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AUTHOR Partin, Ronald L.

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ABSTRACT

The instructional effectiveness of learning programs derived from Gagne-type task analysis, ordering theory analysis, and random sequenced presentation of complex intellectual skills were investigated. Fifty-seven high school students completed a self-instructional program derived from one of the three sequences. No significant differences were found among the three groups in number of objectives mastered. The two groups receiving hierarchical presentations required significantly less time to complete the program than the random sequence group. The study seems to support in part the assumption that an optimal sequence of successful instruction exists. It is concluded that it is unwise to consider the learning of intellectual skills only in terms of prerequisite skills, but that interactions with other variables must be examined. For learning hierarchies to have a profound effect in the classroom, more efficient procedures for task analysis or hierarchy generation are needed. Improvements upon the ordering theory analysis may provide promise in this direction. (Author/LBH)

THE INSTRUCTIONAL EFFECTIVENESS OF RANDOM, LOGICAL AND ORDERING THEORY GENERATED LEARNING HIERARCHIES

Ronald L. Partin

Bowling Green State University

Paper presented at the
Annual Meeting of the
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The Instructional Effectiveness of Random, Logical and Ordering Theory Generated Learning Hierarchies

Models of instructional development generally include one or more steps for analyzing the terminal objective into a sequence of prerequisite objectives (Glaser, 1965; Briggs, 1970). To meet the need for a technology of task analysis, Gagné (1962) suggested a research methodology which would yield hierarchies of learning tasks. The Gagné model and its subsequent modification (Gagné, 1968; White, 1973, 1974b) require teaching the elements of the proposed hierarchy to a group of subjects to empirically validate the proposed hierarchy.

Proponents of an alternative method of hierarchy generation have advocated schemes which omit the controlled instruction as a part of the empirical validation (Phillips and Kane, 1973; Airasian, 1971; Airasian and Bart, 1973). By assessing the performance patterns of a group with a dispersion of scores on the objectives, a hierarchy or network of objectives is derived. It's supporters have suggested that psychometrically generated hierarchies and sequences may be a favorable alternative to the time consuming and expensive task of the Gagné model. Airasian and Bart (Airasian, 1971; Airasian and Bart, 1971; Bart and Krus, 1973) have proposed the ordering theory model as a psychometric means of identifying networks of relationships among skills.

Whereas, the Gagné hierarchy generation procedure is based upon a logical task analysis of the terminal objective, ordering theory psychometrically compares all possible prerequisite relationships which exist in the total set of objectives. By examining the patterns of test responses on the set of objectives, the ordering theory analysis produces a network of hierarchy among the objectives.

The notation used in ordering theory analysis is similar to that of the Gagné hierarchical connection. In a two item hierarchical connection, x and y, there are four possible response patterns: (0,0), (1,0), (1,1), and (0,1). Bart and Airasian propose that the first three response patterns are confirmatory and that the last (0,1) is disconfirmatory of the hierarchical relationship. The absence of disconfirmatory response patterns validates the hypothesized ordering (Airasian and Bart, 1973).

Ordering theory is a deterministic model as opposed to most inferential statistical models which are probabilistic. Although it is derived from Scalogram analysis, ordering theory permits the testing of nonlinear task hierarchies. It may be used to confirm the logical existence of an a priori hierarchy, or in those cases where no a priori hierarchy has been posited, to suggest the best fitting hierarchical relationships of a set of tasks (Airasian and Bart, 1971).

Although several researchers have advocated use of the ordering theory model for hierarchy generation, there is an absence of empirical evidence on the instructional effectiveness of sequences produced by the ordering theory analysis. The primary purpose of this study was to empirically test the validity of a hierarchy generated from the ordering theory procedures. Specifically does the sequence generated from an ordering theory analysis result in greater instructional gains than a sequence generated from a logical Gagné task analysis? Secondly, will the ordering theory hierarchy prove to be valid as empirically assessed by the White and Clark test of inclusion (1973)? The test of inclusion provides for an estimate of the error of measurement in testing the hypothesis that "all the members of a population who possess a certain skill are a subset of the members who possess another skill" (White and Clark, 1973, p. 77).

In evaluating the usefulness of any instructional procedure a necessary, but not sufficient criterion for acceptance is its ability to produce learning. However, it is possible for two approaches to teaching a skill to both result in mastery of that skill, but requiring unequal amounts of time to do so. Thus, all other factors being equal, the instructional procedure requiring less time would be more efficient. In comparing the experimental sequences in this study, time required for subjects to complete the instructional program was also included as a dependent measure.

Generation of Learning Hierarchies

Although all subjects in the main experiment received instructional programs containing the same frames and test items their order varied according to the instructional sequence: 1) a logical sequence generated by Gagné type task analysis, 2) a sequence derived from ordering theory analysis and 3) sequences individually randomized.

A task analysis of the terminal objective "Given the mean and standard deviation of a distribution, to calculate the percentage of cases that fall below a specified score" by the author with recommendations of two professors of education who had previously taught statistics or measurements courses. By successively asking the question "What would the individual already have to know how to do in order to learn this new capability simply by being given verbal instructions?" (Gagné, 1962, p. 357), the hierarchy depicted in Figure 1 was derived. The instructional objectives corresponding to the numerals are listed in Table 1.

INSERT FIGURE 1 APPROXIMATELY HERE

INSERT TABLE 1 APPROXIMATELY HERE

To construct an ordering theory hierarchy a matrix of the percentage of disconfirmatory response patterns (0,1) for all pair combinations of objectives was developed (see Table 2). The set of test questions designated as the posttest for the main experiment was used in the construction of the ordering theory hierarchy. The criterion level for the ordering theory hierarchy was .10, which meant that a connection between two objectives was determined to be hierarchical if less than 10% of the total response patterns were disconfirmatory (0,1). For example, in Table 2 element or objective 1 is determined to be prerequisite to objective 2, as only 6% of the response patterns were disconfirmatory (i.e., only six percent of the students who missed objective 1 were able to pass objective 2).

INSERT TABLE 2 APPROXIMATELY HERE

There were marked differences between the hierarchical structures generated by the two procedures (see Figures 1 and 2). A number of postulated connections were reversed by the ordering theory analysis, such as the 11/12 connection. The most notable occurrance seems to be the isolation of objective 16 in the ordering theory hierarchy. Additionally, the complex network generated by ordering theory analysis suggests the possibility of alternate learning paths to higher objectives.

After the learning hierarchy had been proposed by the Gagné task analysis, a pool of nine test items per objective was developed. These were randomly divided into three separate tests each containing three test items for each of the seventeen instructional objectives. The three tests were identified as pretest, posttest and retention test for the main experiment. To obtain a sample which had had previous exposure to the terminal and enabling objectives, 54 advanced undergraduate and graduate students received one of the three alternate test forms. Sixty percent of the college sample were selected at random to receive the alternate form used to formulate the ordering theory hierarchy. The test items were arranged into a test booklet such that items measuring objectives highest in the proposed hierarchy appeared first and the items from the lowest level of the hierarchy appeared last to minimize the effects of learning from the test. Performance on each objective was scored pass or fail, with two items out of three answered correctly being scored as a pass. One way analysis of variance showed no significant (p.<05) differences in the number of objectives mastered among the three groups of the college sample.

The program frames were adapted from the programmed text Statistical Concept: A Basic Program by Amos, Brown, and Mink (1965). Permission to use the text was obtained from the publishers, Harper and Row and Company. The authors (Amos, Brown, and Mink, 1965) reported five separate validation and error rate studies using the program with error rates of five to seven percent and significant instructional gains.

In proposing a refinement in the Gagné model of hierarchy validation, White (1973) suggested that 1) posttest items for each objective appear immediately after instruction for that objective, and 2) that two or more questions per objective be used to permit the estimate of the error of measurement. To minimize the effects of error of measurement Bart and Airasian (1974) have suggested the use of open-ended questions. Each of these recommendations was followed with the use of three items per objective in the pretest, embedded posttest, and the retention test. The embedded posttest served two functions: 1) to provide a gain score on which the instructional effectiveness of the three sequences could be compared, and 2) to provide test performance patterns for a hierarchy validation using the White and Clark test of inclusion (1973). Although each set of programmed booklets contained the same frames and same test items, their order varied according to the instructional sequence.

INSERT FIGURE 2 APPROXIMATELY HERE

METHOD

Subjects

The sample for the main experiment consisted of 57 high students from two introductory psychology classes. Forty-seven were seniors and ten were juniors. In addition, a quasi-control group of 12 seniors was given the pretest and the retention test to obtain additional information on the instructional effectiveness of the program.

Materials

Each subject in the main experiment received a packet of 8-1/2 by 11 inch (22cm x 28cm) mimeographed programmed booklets. Each of the 17 objectives was contained in a separate booklet. The posttest items appeared on the last page of each booklet. Each booklet was collected before the subject could begin instruction on the next objective in his sequence. The booklets were sequentially numbered as dictated by the experimental condition. Each booklet in the packet also contained the subject's identification number.

Procedures

All subjects in the main experiment were given a pretest on all enabling objectives and the terminal objective. The pretest items were randomly ordered, to avoid possible contaminating effects of the pretest aequence aerving as an advance organizer.

Five days after the pretest the programmed booklets were given to all of the high school subjects. They responded in the booklets to each frame and to all posttest items. After a subject made an overt response to each frame within the instructional program, he uncovered the correct answer.

All posttest questions immediately followed the corresponding instruction within the programmed text. Thus, each student was required to respond to the test items relating to a particular objective before proceeding to the instruction for the next objective in the sequence. A retention test was given all three groups approximately five daya after all students had completed the instructional program.

Each subject's performance on each of the objectives was obtained from the test items embedded within the program, following the recommendations of White (1973). A score of paas or fail was recorded for each objective, with two items out of three answered correctly being scored as a pass. The same criterion level was used for the pretest and the retention test.

Because the test items composed a criterion-referenced instrument, the traditional nom-referenced measures of reliability were inadequate and inappropriate as the deviation from the mean would be misleading. A criterion-referenced correlation coefficient developed by Livingston (1970) waa used for this purpose. This procedure produced a criterion-referenced correlation of .932.

RESULTS

Covariances on Post and Retention Test Scores

As recommended by White (1974) the individual posttests for each objective were given to all subjects immediately after completion of the instruction on that objective and before the students proceeded to the next objective in the sequence. If a student answered correctly two of the three questions for each objective he was credited with a pass for that objective.

An analysis of covariance on the number of objectives passed on the posttest was computed with the pretest as the covariate. No significant differences were found among the three groups ($p > .05$). Means and standard deviations on the pretest and posttest for the three experimental conditions are depicted in Table 3.

INSERT TABLE 3 APPROXIMATELY HERE

INSERT TABLE 4 APPROXIMATELY HERE

As shown in Table 4 no significant differences were found among the three treatment groups in posttest performance when the pretest was held as covariate. No significant differences ($p > .05$) were found from analysis of covariance on objectives passed on the retention test with the posttest as covariate. (See Table 5).

INSERT TABLE 5 APPROXIMATELY HERE

Comparisons of Time to Completion

The total number of minutes that each student spent working on the program and embedded posttests was recorded. The means and standard deviations are shown in Table 6.

The most notable occurrance is, of course, the large difference in average number of minutes to complete the instructional program between the random sequence group ($\overline{X} = 123.21$) and the two ordered sequences ($\overline{X}$ ordering theoretic = 104.05 and $\overline{X}$ logical 106.263). The analysis of variance produced an F-ratio of 5.792 which was significant at the .01 level (see Table 7). Post hoc contrasts with the Scheffe method yielded ranges of 4.48 and 4.48 for both contrasts against the random sequence. Thus, both logical and ordering theory sequences differed significantly ($p < .01$) from the random sequence, but did not differ significantly from each other.

INSERT TABLE 6 APPROXIMATELY HERE

INSERT TABLE 7 APPROXIMATELY HERE

<u>Hierarchy Validations</u>

For each proposed hierarchical connection in both the ordering theory and logical sequences a 4 x 4 table of performance combinations was constructed. An example of such a contingency table is shown in Figure 3.

INSERT FIGURE 3 APPROXIMATELY HERE

By contrasting the observed and expected frequencies in the major disconfirmatory cell (0,3 in the above matrix) a critical value for defining a hierarchical relationship is derived. The critical value is the maximum number of cases which may occur in the 0,3 cell to accept the proposed hierarchical connection. Under the null hypothesis that critical value is the number which might achieve a 0,3 response pattern by errors of measurement alone. Linke (1974) suggests a more tolerable level than allowed by error of measurement alone to permit "legitimate exceptions arising through the use of unidentified prerequisite skills or alternate learning pathways" (p. 915). This is in agreement with Gagne's (1970) proposal for substantial rather than absolute levels of acceptance. Because the number of cases constituting each hierarchy sample was relatively small (19) the null hypothesis was tested at the .01 level as well as the .00 level. Acceptance of a connection as hierarchical under the .00 null hypothesis limits the critical value to only those disconfirmatory cases which could be expected to occur through errors of measurement alone. The summary of results of the validations is presented in Tables 8 and 9. As an example from Table 9 the Gagne analysis suggested that objective #1 was a prerequisite to objective #2. The White and Clark (1973) test of inclusion permitted only one disconfirmatory to occur as a result of error of measurement under the .01 hypothesis, which is always more restrictive than the .00 null hypothesis. As two cases occurred which were disconfirmatory, the proposed hierarchical connection was rejected.

INSERT TABLE 8 APPROXIMATLEY HERE

INSERT TABLE 9 APPROXIMATELY HERE

Of the 24 postulated hierarchical connections in the ordering theory network, 21 were accepted as valid hierarchical connections. Fourteen of the nineteen postulated connections in the logical hierarchy were accepted at the .01 hypothesis level.

DISCUSSION

Many of today's educational developments, including competency-based education, auto-instructional programs, and mastery models of learning, are based upon the assumption that an optimal sequence for successful instruction exists. The present study seems to partially support that assumption. Although no significant differences were found between the logical, ordering theory and random sequences, the random sequence group did take significantly ($p < .01$) longer to complete the instructional program. Thus, subjects exposed to a random sequence of objectives were able to learn, but it took them approximately 17% longer to do so. If time were constant for all three groups, it is probable that the number of objectives mastered would have been significantly less for the random sequence subjects than for the two ordered sequence groups.

Roe, Case and Roe (1961) failed to find significant differences between the posttest scores of logical and random sequence presentations with learning programs which took approximately 45 minutes for completion. Obtaining similar results, Hamilton (1964) compared logical and random sequences of an instructional program which required about 24 minutes to complete. In a later review Tennyson (1972) suggested that the brevity of the programs might have permitted short term memory to compensate for ordering effects. The instructional program of the present study required a mean time of 111.18 minutes to complete. Although this seems significantly longer than the programs used by Roe and Hamilton, relatively high pretest scores ($\overline{X} = 6.526$) could sufficiently reduce the amount of information which would need to be ordered by a subject given a random sequence.

Although posttesting for each skill immediately after its instruction would seem to limit the effects for short term memory, it is difficult to be conclusive as the skills were arranged in a multi-branched non-linear hierarchy. More important than the total number of objectives passed is the response pattern of those objectives passed. This is confounded further by the pretest mastery of some parts of the hierarchy. The only statistical procedure which attempts to analyze the non-linear response patterns of a hierarchy is the ordering theory analysis, which lacks the necessary estimate of error of measurement. Further, the ordering theory procedure does not have a provision for comparing several different response patterns. It seems likely that more sophisticated techniques for analysis of non-linear hierarchies must be developed before the problem can be fully resolved.

An additional explanation for the difficulty in finding the effects of sequence order may be the size of the unit of task analysis. This question has been raised by Resnick (1974). In examining individual differences in progressing through hierarchies, she noted that many students seem able to learn several objectives or skills simultaneously. It may be that the trend has been toward an overly minute analysis.

Perhaps intellectual skills exist in clusters with dimensions which share vertical or horizontal transfer properties. Graphically these skills may be related in a Gagné-type learning hierarchy. The difference is in how students progress through the hierarchy. It may be that higher order learning skills or abilities provide a third dimension to the two dimensional learning hierarchy. A better understanding of what Gagné terms "cognitive strategies" may provide a clue to the comprehension of individual differences in learning the same sequence of intellectual skills. Certain cognitive strategies may permit the learner to skip levels of the hierarchy or condense them. The nature of the learning task must also be considered as a possible variable in determining optimal sequences. The statistical skills developed through the learning program were primarily at the principle level of Gagné's levels of learning (1970). Lacking evidence to the contrary it seems reasonable to believe that all skills are not equal in importance or transfer value. In any hierarchy there may exist a few very key or crucial skills whose mastery will greatly enhance the learning of many other skills.

Learning hierarchy researchers (Resnick, 1974; and Phillips, 1974) have suggested the possibility of alternate learning hierarchies. The possibility that a skill might be mastered by two or more routes indicates that if a "true hierarchy" of all possible routes were known, a number of disjunctive connections would exist. A disjunctive connection leading to a higher element in a hierarchy would indicate two or more alternate skills, any one of which is sufficient to insure mastery of the upper element. Traditional forms of hierarchy generation allow for conjunctive connections where two or more independent skills are jointly necessary for mastery of the higher skill. The statistical possibility of creating disjunctive connections is established through the ordering theory analysis, but the empirical validation of such alternate pathways is lacking. Further investigation in this area might account for some of the individual differences in learning intellectual skills.

If any of the theoretic possibilities described above are valid, the expectation of absolute hierarchies is unrealistic. Interactions with task content, learner characteristics such as cognitive strategies or affective elements may predetermine individual differences in the ability to progress through any proposed learning hierarchy.

An inherent difficulty in conducting research based upon logical task analyses, such as that of Gagné, is that the proposed hierarchy is always dependent upon the intellectual skills and subject matter knowledge of one or a few individuals. The possibility of errant analyses through omission of necessary steps, inclusion of extraneous skills, or misalignment of elements within the hierarchy, must be considered. The more miniscle the analysis, the greater the probability of committing such an error.

Twenty-one of the 24 postulated connections for the ordering theory hierarchy were accepted as valid with the White and Clark (1973) test of inclusion. Of the nineteen connections in the logical hierarchy, fourteen were accepted as valid. Although both hierarchies were substantially valid as defined by the test of inclusion, the rejected connections could account for the lack of significant differences in mastery between the two ordered sequences and the random sequence. For example, of the three postulated prerequisite skills for objective number 15 in the logical hierarchy, two were not accepted as valid connections. As objective 15 was in the middle of the hierarchy, it is possible that instruction on objectives 11, 12, 13, and 14 was not necessary for success on objective 15. Barring the existence of unidentified prerequisites (which may be a tenuous assumption), only objective or skill number 10 is a necessary prerequisite. If a student had passed objective 10 in the pretest, or was able to master it through problem solving strategies, he may master skills 15, 16, and 17 without receiving passing scores on objectives 11 through 14, giving him a low total score although passing higher level objectives.

Another variable which must be considered is the task level of the hierarchy elements. According to Gagné (1970) concepts are necessary for the mastery of principles, and the acquisition of principles is essential to successful problem solving. However, most of the tasks in this learning situation were at the principle level. Had the hierarchy extended down to the concept level, or their prerequisites---discriminations, the hierarchical nature of the learning tasks might be more pronounced, as supported by the findings of Gagné and Bassler (1963). Of course, a more naive sample must be used, as a mean of 6.526 objectives were passed on the pretest by the high school subjects.

The White and Clark (1973) test of inclusion is a relatively untested statistical procedure, as only two major studies (White, 1973; Linke, 1974) have employed the procedure to validate learning hierarchies. Two potential deficiencies must be considered in using this technique in assessing the validity of hierarchical connections.

The provision for an estimate of the error of measurement is an attractive and valuable feature, but it must be noted that the greater the error of measurement, the higher the critical value for acceptance of the connection as hierarchical. Thus, less reliable tests are more likely to yield valid connections.

A second reservation to be considered is that if the successes on the postulated superordinate skill is equal to or less than the critical value for that connection, it is statistically impossible to reject the connection. This is true because the hierarchical connection is rejected only when the number of 0,1 (failure on subordinate task and mastery of the superordinate task) response patterns exceed the critical value. The same situation exists whenever the number of subjects failing the subordinate task is equal to or less than the critical value. In examining the difficulty posed by this occurrance, White (1973) suggested that the hierarchy be verified by a subject matter expert to establish an initial "logical validity."

The central assumption underlying learning hierarchy research has been that failure to learn is attributable primarily to a lack of prerequisite skills. Although substantial research has established that sequence of skill instruction does have a significant role (Gagné, 1962; Gagné and Bassler, 1963) it seems unwise to consider the learning of intellectual skills only in terms of prerequisite skills. Interactions with other variables must be examined. For learning hierarchies to have a profound effect in the classroom, more efficient procedures for task analysis or hierarchy generation are needed. Improvements upon the ordering theory analysis may provide promise in this direction.

References

Airasian, P.W., Method for validating sequential instructional hierarchies. Educational Technology, 1971, 11, 54-56. (a)

Airasian, P.W., The use of hierarchies in curriculum analysis and instructional planning. California Journal of Educational Research, 1971, 22, 34-41. (b)

Airasian, P.W. and Bart, W.M., Tree-theory: A theory-generative measurement model. Paper presented at the annual meeting of the American Educational Research Association, New York, February, 1971.

Airasian, P.W. and Bart, W.M., Ordering theory: A new and useful measurement model. Educational Technology, May 1973, 13, 56-60.

Airasian, P.W. and Bart, W.M., The use of ordering theory in the identification and specification of instructional sequences. Paper presented at the annual meeting of the American Educational Research Association, Chicago, April, 1974.

Amos, J.R., Brown, F.L., and Mink, O.G., Statistical Concepts: A basic program. New York: Harper and Row, 1965.

Bart, W.M. and Airasian, P.W., Determination of the ordering among seven Piagetian tasks by an ordering theoretic method. Journal of Educational Psychology, 1974, 66(2), 277-284.

Bart, W.M. and Krus, D.J., An ordering-theoretic method to determine hierarchies among items. Educational and Psychological Measurement, 1973, 32, 291-300.

Briggs, L.J. Handbook of procedures for the design of instruction. Pittsburgh: American Institutes for Research, 1970.

Gagné, R.M. The acquisition of knowledge. Psychological Review, 1962, 69(4), 355-365.

Gagné, R.M. Learning hierarchies, Educational Psychologist, 1968, 6, 1-9.

Gagné, R.M. Contributions of learning to human development. Psychological Review, 1968, 75, 181.

Gagné, R.M. The conditions of learning. New York: Holt, Rinehart and Winston, 1970.

Gagné, R.M. and Bassler, O.C. Study of retention of some topics of elementary non-metric geometry. Journal of Educational Psychology, 1963, 54, 123-131.

Glaser, R. (Ed.). Teaching machines and programmed learning, II. Washington, D.C.: National Education Association, 1965.

Hamilton, N.R. Effects of logical versus random sequencing of items in an autoinstructional program under two conditions of covert response. Journal of Educational Psychology, 1964, 55, 258-266.

Linke, R.D. Influence of cultural background on hierarchical learning. Journal of Educational Psychology, 1974, 66(6), 911-918.

Livingston, S.A. The reliability of criterion-referenced measures (Report No. 73). Baltimore: John Hopkins University, July, 1970.

Phillips, E.R. Development of optimal instructional sequences. Paper presented at the annual meeting of the American Educational Research Association, Chicago, April, 1974.

Phillips, E.R. and Kane, R.B. Validating learning hierarchies for sequencing mathematical tasks in elementary school mathematics. Journal for Research in Mathematics Education, 1973, 141-151.

Resnick, L.B. In R. Gagne (Chair) Individual differences in learning hierarchies. Symposium presented at the meeting of the American Educational Research Association, Chicago, April, 1974.

Roe, K.V., Case, H.W., and Row, A. Scrambled versus ordered sequence in autoinstructional programs. Journal of Educational Psychology, 1962, 53, 101-104.

Tennyson, R.D. Review of experimental methodology in instructional task sequencing. AV Communication Review, 1972, 20, 147-159.

White, R.T. Learning graphical skills in kinematics. Unpublished doctoral dissertation, Monash University, Victoria, 1971.

White, R.T. Research into learning hierarchies. Review of Educational Research, 1973, 43(3), 361-375.

White, R.T. Indexes used in testing the validity of learning hierarchies. Journal of Research in Science Teaching, 1974, 11(1), 61-66. (a)

White, R.T. Model for validation of learning hierarchies. Journal of Research in Science Teaching, 1974, 11(1), 1-3. (b)

White, R.T. The validation of a learning hierarchy. American Educational Research Journal, 1974, 11(2), 121-136. (c)

White, R.T. and Clark, R.M. A test of inclusion which allows for errors of measurement. Psychometrika, 1973, 38, 77-86.

White, R.T. and Gagne, R.M. Past and future research on learning hierarchies. Educational Psychologist, 1974, 11(1), 19-28.

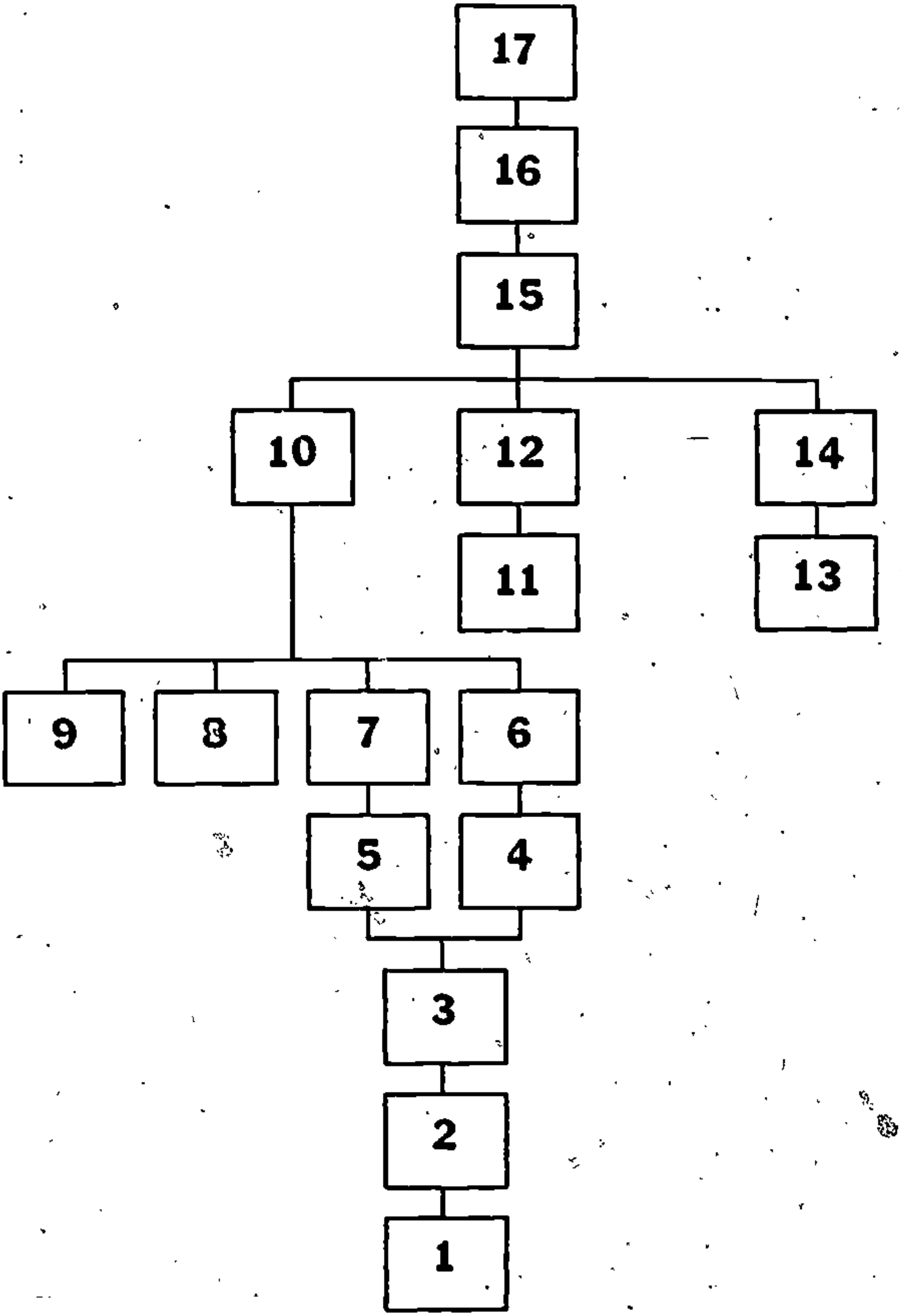

Figure 1 Learning hierarchy derived from Gagné task analysis

Table 1

Instructional Objectives Arranged According To Position In The Logical Sequence

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1. Given a set of scores to identify the frequency of a specified score
2. Given a group of numbers representing test scores, to order according to magnitude in a distribution
3. Given a set of numbers to arrange in a frequency distribution
4. Given a completed frequency polygon, to correctly identify the frequency of a specified score
5. Given a histogram, to identify the frequency with which a specified score occurs
6. Given a group of numbers to correctly construct a frequency polygon
7. Given a group of numbers to construct a frequency histogram
8. Given an odd number of scores, the student will correctly identify the number which represents the median
9. Given a group of numbers to calculate the mean
10. Given three graphs representing normal curves to select the one which represents the most variable group
11. Given N and a score rank, to specify the percentile of the specified score
12. Given N and a percentile, to specify the rank of a specified score

Table 1 (Continued)

Instructional Objectives Arranged According

To

Position In The Logical Sequence

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13. Given any two integers (-3 to +3) designated as standard deviations, to calculate the percentage of cases falling between those two points in a normal distribution

14. Given an integer between -3 and +3 representing a standard deviation of a distribution of scores, to specify the percentage of cases which fall above and below that point

15. Given the mean and standard deviation of a distribution of scores, to calculate the test score which would fall on any given standard deviation point above or below the mean

16. Given a test score, the mean, and the standard deviation, to calculate the appropriate z-score for that test score

17. Given the mean and standard deviation of a distribution, to calculate the percentage of cases that fall below a specified score (TERMINAL OBJECTIVE)

Table 2

Percentage of Disconfirmatory Response Patterns

(N = 33)

		Upper Element																
	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lower Element	1	–	6	9	27	27	3	3	6	15	12	9	12	0	0	0	0	0
	2	42	–	21	61	64	12	9	24	48	33	27	36	3	6	18	9	6
	3	33	9	–	52	55	3	3	18	30	30	21	30	0	0	3	3	3
	4	3	0	0	–	3	0	0	0	3	3	0	0	0	0	0	0	0
	5	0	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0
	6	18	21	24	73	76	–	3	24	48	36	30	42	3	3	18	9	6
	7	55	27	30	76	79	6	–	30	55	39	36	45	3	3	24	12	6
	8	36	18	18	55	55	9	6	–	36	24	18	30	0	3	3	3	0
	9	18	12	3	27	27	0	0	6	–	6	15	15	0	0	0	0	0
	10	30	15	21	45	45	6	3	18	24	–	21	27	3	3	15	3	3
	11	30	12	15	45	48	6	3	12	24	21	–	12	3	3	9	3	3
	12	21	12	15	36	39	6	3	12	21	18	0	–	3	3	6	3	0
	13	64	30	36	89	91	18	12	33	64	48	42	55	–	3	24	9	3
	14	61	30	33	85	89	15	9	33	61	48	42	52	0	–	24	9	3
	15	36	18	15	61	61	6	9	15	36	33	24	30	0	0	–	0	0
	16	55	27	30	79	82	16	12	27	55	39	36	45	0	3	18	–	0
	17	61	30	36	85	89	18	12	30	61	45	42	48	0	3	24	6	–

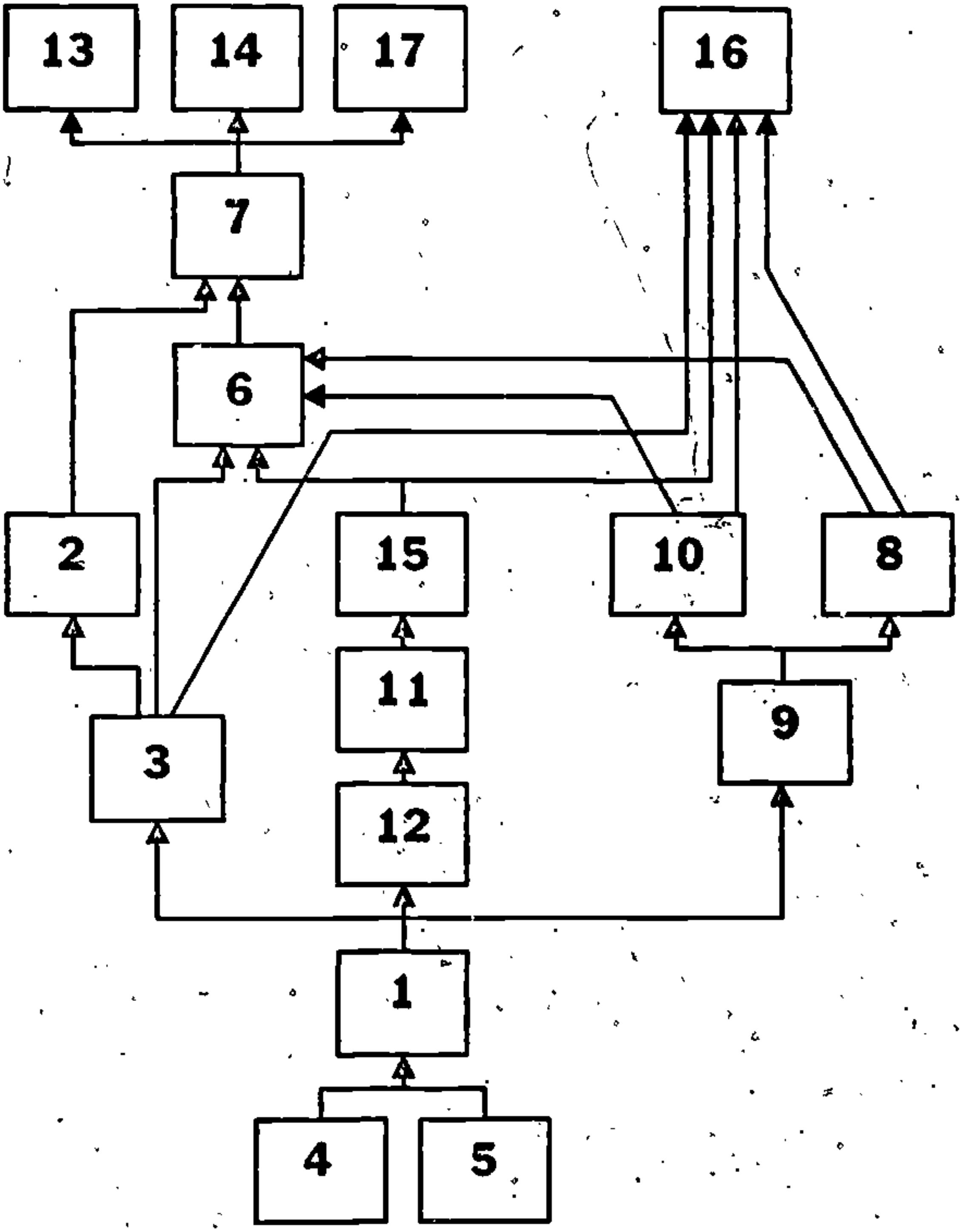

Figure 2 Ordering theory generated learning hierarchy

Table 3

Pretest, Posttest and Retention Test Means and Standard Deviations For the Three Experimental Groups

GROUP	PRETEST MEAN	PRETEST SD	POSTTEST MEAN	POSTTEST SD	RETENTION MEAN	RETENTION SD
Ordering Theory	6.842	2.007	12.789	3.207	10.842	3.005
Logical	5.737	2.513	12.158	3.367	11.421	2.631
Random	7.000	2.449	12.684	2.522	10.157	2.630

A Bartlett's test on the variances found no significant differences ($p > .05$).

Table 4

Analysis of Covariance on Objectives Passed
On
The Posttest With The Pretest As Covariate

SOURCE	RESIDUAL SUM OF SQUARES	DEGREES OF FREEDOM		F-TESTS
Full model	355.102			
Covariate	503.793	1	53	22.193
Adjusted sum of squares	356.363	2	53	.094

Table 5

Analysis of Covariance On Objectives Passed

On

The Retention Test With The Posttest As Covariate

SOURCE	RESIDUAL SUM OF SQUARES	DEGREES OF FREEDOM		F-TESTS
Full model	187.031			
Covariate	411.688	1	53	27.874
Adjusted sum of squares	272.152	2	53	.231

Table 6

Means and Standard Deviations

For

Time To Completion For The Three Treatment Groups

GROUP	MEAN	S.D.
Ordering Theoretic	104.053	13.990
Logical	106.263	18.423
Random	123.211	23.363
TOTAL	111.175	20.543

Table 7

Analysis of Variance

On

To Completion Of Instruction In Minutes

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F-RATIO
Between groups	2	4174.375	2087.188	5.792**
Within groups	54	19457.938	360.332	
TOTAL	56	23632.313		

** $p < .01$

Higher Objective
#16

Questions correct		0	1	2	3	Total	
	0	0	0	0	0	0	
	1	1	0	0	3	4	
Lower Objective #10	2	0	1	0	1	2	Number of subjects
	3	3	0	1	9	13	
	Total	4	1	1	13		

Figure 3.
Contingency table format used in calculating hierarchy validation. (Results derived from ordering theory sequence for proposed connection between objective 16 and objective 10).

Table 8

Description of Validation Results For The Ordering Theory Learning Hierarchy

LOWER	HIGHER	NUMBER OF EXCEPTIONS OBSERVED	EXPECTED*
1	3	1	1/.01
1	9	0	0/.00
1	12	0	0/.00
2	7	1	1/.01
3	2	0	0/.00
3	6	0	0/.00
3	16	0	0/.00
4	1	0	1/.00
5	1	0	0/.00
6	7	2	1/.01+
6	16	2	1/.01+
7	13	0	0/.00
7	14	0	0/.00
7	17	0	0/.00
8	6	1	1/.01
8	16	2	1/.01+
9	8	0	1/.00
9	10	1	2/.00
10	6	0	0/.00
10	16	0	0/.00
11	15	0	1/.00
12	11	0	1/.00
15	6	1	1/.01
15	16	1	1/.01

* The appropriate null hypothesis is included in second column.

+ Connection rejected at .01 alternate hypothesis.

Table 9

Description of Validation Results

For

The Logical Learning Hierarchy

LOWER OBJECTIVE	HIGHER OBJECTIVE	NUMBER OF EXCEPTIONS OBSERVED	EXPECTED*
1	2	2	1/.01+
2	3	0	1/.00
3	4	1	1/.01
3	5	1	1/.01
4	6	0	0/.00
5	7	0	0/.00
6	10	1	1/.01
7	10	1	1/.01
8	10	0	0/.00
9	10	0	0/.00
10	15	3	1/.01+
11	12	0	0/.00
12	15	5	2/.01+
13	14	0	2/.00
14	15	2	3/.00
15	16	0	0/.00
16	17	0	0/.00

N = 19

* The appropriate null hypothesis is included in the second column.

\+ Connection rejected at .01 alternate hypothesis.

mjp1/1