. In fact, the results from week four need not even be reported to curriculum designers and script writers since the purpose of testing the topic during that week was simply to gather baseline data against which the performance of week six could be compared.

In contrast, the results for the topic CD3 should be reported to all concerned since the very high achievement (93%) in that topic is evidence that further practice in that topic is not needed, and that the available time can better be spent on topics with which the children are having more difficulty. (Of course, this conclusion cannot be drawn without a comparison with the desired year-end performance, which in this case would likely be around 85% correct.)

The above discussion illustrates some of the kinds of conclusions that can be drawn from a simple knowledge of how many students can give correct answers to test items. Most of these conclusions will be of two types, either that the children need more practice or that they need no more practice. More dramatic conclusions can occasionally be made from the same kind of statistics, however. Occasionally, testing before instruction reveals that the children already have sufficient mastery of a topic, either because of transfer of learning from related topics, or because they have received instruction from other sources; if the children already show mastery, the topic can be eliminated from the planned curriculum--although it is generally advisable to test the topic again at a later time to ensure that the first results were not spurious or that the children have not forgotten what they once knew.

It is not always the case that poor performance indicates a simple need for more practice. If the children do extremely poorly, even after instruction, there may be a need for a complete review of the topic, teaching it afresh with a different instructional strategy. If after two weeks of direct instruction in a topic, test scores rise from 12% to only 15% it is clear that something went quite badly in the teaching sequence. At that point one needs to know in more detail how the children reacted to the instruction minute by minute, what misconceptions they might have held that prevented their learning, and what misconceptions might have been unintentionally conveyed by the lessons on that topic.

The first place to look for more pertinent information is in the children's performance on prerequisite topics. It is often the case that there is nothing wrong with the instruction as originally conceived. Rather the fault may lie in not having made sure the children had

mastered the necessary prerequisites before the new topic was introduced. The solution is to alter the curriculum plan so as to reteach or practice the lacking prerequisites, then reschedule the introduction to the new topic.

Supposing the children do have adequate mastery of the prerequisites, the other possibilities are that there is interference from some other topic, that the instruction went awry because of pacing or wording of instructions, or that the examples or instructions unintentionally caused the children to acquire serious misconceptions. Knowledge of how the children reacted to the instruction can only be obtained from classroom observation. Accurate identification of misconceptions, however, can rarely be derived from classroom observation but must be sought in other ways. One of the most fruitful methods is an investigation of the incorrect responses given by children; another source is the structured individual interview. Since the test data already collected include incorrect responses, those data should be re-examined before steps are taken to collect further information. Frequently, a careful, detailed analysis of incorrect responses will yield all the information necessary.

3. ANALYSIS OF ERRORS

An error analysis requires, for each test item, a list of all of the incorrect responses given by the children together with the frequencies of each response. The underlying philosophy of error analysis is that children do not give random answers; the answers they give, even though wildly incorrect, usually have some element of logic in them. Figure 10-4 shows how data on incorrect responses can be presented for an analysis of systematic errors. (The data in that figure were taken from a test given to third-grade children in Nicaragua in 1976.) The analysis of errors is best done simultaneously for all items that test the same objective, so that similar errors can be grouped. Although Figure 10-4 shows only two items the analysis described here was done with many more items. The more items there are, the more certain the hypotheses about error patterns.

As shown in Figure 10-4 the most common wrong answers to the test items were 421 and 37 (shown as Incorrect Response A). The reason these two responses are grouped together is that they result from the same incorrect strategy: in both cases, the children did not borrow but simply subtracted the smaller number in each column from the larger number in that column regardless of which was on top. Similarly, both responses in Line B (420 and 30) represent applications of another incorrect strategy; the children again did not borrow but when the number at the top of a column was less than the number below it they wrote zero as the difference in that column. The next place where answers for the two exercises can be grouped is in Line F; in both of these cases, the

		546 - 127		82 - 59	
		Response	Frequency	Response	Frequency
Correct:		419	26%	23	42%
Incorrect,	A:	421	28%	37	20%
	B:	420	8%	30	5%
	C:	410	5%		
	D:	417	3%		
	E:	121	2%		
	F:	429	2%	33	5%
	G:	673	2%	141	4%
	H:			36	3%
		Other	23%	Other	21%

FIGURE 10-4.
Incorrect Responses to Two Items Testing
Subtraction with Borrowing

children did part but not all of the borrowing correctly: they added 10 to the top number of the column on the right but failed to subtract the compensatory 1 from the column to the left of it. Line G shows another common error: the children added instead of subtracting.

From the low percentages correct (26% on one item and 42% on the other) it is clear that the children have not mastered subtraction with borrowing. And because their scores are so very low, it is also clear that practice alone will probably not solve the problem, that children have serious misconceptions that must be dispelled before they can progress. Information about the nature of these misconceptions comes from a combination of error analyses like that described above, and from classroom observation.

In the case of the subtraction problems discussed above, the error analysis indicates that many children simply do not borrow; in the two most common strategies used by children (errors A and B), there is no attempt at borrowing. The question that then arises is: do these children use an alternate "nonborrowing" strategy because they cannot perform the rather complex mechanical operations that are involved in borrowing, or is there some other reason they select the incorrect strategies they are using?

Evidence from classroom observation can now be brought to bear on this issue. From observations of children as they were taking lessons that explicitly warned them that certain exercises would require borrowing, we found that the children were quite adept at the mechanics of borrowing; it was only when they weren't told that borrowing would be needed that they reverted to incorrect nonborrowing strategies. From this evidence, we could then infer that the children's difficulties stemmed from an inability to decide when to borrow. Consequently, the stress in the instruction was shifted from the mechanical aspects of borrowing to the decision making procedure itself.

4. COLLECTING FURTHER INFORMATION

Correctly identifying children's misconceptions and systematic error patterns is a difficult but rewarding task. Often errors can only be tentatively classified until information from other sources is obtained. Children's self-reporting of thinking patterns, as elicited by structured interviews, is frequently quite enlightening. In Nicaragua, when we asked individual children to do subtraction problems, explaining each step as they went along, we learned much about children's mental processes that we could not have learned from post hoc error analysis. For one thing, it was clear from the assurance and speed with which children who used the nonborrowing strategies worked, that they were not hesitating at all to consider whether or not they should borrow; it appeared that many children were unaware that there was a decision to be made. This reinforced our supposition that future instruction should stress the decision procedure itself. We also found that some children consistently worked from left to right instead of right to left as they should have done. The sequence in which operations are performed is critical in most arithmetic algorithms, but a study of completed written answers cannot reveal whether the children are using the correct sequence.

Even with data from individual interviews, many hypotheses about children's misconceptions will still be tentative. One way to confirm hypotheses is by further testing of children using test items that are similar but not identical to the items from which the hypotheses were formulated. For the subtraction example discussed above, for instance, one might postulate the specific incorrect responses that would be given to other subtraction exercises. For an exercise like:

$$\begin{array}{r} 832 \\ \underline{-\ 415} \end{array}$$

predicted incorrect responses would include:

423	(Similar to Error A of Figure 10-4.)
420	(Similar to Error B)
427	(Similar to Error F)
1247	(Similar to Error G)

It could be confirmed by testing that these incorrect responses do indeed occur, and that their frequency of occurrence is in the order listed above. Confirmation of anticipated incorrect responses over a fairly large set of subtraction exercises would lend credence to the postulated descriptions of the chil ren's misconceptions.

5. MAKING FORMATIVE EVALUATION WORK

The most difficult aspect of integrating the feedback process into the production cycle is drawing conclusions from the data that are collected. The rudimentary analyses of data like grading papers and calculating means of test scores are straightforward, but the more refined analyses like error analyses and analysis of children's verbal descriptions of their thinking processes are considerably more difficult and require both imagination and scepticism. Beyond that is an even more difficult task: drawing conclusions and making recommendations for changes in the content of the lessons or in the teaching strategies. In many cases, you will never be completely sure of the right thing to do. If you are too rash and rush into changes too rapidly, without sufficient evidence, the result will be a disorganized curriculum that is no better than the one initially planned. At the other extreme, you cannot always afford to wait for absolutely conclusive evidence before making a decision, since the production of new materials must go forward whether decisions to change are made or not.

A common pitfall in interpreting feedback data is to be influenced by preconceptions. We committed this error in Nicaragua when we persisted in including stories in the radio lessons for first graders, even after the classroom observers reported that the children were not interested. We were all so convinced that children enjoy stories that we could not believe the contrary evidence. In other cases, we were quite convinced that a certain teaching strategy was the best one to use for certain subject matter and when that strategy did not work we tried to attribute the lack of success to the actor's intonations, the design of the worksheet, the lack of prerequisite skills, and other aspects of the lesson design.

One thing to avoid is excessive statistical analysis of data as an excuse for deferring decisions that must be made. No kind of formative evaluation will supply you with ready-made solutions to problems, only with evidence of where the problems are. Creativity and imagination are required for the solutions.

You should also avoid wasting time analyzing data that would best be discarded. No matter how carefully and systematically you have gone about collecting information, you will inevitably find that much of it is useless. Either it provides answers to questions you have never asked, or it is of such questionable reliability that you are not sure the conclusions can be believed. It is not worth the effort of analyzing and reanalyzing in hopes that such data will yield something usable.

At the opposite end of the spectrum is another problem: after the data are collected, it is found that they are insufficient to answer pressing questions. This is a much more serious problem than an overabundance of data, and is the reason for sometimes collecting excessive data, even knowing in advance that much of it will be discarded. If the data are insufficient, there are usually only two courses of action: go back into the field to collect more--or more reliable--data, or make a decision with insufficient evidence. Which of these two alternatives to choose in a particular situation depends on how fast the decision must be made and how much it costs to gather more information. It is important to realize that the issue cannot be sidestepped. No decision at all is equivalent to deciding to proceed with production of materials using the strategies already planned.

APPENDIX A

Script, Lesson 171

MUSIC:	THEME (FADE IN AND UNDER)
ANNOUNCER:	The Radio Mathematics Project presents Lesson 171 of the series "In the Land of Numbers." This mathematics program is specially designed for second grade of primary education. Today: Lesson 171.
MUSIC:	THEME (UP AND UNDER)
ANNOUNCER:	Now we'll give time for the class to prepare for Lesson 171.
MUSIC:	THEME (UP AND UNDER)
ANNOUNCER:	Today Lesson 171.
MUSIC:	THEME (UP AND UNDER)
ANNOUNCER:	Attention, you have ten seconds left before we start Lesson 171. 10 . . . 9 . . . 8 . . . 7 . . . 6 . . . 5 . . . 4 . . . 3 . . . 2 . . . 1 . . . . Go!
MUSIC:	THEME (UP AND OUT)
MUSIC:	[TAPE]
CHILDREN:	Hi, good morning, hi, good morning, How are you, how are you? We are very happy, We are very happy, We are fine, we are fine.
MONSTER:	(continues singing) We are fine . . . We are fine . . . ladi da da.
LITTLE GIRL 1:	Stop, Numbermonster! The song is over.
MONSTER:	What a shame! I like to sing so much.
LITTLE GIRL 2:	Yes, we all like to sing . . . but I think it's all right if we sing some more.
CHILDREN:	(NOT TOGETHER) Yes, yes . . . let's sing some more.
MUSIC:	[TAPED]

MUSIC: TRANSITION TO ORAL SEGMENT

MUSIC: [TAPED]

MONSTER: The clock, the clock
It goes tick tock.
One hour, sixty minutes,
Sixty minutes, one hour.
One hour, sixty minutes,
Sixty minutes, one hour.

ALL: Let's get to work.

LITA: Boys and girls, pay attention because we're going to measure time.

RAMON: Listen carefully . . . think before you answer.

LITA: Remember, one hour has *sixty* minutes.

RAMON: Yesterday, Mary mended socks for *sixty* minutes.

LITA: Boys and girls, did she mend socks for one hour or more?

CHILDREN: One hour.

RAMON: Yes, one hour. Because one hour has sixty minutes.

LITA: Joe has been doing his homework for *fifty* minutes.

RAMON: Boys and girls, has he been working for one hour or less?

CHILDREN: Less.

LITA: *Less* than one hour. Because one hour has sixty minutes.

MONSTER: The clock, the clock
It goes tick tock.
A half hour, thirty minutes,
Thirty minutes, a half hour.
A half hour, thirty minutes,
A half hour, thirty minutes.

RAMON: Let's talk some more about the half hour.

LITA: Remember, a half hour has *thirty* minutes.

RAMON: Boys and girls, Charles studied for *forty* minutes.

LITA:	Tell me, did he study for . . . a half hour or more?
CHILDREN:	More.
RAMON:	Yes, *more* than a half hour. Because a half hour has thirty minutes.
LITA:	A gardener took *thirty* minutes to water the garden.
RAMON:	Did the gardener take a half hour or less?
CHILDREN:	A half hour.
LITA:	Yes, a half hour. Because a half hour has thirty minutes.
MUSIC:	TRANSITION TO ORAL SEGMENT
LITA:	(enthusiastically) Boys and girls, now we're going to do oral addition exercises.
RAMON:	Be ready to answer out loud together.
LITA:	Let's start. How much is forty plus eight?
CHILDREN:	Forty-eight.
RAMON:	Forty-eight.
LITA:	And . . . sixty plus three?
CHILDREN:	Sixty-three.
RAMON:	Sixty-three.
LITA:	And . . . ninety plus two?
CHILDREN:	Ninety-two.
RAMON:	Ninety-two.
LITA:	And . . . seventy plus five?
CHILDREN:	Seventy-five.
RAMON:	Seventy-five. Right!
MUSIC:	TRANSITION TO NOTEBOOKS
CHILDREN:	(LIVELY) Hurrah . . . Hurrah . . . Rah, Rah, Rah!

MONSTER: To the notebooks, to the notebooks.

ALL: Here we go.

(EVERYBODY LAUGHS)

RAMON: Now we're going to do the exercises in Part One.

LITA: Look at the first exercise. Read it out loud.

CHILDREN: One-third plus one-third.

RAMON: Tell me, *one*-third plus *one*-third . . . how much is that?

CHILDREN: Two-thirds.

LITA: *Two*-thirds.

RAMON: Good. After the equal sign write *two-thirds*.

(MUSIC:08)

LITA: Tell me, did you write *two* over *three*?

CHILDREN: Yes.

RAMON: Good. That's how we write two-thirds. Let's go to the next exercise. Tell me, what are you going to add?

CHILDREN: Two-fifths plus one-fifth.

LITA: And *two*-fifths plus *one*-fifth . . . how much is it?

CHILDREN: Three-fifths.

RAMON: *Three*-fifths. Next to the equal sign write *three-fifths*.

(MUSIC:08)

LITA: Tell me, how did you write it?

CHILDREN: Three over five.

RAMON: Three over five. That's how we write three-fifths.

LITA: Look at the next exercise. Read it.

CHILDREN: Four-tenths plus one-tenth.

RAMON: And four-tenths plus *one*-tenth . . . how much is it?

CHILDREN: Five-tenths.

LITA: *Five*-tenths. Next to the equal sign write *five-tenths*.

(MUSIC:08)

RAMON: How did you write it?

CHILDREN: Five over ten.

LITA: Five over ten. That's how we write five-tenths. Look at the last exercise. Read it.

CHILDREN: One-fourth plus two-fourths.

RAMON: And *one*-fourth plus *two*-fourths . . . how much is it?

CHILDREN: Three-fourths.

RAMON: *Three*-fourths. Write it.

(MUSIC:08)

LITA: How did you write it?

CHILDREN: Three over four.

RAMON: Three over four. That's how we write three-fourths.

MONSTER: (singing) Fractions, fractions, fractions. Easy to write.

(EVERYBODY LAUGHS)

RAMON: Boys and girls, put your notebooks to one side because you're going to hear a joke.

MUSIC: TRANSITION TO JOKE

VOICE: A mother and her child are talking.

CHILD: Mommy, mommy. Give me a peso.

MOTHER: Another one? But . . . what did you do with the one I gave you this morning?

CHILD: I gave it to an old man.

MOTHER: Why, that's very nice! You're a good generous boy! Here, you can have another peso . . . but wait a minute! You won't give this one to the old man too, will you?

CHILD: Oh, yes, I will, Mommy, 'cause he's the candy man and he won't give me any candy if I don't.

(EVERYBODY LAUGHS)

MONSTER: That's awful!

MUSIC: TRANSITION TO ORAL SEGMENT

CHILDREN: Let's go on working.

RAMON: Boys and girls, listen to these subtraction exercises and think of the answer.

MONSTER: Answer when we ask, "How much?"

RAMON: Let's begin. Think of *twelve* minus *four*.

(MUSIC:05)

LITA: How much is it?

CHILDREN: Eight.

RAMON: Eight. Twelve minus four . . . eight.

LITA: Let's go on. Think of *seventeen* minus *eight*.

(MUSIC:05)

RAMON: How much is it?

CHILDREN: Nine.

LITA: Nine. Seventeen minus eight . . . nine.

RAMON: Think of *eleven* minus *five*

(MUSIC:05)

LITA: How much is it?

CHILDREN: Six.

RAMON: Six. Eleven minus five . . . six.

LITA: And last of all, think of *fifteen* minus *eight*.

(MUSIC:05)

RAMON: How much is it?

CHILDREN: Seven.

LITA: Seven. Fifteen minus eight . . . seven.

MUSIC: TRANSITION TO NOTEBOOKS

LITA: Boys and girls, let's do some more work in our notebooks.

RAMON: We're going to do the exercises in Part Two.

LITA: Look carefully at the first exercise. What sign does it have?

CHILDREN: Plus.

RAMON: Plus. Then what are you going to do?

CHILDREN: Add.

LITA: Yes, you're going to add. You'll add forty-five plus twenty-seven.

RAMON: Let's begin. In the first column, what are you going to add?

CHILDREN: Five plus seven.

RAMON: And five plus seven, how much is that?

CHILDREN: Twelve.

LITA: Twelve. Then, are you going to carry?

CHILDREN: Yes.

RAMON: Of course, we have to carry. Tell me, below the seven, what are you going to write?

CHILDREN: Two.

LITA: Two. And above the four, what are you going to write?

CHILDREN: One.

RAMON: One. Write the numbers.

(MUSIC:06)

LITA: In the other column you have *one* plus *four* plus *two*.

RAMON: Think how much it is and write the answer.

(MUSIC:08)

LITA: Look at the answer. Read it.

CHILDREN: Seventy-two.

RAMON: Seventy-two.

LITA: Let's go on to the next exercise. What sign does it have?

CHILDREN: Minus.

RAMON: Minus. Then, what are you going to do?

CHILDREN: Subtract.

LITA: Subtract. You are going to subtract fifty-two minus seventeen.

RAMON: Let's begin. In the first column, look carefully at the *two* and the *seven*. Think if you need to borrow.

(PAUSE:03)

LITA: Are you going to borrow?

CHILDREN: Yes.

RAMON: Yes, you are going to borrow because the bigger number is below.

LITA: Now, borrow . . . don't do anything else yet.

(MUSIC:08)

RAMON: Now, you have *twelve* minus *seven* . . . and twelve minus seven, how much is it?

CHILDREN: Five.

LITA: Five. Write it below the seven.

(PAUSE:03)

RAMON: Finish this exercise.

(MUSIC:08)

LITA: In this exercise, what answer did you get?

CHILDREN: Thirty-five.

RAMON: Thirty-five. That's right.

LITA: Look at the next exercise. What sign does it have?

CHILDREN: Plus.

RAMON: Plus. Then, what are you going to do?

CHILDREN: Add.

LITA: Add. Add seventy-six plus nineteen. You know how to work it by yourselves. Do it.

(MUSIC:15)

RAMON: Boys and girls, tell me, did you carry?

CHILDREN: Yes.

LITA: Yes, you needed to carry. Read the answer.

CHILDREN: Ninety-five.

RAMON: Ninety-five. Very good.

LITA: Let's go on to the last exercise. Tell me, what sign does it have?

CHILDREN: Minus.

RAMON: Minus. Then, what are you going to do?

CHILDREN: Subtract.

LITA: Yes, subtract. You are going to subtract eighty-two minus forty-five. Do this exercise.

(MUSIC:15)

RAMON: Boys and girls, did you borrow?

CHILDREN: Yes.

LITA: Of course. Read the answer.

CHILDREN: Thirty-seven.

RAMON: Thirty-seven. Right.

LITA: Fine. Now, put down your notebooks and pencils for a while because . . .

MONSTER: . . . Ladies and gentlemen . . .

CHILDREN: It's time to play a game.

MUSIC: TRANSITION TO GAME

RAMON: Today we are going to play "Simon Says." Here we go. Whatever Simon says . . .

CHILDREN: . . . we all do.

RAMON: Simon says that everyone should play the piano. Let's go. Play the piano.

SOUND: PIANO (TAPE)

RAMON: Stop. Whatever Simon says . . .

CHILDREN: . . . we all do.

RAMON: Simon says that everyone should play the drum. Let's go. Play the drum.

SOUND: DRUM (STUDIO)

RAMON: Stop. Whatever Simon says . . .

CHILDREN: . . . we all do.

RAMON: Simon says that everyone should play the guitar. Play the guitar.

SOUND: GUITAR (TAPE)

RAMON: Stop. Whatever Simon says . . .

CHILDREN: . . . we all do.

RAMON: Simon says that everyone should play the trumpet. Let's go. Play the trumpet.

SOUND: TRUMPET (TAPE)

RAMON: Stop. We're done.

MUSIC: TRANSITION TO CHALKBOARD

LITA: Boys and girls, let's continue working. Look at the chalkboard . . . at Part Three.

RAMON: Look carefully at Row A. There you see some numbers.

LITA: Look at the first number. How do you read it?

CHILDREN: Two hundred fifty-eight.

RAMON: Two hundred fifty-eight. Look at the second number. How do you read it?

CHILDREN: Five hundred eighty-two.

LITA: Five hundred eighty-two. And the last one?

CHILDREN: Eight hundred twenty-five.

RAMON: Eight hundred twenty-five.

LITA: Look carefully at those numbers and think about which is the biggest.

(MUSIC:05)

Which one?

CHILDREN: Eight hundred twenty-five.

RAMON: Eight hundred twenty-five is the biggest.

LITA: Let's go on to Row *B*. Look at the first number. How do you read it?

CHILDREN: Seven hundred six.

RAMON: Seven hundred six. And the next one, how do you read it?

CHILDREN: Six hundred seventy.

LITA: Six hundred seventy. And the last number, how do you read it?

CHILDREN: Six hundred seven.

LITA: Six hundred seven. Look carefully at those numbers and think which is the biggest.

(MUSIC:05)

Which one?

CHILDREN: Seven hundred six.

RAMON: Seven hundred six is the biggest.

LITA: Let's go to Row C. The first number, how do you read it?

CHILDREN: Three hundred forty-one.

RAMON: Three hundred forty-one. And the next one, how do you read it?

CHILDREN: Four hundred thirteen.

LITA: Four hundred thirteen. And the last one?

CHILDREN: One hundred thirty-four.

LITA: One hundred thirty-four. Okay, now think which number is the biggest.

(MUSIC:05)

Which one?

CHILDREN: Four hundred thirteen.

RAMON: Four hundred thirteen is the biggest.

MUSIC: TRANSITION TO NOTEBOOKS

LITA: Boys and girls, open your notebooks again.

RAMON: Find a blank page where you can draw some marbles.

LITA: Yes, you're going to draw marbles to solve some division problems.

RAMON: First you are going to solve *thirteen* divided by *five*.

LITA: Tell me, how many marbles are you going to draw?

CHILDREN: Thirteen.

RAMON: Thirteen. Draw them.

(MUSIC:15)

LITA: The exercise is *thirteen* divided by *five*, so circle *five* marbles.

(MUSIC:08)

RAMON: Circle another five marbles.

(MUSIC:08)

LITA: Tell me, how many marbles are *not* circled?

CHILDREN: Three.

RAMON: Three. Now, tell me, how many groups did you make?

CHILDREN: Two.

LITA: Two. Look carefully at the drawing.

RAMON: Tell me, how much is thirteen divided by five.

CHILDREN: Two and three left over.

LITA: Two and three left over.

RAMON: Let's do another exercise. *Fifteen* divided by *five*.

LITA: Tell me, how many marbles are you going to draw?

CHILDREN: Fifteen.

RAMON: Fifteen, draw them.

(MUSIC:17)

LITA: Since the exercise is fifteen divided by *five*, how many marbles are you going to circle in each group?

CHILDREN: Five.

RAMON: Five. Make groups of five.

(MUSIC:15)

LITA: How many groups did you make?

CHILDREN: Three.

RAMON: Three. Look at the drawing.

LITA: Tell me, how much is fifteen divided by five?

CHILDREN: Three and zero left over.

RAMON: Three and zero left over.

LITA: Let's do another exercise. *Ten* divided by *three*.

RAMON: How many marbles are you going to draw?

CHILDREN: Ten.

LITA: Ten. Draw them.

(MUSIC:12)

RAMON: For the exercise ten divided by *three*, how many marbles are you going to circle in each group?

CHILDREN: Three.

LITA: Three. Make groups of three.

(MUSIC:12)

RAMON: How many groups did you make?

CHILDREN: Three.

LITA: Three. Look at the drawing.

RAMON: Tell me, how much is ten divided by three?

CHILDREN: Three and one left over.

LITA:	Three and one left over.
MUSIC:	TRANSITION TO ORAL SEGMENT
SOUND:	TRUMPET
MONSTER:	Friends . . . something is happening there . . . what can it be?
LITTLE GIRL:	Come . . . let's see what's happening.
ALL:	Let's go.
SOUND:	HARP AND VOICES
LITTLE GIRL:	Oh! It's the race track.
LITTLE BOY:	Yes, they just announced the races for today.
MONSTER:	Let's get closer to see the motorcycle races.
LITA:	Boys and girls, listen quietly to find out how many motorcycles stay in the race.
SOUND:	MOTORCYCLE (TAPE)
ANNOUNCER:	Welcome to today's races. The motorcycle riders are ready. In a few moments they will begin. On the track there are *forty-two* racers. There they go!
SOUND:	(REPEATS)
GEORGE:	There are a lot of motorcycle riders in today's race!
LUIS:	Yeah. There are forty-two.
SOUND:	(REPEATS)
GEORGE:	(startled) Look! Two motorcycles crashed!
LITA:	Boys and girls, tell me, how many motorcycles stay in the race?
CHILDREN:	Forty.
RAMON:	Yes, forty.
SOUND:	HARP

ANNOUNCER: And now we are going to the first foot race of the day. The runners are getting ready. They're ready! They're off!

SOUND: PEOPLE RUNNING (STUDIO)

ANNOUNCER: Look, there are *fifty-six* runners!

LITTLE BOY: They're really moving.

LITTLE GIRL: Look! Look! Six runners have already finished.

LITA: Boys and girls, *six* runners have finished. How many have *not* finished yet?

CHILDREN: Fifty.

RAMON: Yes, fifty runners.

MUSIC: TRANSITION TO NOTEBOOKS

CONTINUES TO

MUSIC: [TAPE]

RAMON: Boys and girls, let's go on working in the notebooks. We are going to dictate some multiplication exercises.

LITA: But you are not going to work them yet. You're only going to write them. Let's begin.

RAMON: You're going to write the exercise one hundred sixty-eight times four like this: first, write the number *one hundred sixty-eight*.

(MUSIC:09)

Below the *eight* write *four*.

(PAUSE:03)

A little to the outside write the times sign.

(PAUSE:02)

And draw a line underneath.

(PAUSE:02)

LITA: Write this other exercise. Write one hundred sixty-nine times three. I'll repeat it. *One hundred sixty-nine* times *three*. Write it.

(MUSIC:16)

RAMON: Let's go on. Write four hundred six times two. *Four hundred six* times *two*. Write it.

(MUSIC:16)

LITA: Last of all, write one hundred fifty-three times five. *One hundred fifty-three* times *five*.

(MUSIC:16)

RAMON: Quietly, do these exercises by yourselves.

LITA: Yes, boys and girls, because we are going now.

MUSIC: THEME (UP AND UNDER)

CHILDREN: Bye little friends.

LITA: See you soon.

RAMON: Behave yourselves.

MUSIC: THEME (UP AND UNDER)

ANNOUNCER: We have presented Lesson 171. The next lesson will be 172.

MUSIC: THEME (UP AND OUT)

APPENDIX B

Teachers' Guide, Lesson 171

PRE-BROADCAST ACTIVITIES

a. Copy on the chalkboard the following groups of exercises (Part One and Part Two), and tell the children to copy them in their notebooks.

Part One

$\frac{1}{3} + \frac{1}{3} = ___$ $\frac{2}{5} + \frac{1}{5} = ___$

$\frac{4}{10} + \frac{1}{10} = ___$ $\frac{1}{4} + \frac{2}{4} = ___$

Part Two

45	52	76	82
+ 27	− 17	+ 19	− 45

b. Copy on the chalkboard Part Three, but tell the children not to copy the numbers in their notebooks.

Part Three

A.	258	582	825
B.	706	670	607
C.	341	413	134

POST-BROADCAST ACTIVITIES

a. *Vertical multiplication from dictation.* After the broadcast let the children solve the multiplication exercises that were dictated by radio. Observe them as they work. If some children have difficulty let them consult their multiplication tables to help them find the answers.

When everyone has finished, have several children go to the chalkboard

and give them the exercises to solve. The other children can verify their answers and make corrections where there are mistakes. The exercises dictated by the radio are:

168	169	406	153
× 4	× 3	× 2	× 5

b. *Vertical Subtraction*. Copy on the chalkboard the following exercises:

540	945	850	562
−286	−757	−279	−173

Ask the children to copy and solve these exercises. Observe them as they work. If some children have difficulty, tell them to pay attention to the digits that they are going to subtract, and that when the digit below is greater than that above, they can not subtract and must borrow. When everyone has finished have several children solve the exercises on the chalkboard. The other children can check their work and make corrections if necessary.

c. *Vertical division*. Copy on the chalkboard the following exercises:

95) 2 847) 4 68) 3 465) 2

Ask the children to copy and solve these exercises. Give help where necessary to the children having difficulty. Afterwards have several children solve the exercises on the chalkboard so that the others have the opportunity to check their answers. The children who made mistakes may correct them. Check the corrections of these children.

d. *Writing numbers by dictation*. Dictate to the children the following numbers to write in their notebooks.

5091 3871 2302 6800 9001 4101

Give sufficient time for the children to write every number. After you have dictated all of the numbers, tell the children: "Look at the number 5091. What digits did you write? (five, zero, nine, one) Now look at the following number, 3871. What digits did you write? (three, eight, seven, one)" Ask the same questions for each number. Have several children come to the chalkboard and give them the same numbers to write so that the other children have a chance to compare and correct their work. Finally point with a pointer to each number written on the chalkboard so all the children can read them aloud.

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INDEX

Achievement test, see Evaluation, see Baseline data; see also Testing
Administration of tests, 112
Attention, see Listening skills
Attention span, see Listening skills
Attitudes, children's, 19, 123
teacher, see Teachers' attitudes

Baseline data, 51, 52, 55, 58, 59, 89, 104
Batteries, 45; see Radio receivers
Behavorial objectives, 47, 57; see Curriculum design; see also Proficiency standards
Blackboard, see Chalkboard

Calisthenics, see Entertainment
Carrying, in addition, 20
Cassettes, 101
Chalkboard, 6, 18
Change of topic, 6
Choral responses, see Responses, oral
Classroom observation form, 121
Classroom observations, 117ff.
Comparative achievement, see Evaluation
Concept formation, 20, 71
Copying, 19
Correct answers, see Reinforcement
Costs, 14, 27ff.; see Teachers' expenses
Criteria of performance, see Proficiency standards
Curriculum design, 17, 47ff., 63; see Skills
Curriculum structure, see Prerequisites

Data analysis, 129ff.
Data, from classroom observations 24, 129; see Classroom observations
Data from tests, 24, 129ff.; see Evaluations; see also Testing
Deferred oral responses, see Responses, oral deferred
Delayed responses, see Responses, oral deferred
Dictated exercises, see Exercises
Distributed practice, 21, 132
Division, 11
Drill, see Distributed practice

Effectiveness of radio lessons, see Evaluation
Entertainment, 8, 10, 11, 18, 87ff.
Error, analysis, 20-21, 133; see Skills
Errors, children's, see Systematic errors
Evaluation, of radio mathematics lessons, 14; see Formative evaluation; see also Field testing
Exercise pools, 60ff., 70ff.; see Item pools
Exercise types, 52, 61ff.
Exercises, dictated, 18
Exercises, structure of, 77
Experimental phase, 1, 5, 14

Feedback, to production, 24, 58, 118, 127; see Testing
Feedback, to students, see Reinforcement
Field testing, 95ff.
Formative evaluation, see Feedback, to production; see also Field testing
Formats, 17; see Responses
Fractions, 9

Games, see Entertainment
Group responses, see Responses, oral

Hawthorne effect, 96, 117

Hierarchy of topics,
see Prerequisites
Home audience, 2, 15

Individual testing, 123ff.
Induction, see Concept formation
Institute for Mathematical Studies in the Social Sciences, 5
Instructional design,
see Curriculum design
Instructional segments, 75, 76
Instructions, phrasing, 80ff.
Interviews, with children, 123, 135; see Attitudes
Item pools, 106

Knowledge of results,
see Reinforcement

Lesson 171, see Typical lesson
Lesson characteristics, 5, 6
Lesson outline, 13, 63
Listening skills, 5, 18, 22

Maintenance of equipment, see Radio receivers, maintenance
Ministry of Public Education, 14
Misconceptions, see Concept formation; see also Skills
Multigrade classrooms, 14

Nicaragua, 5

Observation form, 121
Observing,
see Classroom Observation
Oral exercises, 8;
see Oral responses
Overt response, see Responses

Pace, 6
Participation, 17; see Responses
Pauses, 72, 83-84
Pedagogy, see Curriculum design
Postbroadcast activities, 12
Posters,
see Supplementary materials
Planning, see Curriculum design
Practice, see Distributed practice
Prerequisites, 53, 58, 132
Pretesting, 104;
see Baseline data
Principles, design,
see Instructional design
Production of curriculum materials, 75ff.
Production cycle, 63
Proficiency standards, 58

Radio Mathematics Project, 1, 5
Radio mathematics lessons, 5
Radio receivers, 44
Radio receivers, maintenance, 44
Reinforcement, 18ff., 79, 84
Repetition, 22;
see Distributed practice
Reports, 130
Response rate, 5, 9, 12, 18
Responses,
distribution of, 5, 12, 13
oral, 8, 17, 82
oral, deferred, 10
types of, 12, 18, 77ff., 83
written, 8, 82
Retention,
see Distributed practice
Revision of lessons,
see Feedback to production
Review, see Distributed practice
Rural schools, 14

Scheduling of topics, 59, 86, 87, 104ff.
Script writing, 75ff.;
see Production
Skills, 49ff.
Skills analysis,
see Task analysis
Songs, 8, 88; see Entertainment
Sound effects, 91
Stanford University, 1, 5
Statistical analysis, 127
Studio production, 90
Supervision of teachers,
see Teachers, supervision of
Supplementary materials, 6ff., 38, 45, 72, 83, 91, 100;
see Worksheets
Systematic errors, 20ff., 71, 133ff.

Task analysis, 50; see Skills
Teacher cooperation, 23
Teacher training, 23, 97ff.
  cost of, 41, 97
Teachers'
  attitudes, 15, 23, 24, 124
  expenses, 24
  guides, 23, 43, 93, Appendix B
  role, 2, 6ff., 14, 17, 23, 69
  supervision of, 42, 100
  workload, 23
Test
  items, 107
  results, 129ff.
Testing, 103ff.
Timing, 91; see Pauses
Training of
  observers, 119
  teachers, see Teacher training
Transfer of learning, 55
Transitions between segments, 89
Transition segments, 12, 87
Typical lesson, 6, Appendix A

United States Agency for
  International Development
  see USAID
USAID, 1, 4, 5
Utilization costs, see Cost

Validity, 107
Vocabulary, 70, 80
Voices, 90

Worksheets, 17, 92;
  see Supplementary material
Worksheets, cost of, 38
Worksheets, effectiveness of, 39
Written exercises,
  see Responses, written