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By-Rahmlow, Harold F.

A SERIES OF PROGRAMMED INSTRUCTION BOOKS FOR LEARNING OCCUPATIONALLY ORIENTED BASIC MATHEMATICS. REPORT NO. 16. FINAL REPORT.

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The purpose of this project was to develop and test a series of programed mathematics textbooks for students who plan to enter clerical, retailing, construction, electronics, food service, child care, or agricultural occupations. Behavioral objectives were derived from an earlier analysis of tasks in these occupational clusters. From these, three mathematicians with aid from workers, supervisors, vocational teachers, and mathematics teachers, identified 21 specific mathematics competencies and constructed a sequential content structure. The structure's major elements were (1) Symbols, (2) Representing Numbers by Letters, (3) Reduction of Fractions, (4) Ratios and Fractions, (5) Addition of Fractions, (6) Subtraction of Fractions, (7) Multiplication of Fractions, (8) Division of Fractions, (9) Concepts of Decimals and Fractions, (10) Addition and Subtraction of Decimals, (11) Multiplication of Decimals, (12) Division of Decimals, (13) Conversion of Fractions into Decimals, (14) Equivalent Forms of A=BC, (15) Solutions of A=BC, (16) Percentage, (17) Commutative Law, (18) Reciprocals, (19) Scientific Notation, (20) Proportions, and (21) Concepts of Number Bases. The 27 programed texts which cover this content are available as VT 006 883-VT 006 909, and VT 006 975. (EM)

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FINAL REPORT
Project No. 0E7-0031
Contract No. OEG-4-7-070031-1626
Report No. 16

A SERIES OF PROGRAMMED INSTRUCTION BOOKS FOR LEARNING OCCUPATIONALLY ORIENTED BASIC MATHEMATICS

June 1968

U.S. DEPARTMENT OF
HEALTH, EDUCATION AND WELFARE

Office of Education
Bureau of Research

ERRATUM

Please delete the following from page 19:

"The books can be obtained from the Vocational Education Center of ERIC, Ohio State University, Columbus, Ohio."

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The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

Washington State University, Department of Education, Pullman, Washington
State Coordinating Council for Occupational Education, Olympia, Washington

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The author further wishes to acknowledge the assistance of Gordon McCloskey, Project Director, and Professor of Education, Washington State University and Paul N. Ford, Director of Communication, Northwest Regional Educational Laboratory. Finally, the author wishes to thank Mrs. Raymond Rantanen for her assistance.

SUMMARY

The purpose of this project is to develop and test a series of programmed instruction books that will help pupils acquire mathematics capabilities widely useful in occupations likely to provide opportunities for large percentages of youth who will not complete college.

Bureau of Labor Statistics projections were utilized to identify such occupations. The following occupational areas were selected as a basis for determining content: office, retailing, building trades, electronics, food services, child care and agriculture.

The behavioral objectives for these self-instructional mathematics were derived from facts obtained by studies of clusters of tasks actually performed by workers engaged in those occupations and from related studies. Utilizing those facts, a team of three mathematicians identified widely useful mathematics competencies by the following process. They conferred with workers and supervisors in each occupation to verify the usefulness of 21 specific basic mathematics competencies. They also conferred with vocational teachers and mathematics teachers to conceptualize a structure of instruction which experience and research indicate to be realistic in terms of what is known about pupil characteristics, learning and instruction.

By those processes the staff constructed a SEQUENTIAL STRUCTURE FOR OCCUPATIONALLY ORIENTED MATHEMATICS INSTRUCTION. This was used as a framework for development of the following interrelated self-instructional programmed books.

1. Symbols
2. Representing Numbers by Letters
3. Equivalent Forms (Reduction of Fractions)
4. Ratios and Fractions

5A. Addition of Fractions
5B. Subtraction of Fractions

6. Multiplication of Fractions
7. Division of Fractions
8. Concepts of Decimals and Fractions
9. Addition and Subtraction of Decimals
10. Multiplication of Decimals
11. Division of Decimals
12. Conversion of Fractions into Decimals
13. Equivalent Forms of A=BC
14. Solutions of A=BC
15. Percentage

16. Commutative Law
17. Reciprocals
18. Scientific Notation
19. Proportions
20. Concepts of Number Bases

These books are designed to help individual pupils independently acquire, or enlarge, specific mathematics capabilities at whatever time a need is recognized. We assume that the books will be particularly useful for pupils acquiring occupational competence. However, they can be equally useful for general basic mathematics instruction.

Plans for field testing the books with junior and senior high school students possessing various types of mathematics background and various levels of mental ability are in progress.

INTRODUCTION AND RATIONALE

Observation and research demonstrate that as occupations grow more technical and interrelated larger percentages of workers need certain basic mathematics capabilities. Social economic competence also requires similar capabilities. So does wise consumer buying. For those reasons it is urgent that schools optimize their ability to help all pupils acquire those basic capabilities as expeditiously as possible.

Purpose

This project was undertaken (a) to identify the specific mathematics capabilities most widely useful in occupations which in the forseeable future are most likely to provide employment opportunity for youth who do not complete college and (b) to develop and test programmed self-instructional materials designed to help individual pupils independently acquire those capabilities.

Development of these books, like other phases of Project work, is rooted in the philosophic premise that occupational freedom involves both informed choice of alternatives and competence to work effectively. The economy needs constantly larger numbers of workers possessing new capabilities. But youth can evaluate only those occupational choices that they perceive. They are free to perform only the kinds of work for which they acquire competence.

METHOD

Bureau of Labor Statistics forcasts were utilized to identify occupations in which substantial percentages of non-college graduates can be expected to find employment. From those projections the following occupations were selected for study:

retailing	food service
office work	child care
building trades	agriculture

During 1966-67 the staff of USOE, Bureau of Research, Project ERD-257-65 conducted studies of clusters of major tasks and knowledges associated with work in those occupations.

A team of three mathematics instructors utilized results of that research, and related studies, to derive an exploratory minimum list of specific basic mathematics capabilities widely useful in performance of tasks constituting major portions of work in those occupations.

The team then conferred with workers and supervisors in each occupation to verify the usefulness of each competency on their tentative list. The team also conferred with vocational and mathematics teachers to conceptualize and structure 21 interrelated sets of mathematical capabilities which experience and research indicate to be realistic and achievable in terms of available facts about pupil characteristics, learning processes and instructional procedures.

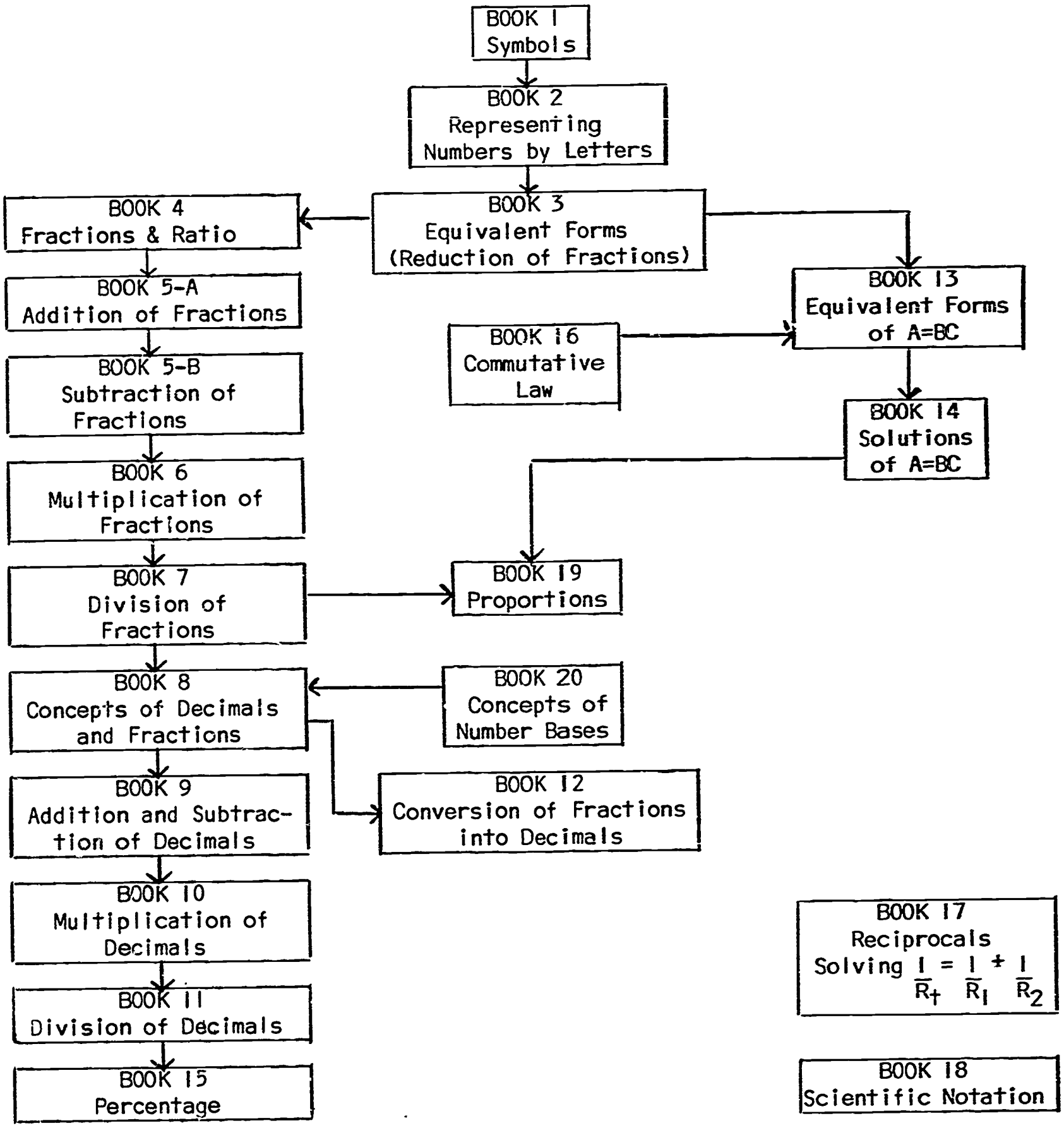
By that process the teams formulated the SEQUENTIAL STRUCTURE FOR OCCUPATIONALLY ORIENTED MATHEMATICS INSTRUCTION shown on Chart I.

Behavioral Objectives

In further conferences with workers, supervisors and instructors, the team then proceeded to formulate behavioral objectives for instruction aimed at development of each of the 21 general capabilities shown on Chart I. Those objectives follow. The acceptable level of performance is the same for all objectives. The student should be able to demonstrate that he has attained these objectives by correctly answering four out of five multiple-choice test items covering each objective of each unit.

Chart I

SEQUENTIAL STRUCTURE FOR OCCUPATIONALLY ORIENTED MATHEMATICS INSTRUCTION



Symbols

1. The student should be able to correctly use = and ≠ signs. (e.g. $4 = 3 + 1$, $3 \neq 2 - 1$)

2. The student should be able to correctly use the symbols (–, /, ÷) to denote division. (e.g. $\frac{a}{b}$, a/b, and $a \div b$)

3. The student should be able to correctly use the following symbols which denote multiplication: $a \times b$, $a \cdot b$, ab, $a(b)$, $(a)(b)$.

Representing Numbers by Letters

1. The student should know that a letter may be used to represent a number.

2. The student should know that algebraic and arithmetic rules of operation apply to letters as well as numbers.

3. The student should be able to make correct numeric substitutions for general literal expressions.

4. The student should be able to construct general formulas that represent simple relationships.

Equivalent Forms (Reduction of Fractions)

1. The student should be able to change integers into equivalent forms. (e.g. $3 = 4 - 1$)

2. The student should be able to change fractions into equivalent forms. (e.g. $3 = \frac{6}{2}$, $\frac{3}{6} = \frac{1}{2}$)

3. The student should be able to recognize prime numbers up to 20.

4. The student should be able to factor a number 100 into primes. (e.g. $12 = 2 \times 2 \times 3$)

5. The student should be able to reduce literal or numeric fractions. (e.g. $\frac{6}{18} = \frac{1}{3}$, $\frac{ab}{abc} = \frac{1}{c}$)

Ratios and Fractions

1. The student should be able to demonstrate his recognition of fractions of the form a/b where a and b are letters or positive integers less than 100.

2. The student should be able to demonstrate his knowledge of the terms numerator and denominator.

3. The student should be able to demonstrate how shaded areas of plane figures can be represented by fractions.

   (e.g. The shaded area of the figure  represents 1/4 of figure.

4. The student should be able to demonstrate his knowledge of the relationship between a ratio and a fraction.

Addition of Fractions

1. The student should know that the word "sum" indicates the operation of addition.

2. The student should be able to add two or three numeric fractions of the form a/b where $0 < (a,b) < 100$. (e.g. $\frac{1}{2} + \frac{1}{4} = \frac{3}{4}$)

3. The student should be able to add two or three fractions of the form k/y, where $0 < k < 100$, and y is the same literal denominator for all fractions. (e.g. $\frac{3}{m} + \frac{4}{m} = \frac{7}{m}$)

4. The student should be able to add two or three literal fractions with the same denominators. (e.g. $\frac{a}{b} + \frac{c}{b} = \frac{a+c}{b}$)

5. The student should be able to add mixed numbers of the form X a/b, where $0 < (x,a, \& b) < 100$. (e.g. $1\frac{1}{4} + 2\frac{1}{2} = 3\frac{3}{4}$)

Subtraction of Fractions

1. The student should know that the "difference" indicates the operation of subtraction.

2. The student should be able to order any set of fractions. (e.g. $\frac{1}{3}$ is less than $\frac{1}{2}$)

3. The student should be able to subtract a small fraction of the form a/b, where $0 < (a,b) < 100$, from a larger fraction of this form with the same denominator. (e.g. $\frac{3}{6} - \frac{1}{6} = \frac{2}{6}$)

4. The student should be able to subtract a small fraction of the form a/b, where $0 < (a,b) < 100$ from a larger fraction of this same form with unlike denominators. (e.g. $\frac{3}{6} - \frac{1}{3} = \frac{1}{6}$)

5. The student should be able to subtract two literal fractions with common denominators. (e.g. $\frac{3}{a} - \frac{1}{a} = \frac{2}{a}$)

6. The student should be able to subtract two literal fractions with unlike denominators. (e.g. $\frac{2}{a} - \frac{3}{b} = \frac{2b-3a}{ab}$)

7. The student should be able to subtract a small mixed number from a larger one of the form X a/b, where $0 < (x,a,b) < 100$. (e.g. $7\frac{1}{4} - 4\frac{1}{2} = 2\frac{3}{4}$)

Multiplication of Fractions

1. The student should know that the word "product" indicates the operation of multiplication.

2. The student should be able to multiply two or three numeric fractions of the form a/b, where $0 < (a,b) < 100$. (e.g. $\frac{2}{3} \cdot \frac{3}{4} = \frac{6}{12}$)

3. The student should be able to multiply a numerical fraction of the form a/b, where $0 < (a,b) < 100$, by a fraction containing a letter and a positive integer less than 100. (e.g. $\frac{3}{4} \cdot \frac{2a}{5} = \frac{6a}{20}$)

4. The student should be able to multiply two literal fractions of the form a/b. (e.g. $\frac{a}{b} \cdot \frac{c}{d} = \frac{ac}{bd}$)

5. The student should be able to multiply a numeric fraction of the form a/b, where $0 < (a,b) < 100$, by a constant number less than 100, or a letter. (e.g. $\frac{3}{4} \cdot C = \frac{3C}{4}$)

6. The student should be able to multiply two mixed numbers of the form X a/b where $0 < (X, a \text{ and } b) < 100$. (e.g. $2\frac{1}{2} \cdot 3\frac{1}{3} = 8\frac{1}{3}$)

Division of Fractions

1. The student should know that the word "quotient" indicates the operation of division.

2. The student should be able to divide a fraction of the form a/b, where $0 < (a,b) < 100$, by a positive integer less than 100. (e.g. $\frac{1}{4} \div 2 = \frac{1}{8}$)

3. The student should be able to divide a fraction of the form a/b by a fraction of the form c/d, where $0 < (a,b,c,d) < 100$. (e.g. $\frac{1}{5} \div \frac{3}{4} = \frac{20}{3}$)

4. The student should be able to divide mixed numbers by mixed numbers where the mixed numbers are of the form X a/b and $0 < (X,a,b) < 100$. (e.g. $2\frac{1}{3} \div 1\frac{1}{2} = \frac{14}{9}$)

5. The student should be able to divide literal fractions. (e.g. $\frac{a}{c} \div \frac{m}{k} = \frac{ak}{cm}$)

6. The student should be able to divide any combination of the letters, fractions, integers, and mixed numbers listed above. (e.g. $\frac{m}{3} \div 2\frac{1}{4} = \frac{4m}{27}$)

Concepts of Decimals and Fractions

1. The student should know the place value concept for decimals.

2. The student should be able to convert fractions whose denominators are 10, 100, or 1000 to decimal form. (e.g. $\frac{13}{100} = .13$)

3. The student should be able to write equivalent forms of integers and decimals by adding or removing zeros. (e.g. .53 = .530)

Addition and Subtraction of Decimals

1. The student should be able to add decimal numbers to one another, or add them to integers. (e.g. .26 + .53 = .79)

2. The student should be able to find the difference between any two decimal numbers, or between a decimal number and an integer. (e.g. .74 - .25 = .49)

Multiplication of Decimals

1. The student should know how to count decimal places.

2. The student should be able to multiply any two decimals. (e.g. $.3 \times .24 = .072$)

3. The student should be able to round off a product to a given number of decimal places. (e.g. .317 round off to the nearest tenth is .3)

Division of Decimals

1. The student should be able to divide any two decimals. (e.g. $.6 \div .2 = 3$)

2. The student should be able to round off the quotient to any decimal place.

Conversion of Fractions to Decimals

1. The student should be able to change simple fractions into decimals by writing them as equivalent fractions with their denominator a power of ten. (e.g. $\frac{1}{4} = \frac{2}{10} + \frac{5}{100} = .25$)

2. The student should be able to change fractions into decimals by dividing the numerator by the denominator. (e.g. $\frac{1}{4} = 1 \div 4 = .25$)

Equivalent Forms of A = BC

1. The student should be able to demonstrate a recognition of a correct equation of the type a = bc, where a, b, c are either letters or positive integers less than 100. (e.g. $10 = 5 \times 2$ is a correct equation)

2. The student should be able to demonstrate a recognition of equivalent statements of the general equation a = bc, when these statements are obtained by replacement, multiplication or division. (e.g. $10 = 2 \times 5$ is equivalent to $2 = \frac{10}{5}$, $I = \frac{E}{R}$ is equivalent to $E = IR$)

3. The student should be able to select the correct method (replacement, multiplication or division) for deriving an equivalent statement from an equation of the form a = bc.

Solutions of A = BC

1. The student should be able to solve equations of the form a = bc for any one letter given positive integral values for the other two. (e.g. Solve 6 = 2c for c. Answer: c = 3)
   Prerequisite: Unit 13.

Percentage

1. The student should be able to convert from a fraction of the form a/b, where $0 < (a,b) < 1000$ to a percentage. (e.g. $\frac{1}{2}$ is equivalent to 50%)

2. The student should be able to convert from a per cent to a fraction. (e.g. 75% is equivalent to $\frac{75}{100}$)

3. The student should be able to convert from a decimal to a percentage. (e.g. .68 is equivalent to 68%)

4. The student should be able to convert from a per cent to a decimal. (e.g. 62% is equivalent to .62)

5. The student should be able to solve percentage problems of the form A = % x Base for A, %, or Base given the other two. (e.g. What is 5% of 75? Answer: 3.75)

Commutative Law

1. The student should be able to correctly use the commutative law of addition. (e.g. 3 + 4 = 4 + 3)

2. The student should be able to correctly use the commutative law of multiplication. (e.g. 4 · 3 = 3 · 4)

3. The student should know that the commutative law does not hold for subtraction and division. (e.g. $3 - 4 \neq 4 - 3$ and $\frac{4}{3} \neq \frac{3}{4}$)

Reciprocals

1. The student should be able to write the reciprocal of an integer or a fraction. (e.g. The reciprocal of 3 is $\frac{1}{3}$)

2. The student should be able to add the reciprocals of integers. (e.g. The sum of the reciprocal of 6 and the reciprocal of two is $\frac{1}{6} + \frac{1}{2} = \frac{2}{3}$)

3. The student should be able to solve the equation:
$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \text{------}$ for R_t .

(e.g. Solve $\frac{1}{R} = \frac{1}{2} + \frac{1}{3}$ for R. Answer: $R = \frac{6}{5}$)

Scientific Notation

1. The student should know that a number x having an exponent n means that x is multiplied by itself n times.
(e.g. $3^4 = 3 \times 3 \times 3 \times 3$)

2. The student should be able to perform the basic operations of addition, subtraction, multiplication, and division with numbers containing exponents. (e.g. $2^3 \circ 2^2 = 2^5$)

3. The student should be able to convert any number into standard scientific notation. (e.g. $3174 = 3.174 \times 10^3$)

4. The student should be able to convert a number from scientific notation into standard decimal notation. (e.g. $3.174 \times 10^3 = 3174$)

5. The student should be able to perform the basic operations of addition, subtraction, multiplication, and division using scientific notation. (e.g. $(4.12 \times 10^6) \div (2 \times 10^3) = 2.06 \times 10^3$)

Proportions

1. The student should be able to distinguish between correct and incorrect proportions.

2. The student should be able to solve a proportion for one unknown quantity (given values for the other three.)
(e.g. Solve for n: 3:n = 6:12 Answer: n = 6)

3. The student should be able to solve specific problems involving proportions.

Concepts of Number Bases

1. The student should be able to change from exponential form to expanded form and vice versa. (e.g. $2^3 = 2 \times 2 \times 2$)

2. The student should be able to write a number in the base 10 system in expanded exponential form.
(e.g. $317 = 3 \times 10^2 + 1 \times 10 + 7$)

3. The student should be able to write a number in the base 2 system in expanded exponential form.
(e.g. 111 (base 2) $= 1 \times 2^2 + 1 \times 2 + 1$)

4. The student should be able to convert numbers from base 2 and base 5 to base 10. (e.g. 111 (base 2) = 7)

To implement each of the 21 sets of objectives, 21 programmed books were developed. The following principles and procedures were utilized.

1. Use the simplest vocabulary possible.

2. When a mathematical term is used, be sure it is either common knowledge or carefully defined and tested for understanding of the term. If in doubt, test for the term and provide a remedial sequence.

3. In sentences, if possible, use the sentence structure: subject -- verb -- object.

4. Each modular unit within the major units should have the following structure:

   a) brief introduction
   b) test items (the student should get <u>two</u> consecutive, parallel test items correct before proceeding)
   c) remedial instruction and evaluation as necessary

5. Any new concept should be briefly explained, tested, and if necessary, the student should be branched to another unit. For example, in Unit 5 it is necessary to know how to reduce fractions. Within Unit 5 there should be a brief explanation and evaluation of reduction of fractions. If the student requires more than a brief introduction, he should be sent to Unit 3. (Remember: Unit 14 is the <u>only</u> one with other units as prerequisites.)

6. Page ordering of a unit should be partially ordered -- ordered between modules and random within modules.

7. The first notation on each page should restate the student's answer to the previous question and reinforce a correct response if the response is correct.

8. A very brief review of the total unit should be provided at the close of the unit. A reworded statement of the unit objectives along with examples might be useful.

9. Five multiple-choice evaluation items covering each objective should be written.

10. Be certain that the presentation follows the general flow chart and reflects the objectives. (The students who complete a unit should be able to answer questions developed by an independent test writer who has seen only the objectives.)

In plotting instructional sequences care was taken to consider the interrelationship between the knowledges necessary for the performance of one objective and those necessary for the performance of another. For example, in developing the components for the books dealing with addition of fractions and those dealing with subtraction of fractions care was taken to use the same method for finding common denominators.

The series of books was also designed so that in no case would it be necessary for the student to repeat work.

In general the books utilize a conversational branching programmed method. The student is confronted with an item of knowledge, responds to a question, and then is branched according to his response. In each case the student is given immediate feedback on whether he is correct or incorrect. Correct responses are reinforced at that time.

Self-testing devices enabling the student to determine when he has achieved each objective are being prepared. For each objective five items will provide measures of achievement. Correct responses to four of the five items can be considered satisfactory achievement.

RESULTS

The following 21 programmed books have been completed.

1. Symbols
2. Representing Numbers by Letters
3. Equivalent Forms (Reduction of Fractions)
4. Ratios and Fractions
5A. Addition of Fractions
5B. Subtraction of Fractions
6. Multiplication of Fractions
7. Division of Fractions
8. Concepts of Decimals and Fractions
9. Addition and Subtraction of Decimals
10. Multiplication of Decimals
11. Division of Decimals
12. Conversion of Fractions into Decimals
13. Equivalent Forms of A=BC
14. Solutions of A=BC
15. Percentage
16. Commutative Law
17. Reciprocals
18. Scientific Notation
19. Proportions
20. Concepts of Number Bases

The books can be obtained from the Vocational Education Center of ERIC, Ohio State University, Columbus, Ohio.

DISCUSSION

The programmed books described above can be used as part of any instructional system which has need for components aimed at development of the mathematics capabilities with which the books deal. A student can examine the objectives and determine which ones he wishes to pursue. He can take a diagnostic test to see if he possesses those capabilities. He can use whatever of the books he deems necessary to attain the objectives he selects. He can verify attainment of his objectives by taking the posttests provided. In this way the student can acquire desired capabilities as rapidly as his individual abilities permit.

Facts regarding the degrees to which the books enable pupils with varying backgrounds and abilities to acquire various capabilities await adequate testing.

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TITLE

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Rahmlow, Harold F.

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ABSTRACT

Twenty-one programmed instruction books designed to help pupils independently acquire mathematics capabilities associated with work in building trades, office, retailing, electronics, food service, child care and agricultural occupations. The books cover:

Symbols
Representing Numbers by Letters
Equivalent Forms
Ratios and Fractions
Addition of Fractions
Subtraction of Fractions
Multiplication of Fractions
Division of Fractions
Concepts of Decimals & Fractions
Addition & Subtraction of Decimals
Multiplication of Decimals
Division of Decimals
Conversion of Fractions into Decimals
Equivalent Forms of A = BC
Solutions of A = BC
Percentage
Commutative Law
Reciprocals
Scientific Notation
Proportions
Concepts of Number Bases

Books are presently being field tested. Content is also being computerized for experiments with computer aided instruction.