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ABSTRACT

Details are given of a seven-diget coding system used to analyze instructional materials in elementary school mathematics. Four variables are analyzed: the first four digits of the code identify a mathematical concept or skill; the fifth digit identifies the highest cognitive level expected of the student in completing the task; the sixth digit identifies the stage of mastery at which the pupil is expected to perform; and the seventh digit of the code gives the mode of pupil response. Lists of numbers keyed to specified cognitive verbs, stages of mastery, and modes of response are included in this document. An experiment in which pre-service mathematics education majors used this system to code instructional materials is briefly described. (DT)

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SEQUENCING OF INSTRUCTIONAL ACTIVITIES

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Many systems have been devised for analysis of communications for their manifest content. Typically such analysis is performed with respect to one or more variables in which different units of analysis might be expected to exhibit differences. For example, during World War II, certain domestic and foreign publications were analyzed for their propaganda content. When material is analyzed, a code is often used to indicate the presence of a given property. Coding sources define the codes and are used in the analysis process. The coding sources, together with instructions for their use, are said to constitute the coding system.

The sequence of instructional activities to be described is based upon a coding system whose purpose is the analysis of instructional materials in elementary school mathematics. The coding system is based upon a seven-digit code and analyzes instructional materials for four variables, each of which is described below. A description of the sequence, experimental evidence for its effectiveness, and implications for further study follow.

The coding system is based on a seven-digit code and designed for elementary school mathematics curricula. The principles of the coding system can, however, easily be applied in other areas of instruction.

The first four digits of the seven-digit code identify a mathematical concept or skill called content as defined by the Mathematics Content Authority List: K-6 (PRIMES, Pennsylvania Department of Education) of which Figure I is a sample page.

The fifth digit identifies the highest cognitive level expected of the pupil in completing the task as defined by the Cognitive Verb List (Figure II). Any level two or higher verb requires the use of some lower level verb as a component behavior. For example, compare must be used as a tool in both illustrate and categorize. Thus there is evidence for the contention that the Cognitive

0160 (contd) . . . . (3) The associative property is sometimes called the <u>grouping</u> property.

Ex. The operation of addition of whole numbers is associative.

$$5+2+1 = (5+2)+1 = 5+(2+1)$$
$$7 + 1 = 5 + 3$$
$$8 = 8$$
$$a + b + c = (a+b) + c = a + (b+c)$$

0170 . . . . g) Zero, the identity element in addition

The identity element in addition is the number which when added to any number leaves that number unchanged.

Ex. $3 + 0 = 0 + 3 = 3$
$n + 0 = 0 + n = n$
0 is the identity element for addition.

0180 . . . . h) Role of one in addition

When 1 is added to a whole number the sum is the next greater whole number.

Ex. $23 + 1 = 24$ $102 + 1 = 103$

0182 . . . . 2) Computation

0184 . . . . a) Two addends

0190 . . . . (1) Elementary facts of addition

An elementary (basic) fact of addition has two whole number addends, each less than ten.

Ex. $6 + 7 = 13$

FIGURE I

SAMPLE PAGE FROM THE MATHEMATICS CONTENT AUTHORITY LIST: K-6

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COGNITIVE VERB LIST

LEVEL 9	9e	EVALUATE		
LEVEL 8	8p	PROVE	8s	SOLVE
	8t	TEST (experiment)	8d	DESIGN
LEVEL 7	7h	HYPOTHESIZE (theorize)		
	7s	SYNTHESIZE (organize, structure)		
	7g	GENERALIZE (induce)	7d	DEDUCE
LEVEL 6	6j	JUSTIFY (support)		
	6e	EXPLAIN (interpret)		
	6a	ANALYZE		
LEVEL 5	5a	APPLY		
	5r	RELATE		
	5c	CONVERT (translate)	5y	SYMBOLIZE
	5u	SUMMARIZE (abstract)		
	5d	DESCRIBE		
LEVEL 4	4c	CATEGORIZE (classify, group)		
	4i	ILLUSTRATE (exemplify)		
LEVEL 3	3c	COMPARE		
	3s	SUBSTITUTE		
LEVEL 2	2i	Iterate		
LEVEL 1	1a	RECALL		
	1o	RECOGNIZE		
	1p	REPEAT; COPY (imitate, reproduce)		
LEVEL 0	0n	NO TASK	0o	OBSERVE 0r READ

FIGURE II
COGNITIVE VERB LIST

STAGES OF MASTERY LIST

0	NOT APPLICABLE	
1	READINESS	development, practice, demonstration, or maintenance of pre-requisite skills to be used in the development of another topic. (Content coded is the pre-requisite skill.)
2	DEVELOPMENT	generating or evolving concepts. Student demonstrates the skills necessary to contribute to the development.
3	PRACTICE	performance of behaviors (not for the first time) prior to demonstration of mastery or prior to demonstration of over-learning.
4	DEMONSTRATION	performance of behaviors at or beyond established criteria. (test)
5	MAINTENANCE	practice after a lapse of time to enable students to retain behaviors at established criteria. (review)

FIGURE III

STAGES OF MASTERY LIST

Verb List is hierarchical with respect to complexity of expected student behavior.

The sixth digit identifies the stage of mastery at which the pupil is expected to perform as defined on the Stages of Mastery List (Figure III). If content and cognitive level are held constant, then stage of mastery codes one through five represent a chronological sequence from readiness through development to practice to demonstration to maintenance.

The seventh digit of the code gives the mode of pupil response as defined by the Modes of Response List (Figure IV).

Because cognitive levels and stages of mastery can be ordered, the sequence of activities by which members of the experimental group were taught to code were ordered by these variables.

The sequence consists of 50 activities. Each activity is represented by an ordered pair (m, n) of whole numbers where m stands for a cognitive level and n a stage of mastery. For example, the activity represented by (1, 3) would be some activity with a level 1 cognitive verb and level 3, or practice, stage of mastery. The order of activities is given by the sequence of ordered pairs (Figure V). The choice of a particular cognitive verb at any level was dictated by practical considerations.

Every ordered pair except the first and last lies on some diagonal of the Matrix of Coder Training Activities (Figure VI). The ordered pairs on any diagonal are grouped together by brackets in the ordered pair sequence (Figure V).

Learning experiences have been devised for each ordered pair in the sequence. For example, the activity associated with the ordered pair (1, 3) requires students to practice recognizing cognitive verbs that occur in instructional materials to which they are referred. They are asked to respond by writing on their answer sheets those underlined words in the instructional material that they

MODES OF RESPONSE LIST

0 NO OVERT MODE OF RESPONSE

1 CHECK, RING (encircle), UNDERLINE, CROSS OUT, MARK, CONNECT (with a line segment), GROUP

2 PUT, TAKE, AFFIX, PLACE

3 DRAW, GRAPH, TRACE, DIAGRAM

4 COLOR, SHADE

5 WRITE

6 POINT AT

7 SAY

8 MANIPULATE, CUT, FOLD

9 DRAMATIZE, SIMULATE

FIGURE IV

MODES OF RESPONSE LIST

[(0,1), (read, readiness)]

[(1,1), (recognize, readiness)
(0,2), (read, development)]

[(2,1), (iterate, readiness)
(1,2), (recognize, development)
(0,3), (read, practice)]

[(3,1), (compare, readiness)
(2,2), (iterate, development)
(1,3), (recognize, practice)
(0,4), (read, demonstration)]

[(4,1), (categorize, readiness)
(3,2), (compare, development)
(2,3), (iterate, practice)
(1,4), (recall, demonstration)
(0,5), (read, maintenance)]

[(5,1), (apply, readiness)
(4,2), (categorize, development)
(3,3), (compare, practice)
(2,4), (iterate, demonstration)
(1,5), (recall, maintenance)]

[(6,1), (justify, readiness)
(5,2), (apply, development)
(4,3), (categorize, practice
(3,4), (compare, demonstration)
(2,5), (iterate, maintenance)]

[(7,1), (generalize, readiness)
(6,2), (explain, development)
(5,3), (apply, practice)
(4,4), (categorize, demonstration)
(3,5), (compare, maintenance)]

[(8,1), (solve, readiness)
(7,2), (deduce, development)
(6,3), (analyze, practice)
(5,4), (apply, demonstration)
(4,5), (categorize, maintenance)]

[(9,1), (evaluate, readiness)
(8,2), (design, development)
(7,3), (synthesize, practice)
(6,4), (analyze, demonstration)
(5,5), (apply, maintenance)]

[(9,2), (evaluate, development)
(8,3), (design, practice)
(7,4), (synthesize, demonstration)
(6,5), (analyze, maintenance)]

[(9,3), (evaluate, practice)
(8,4), (design, demonstration)
(7,5), (hypothesize, maintenance)]

[(9,4), (evaluate, demonstration)
(8,5), (design, maintenance)]

[(9,5), (evaluate, maintenance)]

FIGURE V

SEQUENCE OF CODER TRAINING ACTIVITIES

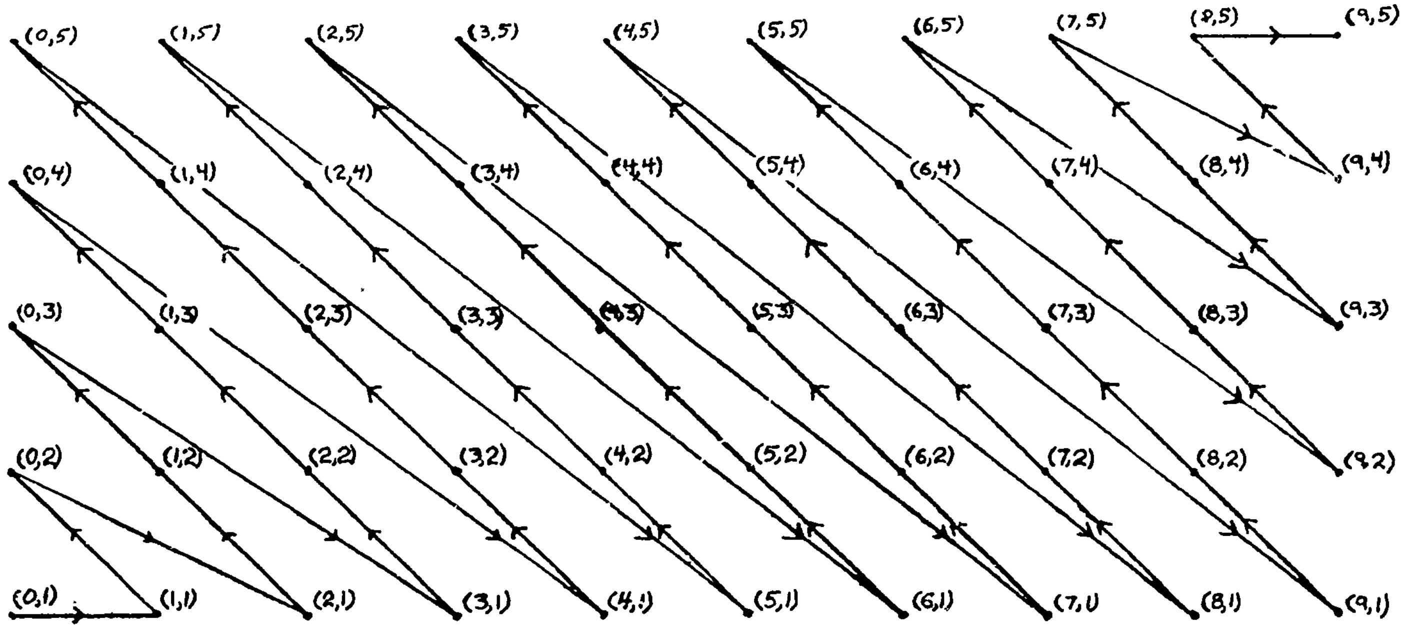

FIGURE VI
MATRIX OF CODER TRAINING ACTIVITIES

recognize as cognitive verbs.

Self-instructional materials were written for the first twenty-eight of the fifty ordered pairs above and formed the core of the experimental treatment. An additional two exercises not in the sequence were included for enrichment.

As stated above, all behaviors represented by level two and higher cognitive verbs require the use of lower level behaviors as tools.

Therefore, when a cognitive level is introduced for the first time, students will already have been exposed to each lower cognitive level at successively higher stages of mastery. Thus the stage of mastery order is preserved. It is judged to be too much to ask of students to increase both cognitive level and stage of mastery at once. It was also considered desirable to present the student with experiences at a variety of cognitive levels rather than to hold cognitive level constant and vary stage of mastery. This spaced activity with each cognitive level is consistent with the concept of a spiral curriculum and reduces the probability of students becoming bored with the sequence of activities to which they are exposed. This is also consistent with Bruner's contention that "the development of intellectual functioning...is shaped by a series of technological advances in the use of mind."[1]

The experiment by which the effectiveness of the instructional materials based on this design was tested used a pre-test, post-test, control group design. All but one of the subjects were college students preparing to teach mathematics. The differences between consistency gains in coding the experimental group from pre-test to post-test exceeded those of the control group by an amount significant at the .025 level or better for every coding source.

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[1]See Bruner, Jerome S. "The Course of Cognitive Growth," American Psychologist, 19, January, 1964, p.1

Evidence has been referred to above to support the hierarchical nature of the Cognitive Verb List and the sequential nature of Stages of Mastery List. Learning activities were ordered according to these supported assumptions. It has not been demonstrated that the sequence of ordered pairs thus generated represents a sequence of activities that is of increasing challenge to the student.

This could be investigated by asking randomly selected individuals to complete a sequence of tasks each of which represents an ordered pair in the matrix. If the ordering given by the matrix does represent a hierarchy, then significantly fewer individuals should successfully complete higher level tasks than complete lower level tasks.

It may be that students who have undergone the experimental treatment will become better teachers than they otherwise would have been because of their increased sensitivity to the variables with respect to which they coded instructional material. This question could be investigated by analyzing the teaching of members of the experimental group for the presence of decisions about each of the four variables and comparing the results with analyses performed on the teaching behavior of other teachers.

The experiment descrived above demonstrates that the design by which instructional activities were sequenced was more effective than testing alone. A next step would be to compare the effectiveness of instructional activities based on this design with instructional activities sequenced by content only.