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ABSTRACT

The sequences of learning sets (intersequence) and instructional events (intrasequence) were empirically validated for a hierarchy of concept and rule using skills. Experiments with high school students showed no differences between empirical and reordered inter- or intrasequence on time to mastery; nor was there a difference in the number of skills mastered between the empirical and reordered intersequence groups. The data suggest the use of examples allowed learners to acquire higher-order skills even though they did not at the same time demonstrate mastery of subordinate skills. Effectiveness of the instruction indicates that the events included are more critical than their sequence. (Author)

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The Effect of Empirically Validated Versus Reordered Inter and Intra-Sequencing of Instruction on Learning

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The Effect of Empirically Validated Versus Reordered Inter and Intra-sequencing of Instruction on Learning.

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The sequences of learning sets (inter-sequence) and instructional events (intra-sequence) were empirically validated for a hierarchy of concept and rule using skills. Experiments with high school students showed no differences between empirical and reordered inter or intra-sequences on time to mastery; nor was there a difference in the number of skills mastered between the empirical and reordered inter-sequence groups. The data suggest the use of examples allowed learners to acquire higher-order skills even though they did not at the same time demonstrate mastery of subordinate skills. Effectiveness of the instruction indicates that the events included are more critical than their sequence.

Introduction

Inter-sequence. Gagne describes the concern of his book The Conditions of Learning (1970a) as that of finding an answer to the question, What is learning? The answer is phrased mainly in terms of "an objective description of the conditions under which learning takes place (p. 3)." It is Gagne's position that learning is very much dependent on the conditions which accompany it, and that discernment of these conditions and arranging for their occurrence facilitates the learning process.

Gagne describes two types of conditions of learning, conditions internal to the learner, and those external to him. Internal conditions are those capabilities, or learning sets, which are already in the learner's repertoire. To be sure, most of a learner's capabilities are not relevant to a particular instance of learning, but some are. Take for example a child who is attempting for the first time to learn addition of two integers. He brings with him to the situation a number of relevant capabilities, such as adding whole numbers, identifying numerals, use of associative and commutative properties, and so on. It is hypothesized by Gagne that all of these capabilities, or intellectual skills, will be used to facilitate the learning of other higher-order skills, such as the adding of integers. By examining the relations of learning tasks, Gagne concluded that learning is cumulative. Each capability is used in learning a new skill, which is in turn used in the learning of yet another.

A hierarchy can be constructed which illustrates the dependent and independent relationships between these learning sets. The construction begins by examining the terminal task and asking the question, "What would the learner have to know how to do in order to achieve successful performance of this class of tasks, assuming he were given only instructions?" This process of task analysis is continued for each of the identified skills until a level of basic competencies is obtained.

Such a hierarchy serves to imply a sequence for the presentation of instructional materials to the learner. He should first learn any prerequisite skill which he lacks before beginning instruction on a higher order skill. The hierarchy also denotes when the sequencing can be random or optional. Instruction for two or more skills prerequisite to a common higher-level skill could be presented in optional chronological order. However, instruction for all of the prerequisite skills should be presented before instruction for the higher-level skill.

Such a hierarchy was constructed by Gagne, Mayor, Garstens, & Paradise (1962), for a terminal task of adding integers and is reproduced in Figure 1. Each box in the diagram represents one of the skills in the hierarchy. The skills at the base of the hierarchy are subordinate to the skills directly above them. Gagne contends that the lower order skills facilitate the learning of the higher order, or superordinate skills. Learners who do not have one or more of those subordinate capabilities will have difficulty learning the adjacent superordinate skill.

In this and similar studies (Gagne and Bassler, 1963, Gagne and Paradise, 1961; and Gagne and Staff, 1965) Gagne examined the pass-fail patterns of

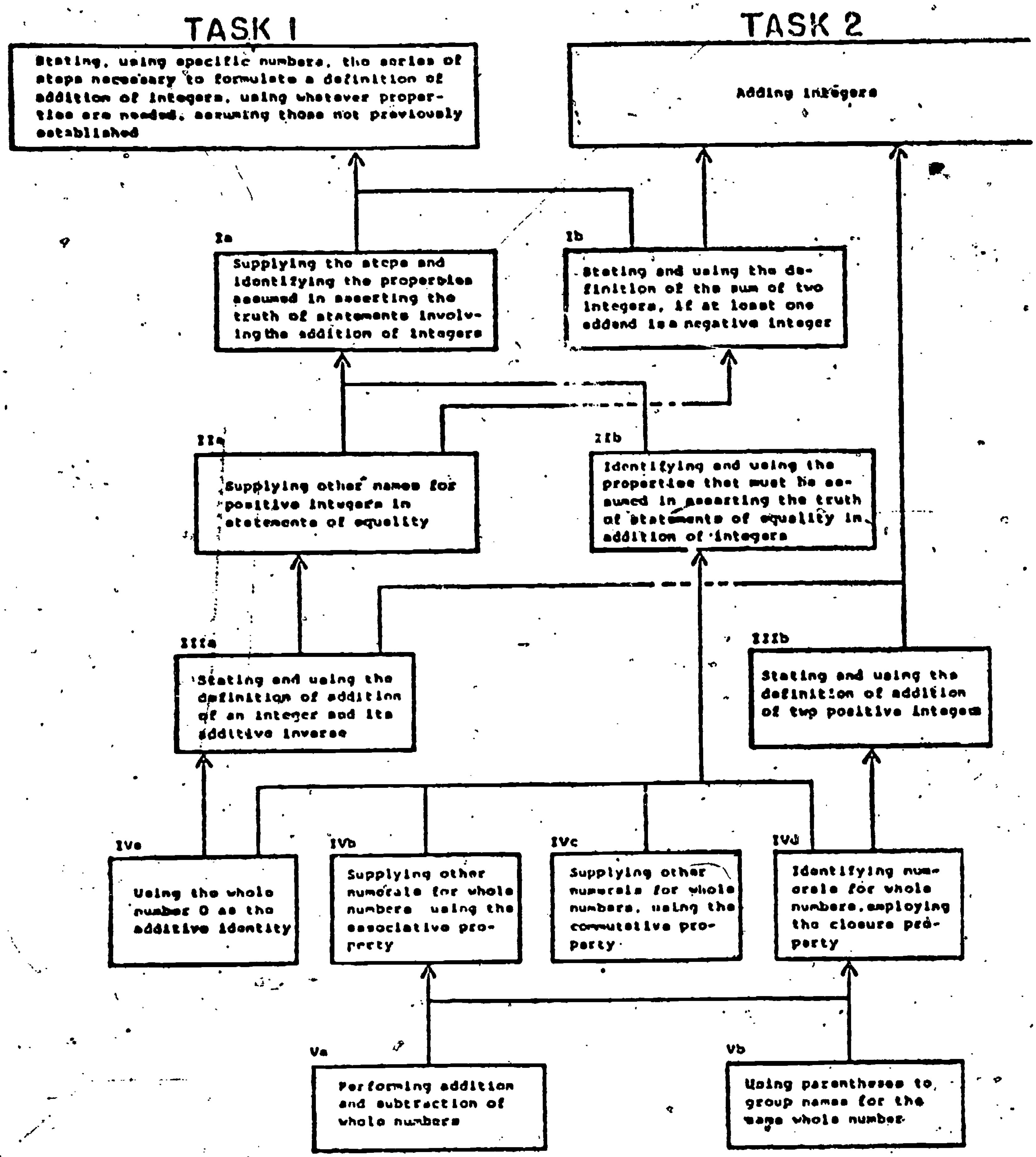


FIGURE 1. A curriculum hierarchy on the addition of integers. (From Gagné, R.M., Mayor, J.R., Garstens, H.L., & Paradise, N.E. Factors in acquiring knowledge of a mathematical task. Psychol. Monogr., 1962, 76, Whole No. 526.)

the learners who had received programmed instruction on each skill in the hierarchy after completion of instruction. Based on their patterns of pass-fail for each learning set the Ss were divided into four groups:

1) those successful at the tests of a skill and all its subordinate skills;
2) those unsuccessful at the test of a skill and at the test of at least one of its subordinate skills;
3) those successful at the test of a skill and unsuccessful at the test of at least one of its subordinate skills;
4) those unsuccessful at the test of a skill and successful at the tests of all its subordinate skills.

In each of the studies the number of Ss who learned the higher-order skills without acquiring the lower order skills (group 3) was very small. Gagne used these data to support his contention that learning is cumulative.

In a 1962 study Gagne developed a hierarchy with the terminal task of "finding formulas for the set of n terms in a number series." Test items for each learning set in the hierarchy were administered to seven ninth grade boys. Each boy was tested first for the terminal skill and, if he failed received the test for a subordinate learning set, and so on until the boy passed on a learning set. At this point the testing was temporarily stopped and each boy received programmed instruction for the next highest learning set (which was previously failed). When instruction was completed the Ss received test items for all competencies in the hierarchy. There were no instances in which a learner passed a higher order skill without also passing all lower level skills.

However, in reviewing the theory and results of these studies Anderson (1967) states that none of the results from the above studies

> proves that one concept of skill must be mastered before the next one can be learned. Since topics in the program were ordered from the lowest level to the highest level, any factor that caused a subject to "tune out" at any point within the program could have produced the post-test results that were obtained. Direct experimental manipulation of the instruction designed to teach subordinate knowledges, rather than post-experimental correlation analysis, will be necessary to clinch the argument. (pp. 157-158).

Merrill (1965) also examined the necessity of requiring mastery of subordinate skills before learning superordinate skills. A complex science system called Xenograde was created for use in the study. It was hypothesized that learning of this hierarchical task is facilitated by mastering each successive part of the material before proceeding to the next. Sixty-two college students were assigned to five groups which were given various level tasks. The results contradicted the hypothesis. The group which performed best was not required to master all the skills but received a summary of each lesson prior to the review exercise which preceded the test. The groups which received the most correction/review took progressively more time but did not make fewer mistakes. Merrill concluded his study by saying that, "The results seem to indicate that it is not necessary to master one level before proceeding to the next (p. 233)."

Briggs (1967) rebutted Merrill's conclusion by contending that he "went beyond his own data in interpreting his task as hierarchical (p. 66)." Briggs also felt that the experiment was more a test of the effectiveness of varying degrees of review on learning, rather than the necessity to master subordinate skills. Such comments indicate that results obtained in the Merrill study may be due more to methodological error than to the lack of need for mastery of subordinate skills.

In regards to Anderson's statement concerning the weakness of the correlational design of Gagne's studies, Briggs notes that the 1962 study went beyond mere post-experimental correlational analysis to include instructional manipulations of the Ss. Briggs did concede that even this study did have some methodological weaknesses and he recommended an alternative design to test the assumption of cumulative learning and the effects of hierarchical sequencing. The design would require (p. 7):

1. the derivation of an inferred structure or hierarchy by analyzing the objectives of the course;
2. sequencing the units of instructi in accordance with the inferred structure;
3. testing the "optimal" sequence ainst a random or reordered sequence.

Related research. Many studies in recent years have examined the issue of "logical" versus reordered sequencing using the hierarchical approach recommended by Gagne. Of those that have, five (Boston, 1970; Brown, 1970, Caruso & Resnick, 1971; Resnick, Siegel, & Kresh, 1970; and Eustace, 1969) have shown differences favoring the hierarchical sequence, where six (Kane, 1971; Niedermeyer, Brown, & Sulzen, 1969; Oliver, 1971; Pano, 1972; Phillips and Kane, 1972; and Spencer, 1971) show no differences.

Boston (1970) hypothesized that more students following an empirically validated sequence of learning sets master the terminal task than students following a reordered sequence. He also hypothesized that students following a reordered sequence take longer to master the skills. Boston developed and empirically validated a hierarchy and instruction for a concept of "redness". Computed tests comparing the effect of ordered and reordered sequences on time to mastery on each learning set produced a trend of significant results supporting the favorable effects of the hierarchical sequence. Results also showed a larger number of the ordered sequence group mastered each task.

Brown (1970) examined the effects of logical versus scrambled frame order with an improved version of the Number Series program. This program was used to teach 67 high ability eleventh grade students the necessary learning sets prerequisite to a mathematical problem solving task. The logical sequence group performed better than the scrambled frame sequence group relative to time to complete the instructional program, errors made on the program and errors made on a criterion test of complex, problem solving number series skills.

Caruso and Resnick (1971) trained fify-five kindergarten children on matrix tasks involving color and shape. The subjects were divided into four groups: 1) trained in the hypothesized optimal sequence; 2) trained on the same tasks in the reverse sequence; 3) given overtraining on the simplest task followed immediately by training on the most complex task; and 4) trained to criterion (without overtraining) on the simplest task followed immediately by training on the most complex task. More subjects learned the most complex task and they learned in fewer trials, when taught in the optimal order. [illegible] subject learned a higher-order task without also having learned the lower-level one.

A hierarchy of skills for a terminal task involving the complex concept of "noun" was developed by Eustace (1969). It was hypothesized that in a hierarchical task directed toward the learning of a concept, more learning occurs when the levels of the complex material are presented in an ordered sequence. Four experimental groups were given the program in varying degrees of order of the sequence of learning sets. An analysis of variance tests for linear trend using the means of the residual gain scores for each treatment group was significant at the .05 level. The analysis indicated that as the sequence was progressively reordered, mean scores were lower.

Resnick, Siegel, and Kresh (1970) trained twenty-seven kindergarten children on two different double classification matrix tasks. One group of students received instruction in the "optimal" sequence, the other students received instruction in the reversed sequence. Those who learned the tasks in the optimal order learned the more complex task in fewer trials than those who learned the tasks in the reverse order. In addition, students in the reverse order group who did acquire the higher-order skill showed evidence of having acquired the simpler task in the process.

Kane (1971), and Phillips and Kane (1972), reporting on the same study compared seven different sequences of a mathematical task derived by different means. The original sequence was constructed through task analysis and the instruction was empirically validated. Pilot test data was reanalyzed to produce six more sequences. The seven types of sequences were: 1) task analyzed, 2) Guttman scaling, 3) random, 4) item difficulty, 5) correlation, 6) textbook, 7) AAAS method. One hundred and seventy-five grade school children participated in the experiment. Two pretests were given to the students. Pretest I indicated whether the children had the necessary prerequisites; while Pretest II was designed to determine if the students had already mastered the skills to be taught by the instruction. Those learners who passed Pretest I were given Pretest II. The subjects who were judged to have mastered an insignificant number of skills on Pretest II were involved in the experiment. The sequence derived from task analysis was reordered for each method and given to groups of children. The researchers examined the effects of sequence on achievement, retention, transfer and time on task. A one way analysis of variance for each dependent variable showed no overall differences between the various sequences. However, the task analysis sequence did require less time to complete than the correlational sequence. The researchers concluded that no sequence maximally facilitated achievement, retention, and transfer and required less time to complete.

It should be noted that in the Kane (1971) and Phillips and Kane (1972) studies none of the dependent variables were concerned with the number of learners who mastered the terminal task. The importance of the distinction between achievement and mastery is discussed in the following section on methodology.

Niedermeyer, Brown, & Sulzen (1969) used the program, Number Series developed by Gagne and Brown (1961). The program was presented to 64 ninth grade students in logical, scrambled, and reverse orders. While the logical order group was the only sequence group to perform significantly better than the controls on both a test of concepts and a problem solving test, none of the three sequence groups differed from each other on post test performance. Since the program was developed by Gagne it was assumed to be hierarchical. Niedermeyer (1968, p. 307), however, observed, that "The Number Series program must have been developed prior to Gagne's derivation of this knowledge hierarchy since little correspondence could be found between the frames of the learning program and the tasks identified in hierarchy." It would appear that the Niedermeyer, et al. study did not provide a valid test of hierarchical sequencing.

Oliver (1971) developed an index which can be used to determine the degree to which a sequence constructed by the learner is reordered from the logical form of that sequence. This index enabled him to conduct an experiment in which learners were allowed to determine their own sequences and compare the effects of the degree of reordering on learning. The Xenograde Program (Merrill, 1965) was used in the study. Oliver found that not only was learning not progressively impeded by progressively reordered sequences, but that there was no difference of effect between the logical sequence and the set of all reordered sequences. Oliver noted that those students who scored higher on a test of the basic ability of Induction were affected less by the reordering. However, Oliver failed to demonstrate that the instruction used in the experiment was effective prior to the reordering of the sequence.

Panos (1972) developed a hierarchy for a "Martian language" using the task analysis recommended by Gagne (1962). Panos used an empirical procedure also recommended by Gagne (1967) to validate the interdependency of the tasks in the hierarchy. The instructional materials developed by the researcher were shown to be effective in a pilot study where 100% of the students mastered all of the tasks in the hierarchy. The empirical sequence was then compared to two degrees of reordered sequences of learning sets. The hypothesis was that as the empirical sequence is reordered the total learning time increases. A trend just short of the .05 significance level resulted. The lack of significance was attributed to two factors. The analysis of variance used in the study required an equal number of cases in each cell. Because of a low number in one of the cells the total sample was greatly reduced from 66 to 45. Lowering sample size increase the chance of rejecting a true hypothesis (type I error). The second factor affecting the results was that the maximum time limit used for the experiment did not allow the slowest students to achieve mastery. If there is an interaction effect between learning rate and sequence, the elimination of these students may have biased the data.

Spencer (1971) developed a hierarchy and instruction for an algebraic task. The experiment compared the effect of hierarchical, reversed and random sequences on a number of criterion variables. The variables included: time to complete the program; number of errors on program frames; mastery of subordinate competencies; attitude toward the program; mastery of the task; and retention of the task. The results of an analysis of variance indicated difference on only one variable. Those students following a forward sequence made fewer frame errors. No other main effects or interactions with ability were significant. Doubt is cast on the interpretation of the above results by the fact that validation of the instructional materials resulted in only a 67/49 (67% of the learners scored 49% or better) criterion for the terminal task. With such a low level of effectiveness it is doubtful that any statement can be made regarding the relative effect of ordered and re-ordered sequence on learning.

Wodtke, Brown, Sands, & Fredricks (1968) conducted two experiments involving computer administered programs. One program, concerning number bases, was hypothesized to be hierarchical; while the second program, teaching the anatomy of the ear, was described as non-hierarchical. Comparison of within-program performance measures for each program confirmed the hypothesized structures. Whereas a reordering of the number bases program affected the error rate, the reordering of the ear anatomy program did not. The experimenters took this differential effect on error rate to "...support their contention that the ordered version of the modern mathematics program... did contain an ordered conceptual sequence (p. 64)." However the hypotheses that (a) scrambling the sequence of instruction has a detrimental effect on learning a subject matter containing a conceptual hierarchy as opposed to a program containing a relatively discrete set of facts; and (b) that the scrambled sequence is more detrimental to the learning of low aptitude students than high aptitude students, were not supported. There were no achievement differences or Aptitude X Sequence interaction with respect to post-test performance.

A simple box score of the results of the studies reviewed, showing 5 for and 6 against, does not provide emphatic support for the position taken by Gagne. The conflicting results, however, indicate that methodological errors rather than treatment effects may have played a significant role in the research.

Methodological considerations. A number of methodological considerations are relevant to this area of research. One such concern was the topic of a study by Tobias (1972). He contended that lack of support for the positive effects of proper sequencing could be explained by the fact that many of the studies used instructional content with which the learners had prior knowledge, and that the experiments did not take into account this source of variance. Tobias hypothesized that the effect of sequence is modified by subjects' prior familiarity with the content. It was assumed that on material with which subjects had extensive previous experience even a scrambled sequence could facilitate achievement. On unfamiliar content, however, it was assumed that subjects would learn less from a scrambled sequence than from a "regular" sequence. Two programs were developed by Tobias. The familiar content concerned the definition, prevalence, and factors affecting heart disease. The unfamiliar material dealt with the diagnosis of myocardial infarction from the fifth precodial lead of the electrocardiogram. Logical and scrambled versions of both programs were given to 117 educational psychology students. The results indicated that scrambling had a strong effect on achievement for the unfamiliar content but no difference for the familiar material.

The Tobias study indicates the need for any research on sequence to avoid content which is familiar to the students involved in the experiment. Caruso and Resnick (1971), Oliver (1971), Resnick, Siegel and Kresh (1970), and Panos (1972) used content which was invented, thereby eliminating prior knowledge on the part of the learners. Kane (1971) and Phillips and Kane (1972), and Wodtke et al. (1968) used school subject matter but made sure that there was no prior-learning of the material. The other studies reviewed (Boston, 1970; Brown, 1970; Eustace, 1969; Niedermeyer, et al., 1969; and Spencer, 1971) used school subject matter without providing the assurance that there was no prior learning.

A second methodological consideration is one of the empirical validation of the proposed hierarchy. Once a hierarchy is constructed using task analysis (Gagne, 1962) or some other approach, there remains a need to validate the structure empirically. Without making this provision the researcher could not be confident that the structure of the learning sets was indeed a hierarchy. A study which does not use an empirically validated hierarchy compares, in effect, the "researcher's hierarchy" with a scrambled version of the "researcher's hierarchy."

Boston (1970), Brown (1970), and Panos (1972) used a method recommended by Gagne (1962) to validate their hierarchies. Kane (1971) and Phillips and Kane (1972) used a method described by Walbesser (1968), and Eisenberg and Walbesser (1971). Eustace (1969), Niedermeyer, et al. (1969), Oliver (1971), Spencer (1971), and Tobias (1972) did not report an empirical validation of their hierarchies. Caruso and Resnick (1971), and Resnick, Siegel and Kresh (1970) did not validate their hierarchy other than by the experiment itself.

A third methodological concern is one of empirically validating the instruction used in the experiment. The need for effective instruction in a study which examines the effect of sequence is obvious. Without effective instruction there is no "effect" to examine other than the relative lack of achievement.

Despite the importance of effective instruction, four researchers (Brown, 1970; Caruso and Resnick, 1971; Eustace, 1969; Oliver, 1971; Resnick, Siegel and Kresh, 1970; and Tobias, 1972) failed to report the validation of their instruction. Spencer (1971) achieved only a 67/49 criterion for the terminal task in her validation attempt. Boston (1970), Kane (1971) and Phillips and Kane (1972), Panos (1972) and Wodtke et al. (1968) reported the validation of effective instructional materials.

A fourth methodological consideration is whether the sequence was reordered by learning sets or by instructional frames. The theory of Gagne discussed previously contends that it is the mastery of a subordinate learning set which facilitates the learning of a superordinate learning set. No contention is made regarding the relation between instructional frames and learning sets. The reordering of frames has an uncertain effect on the structure of the hierarchy; it also has an uncertain effect on the results obtained. A number of researchers whose work was reviewed (Brown, 1970; Niedermeyer, et al., 1969; Tobias, 1972; and Wodtke et al., 1968) reordered their sequences by program frame rather than by learning sets.

A final consideration is whether mastery of a skill was used as the criterion rather than an achievement test score, or merely time on task. The writings of Bloom (1968) and Carroll (1970) emphasize the need for the use of a mastery criterion. Mastery is defined as the display of a predetermined level of competency of a specific skill on the part of the learner. The use of mastery as a criterion provides a more valid measure of the intended outcome of the instruction: ability to perform the acquired skill. Whereas mastery indicates a difference between knowing (to the degree desired by the instructor) and not knowing, achievement scores create dubious differences between a score of 55 and a score of 60 (for example). Although a mean score of 55 (out of 100) and a mean score of 60 could be statistically significant, it is of doubtful meaning in practical terms. A statistical difference in the number of skills mastered has much practical significance.

Treatment effects on mastery can be measured as the number of learners mastering a particular skill, the number of skills mastered, or the amount of time or number of trials needed by each learner to master a skill. Boston (1970), Caruso and Resnick (1970), Panos (1972), Resnick, Siegel and Kresh (1970) and Spencer (1971) examined the effects of sequence on the mastery of the subject content.

A list of the studies reviewed in this section is shown in Table 1. An "X" indicates that one of the methodological considerations discussed above was taken into account by the author. A question mark indicates that the author did not report on that aspect of the methodology. As can be seen, the only study which accounted for all the listed concerns is Panos (1972). Although the results of his study were not significant, promising trends exhort further study of the topic.

<u>One further methodological consideration</u>. Confusion exists as to the exact effect sequencing has on learning. In one work Gagne (1970a) describes the relationship between superordinate and subordinate skills as this:

Table 1

Methodological Considerations in Reviewed Research on Hierarchical Sequencing

Study	Avoid Prior Knowledge	Validate Hierarchy	Validate Instruction	Reorder by Learning Sets	Mastery Criterion	Results
Boston (1970)		X	X	X	X	Support
Brown (1970)		X	?			Support
Caruso & Resnick (1971)	X		?	X	X	Support
Eustace (1969)		?	?	X		Support
Kane (1971) and Phillips and Kane (1972)	X	X	X	X		No Support
Niedermeyer et al. (1969)						No Support
Oliver (1971)	X	?	?			No Support
Panos (1972)	X	X	X	X	X	Trend
Resnick, et al. (1970)	X		?	X	X	Support
Spencer (1971)		?		X	X	No Support
Tobias (1972)	X	?	?			Support
Wodtke, et al. (1968)	X	X		X		No Support

X = Methodological considerations accounted for
? = Methodological considerations not reported on

> the superordinate capability will be more readily learned (on the average, throughout a group of students) if the subordinate capabilities have been previously acquired and are readily available for recall (p. 239).

In a second statement it is described like this:

> An individual will not be able to learn a particular topic if he has failed to achieve any of the subordinate topics that support it (Gagne, 1963, p. 624).

The question arises: Are subordinate skills facilitators or necessities?

It is the position of the researcher that such a discrepancy is of methodological rather than a theoretical nature. The degree to which intersequencing affects learning depends in part on the degree to which the learner has control of the processing of the instructional materials. Whereas the learner who can control instructional materials can manipulate them in such a way as to compensate for a reordered sequence (although at a cost in time), a learner who does not have control of the materials will not be able to learn if the materials are out of order. In the first case the subordinate skills are facilitators, in the second case they are necessities.

This position requires that a study of the effects of sequencing be divided into two experiments. In one experiment learners are assigned to either an empirically validated or a reordered sequence. Learners in this experiment do not have control over the sequence. Each learner is allowed as much time as needed to complete instructions for each level of the hierarchy but in a predetermined sequence. The variable examined for this experiment would be the number of learners who mastered skills, and how many they mastered.

In the second experiment the learners are initially given either empirically validated or reordered inter and intra-sequences. The students are required to continue working on the materials until they mastered the terminal task. Therefore they are allowed to resequence the materials if they find it necessary. The effect of sequencing on time to mastery would be observed, thus examining the facilitative function of proper sequencing.

Intra-sequencing. The second type of condition that Gagne discusses is that external to the learner. These conditions are stimulus situations surrounding him at the time learning occurs (Gagne, 1970a, p. 302). Most commonly these are the verbal communications that are made to the learner. These communications, or instructional events, function to facilitate learning by "informing him of what he is going to achieve, reminding him of what he already knows, directing his attention and actions, and guiding his thinking along certain lines (1970a, p. 29)." These events correspond to the way the learner internally processes information for learning. This process is described by Gagne (1970a, p. 71) as having four phases: apprehending, acquisition, storage, and retrieval.

External conditions should be arranged in the instructional materials so as to assist the learner in his information processing. Gagne (1970a) lists the events of instruction and their order:

1. Gaining and controlling attention.
2. Informing the learner of expected outcomes.
3. Stimulating recall of relevant prerequisite capabilities.
4. Presenting the stimuli inherent to the learning task.
5. Offering guidance for learning.
6. Providing feedback.
7. Appraising performance.
8. Making provisions for transferability.
9. Insuring retention.

The importance of the order of the instructional events is noted by Gagne:

> Typically, they occur in approximately the order listed, although there is no absolute requirement about this order. As is implied, however, the critical learning occurrence transpires between events 5 and 6 in this list. One could hardly expect, therefore, that events transpiring prior to 5 could be temporally switched with those occurring after 5 (ibid., p. 305).

Related research. If the hypothesis regarding the sequencing of learning sets seemed to hold conflicting support from the research, the above statement would hold almost no support. The large majority of research done during the past decade on logical versus random sequencing of instructional items could be interpreted as addressing itself to the hypothesis that the order of instructional communication makes a difference in learning. Of the notable studies examining the effects of the sequence of instructional frames (Balson, 1971; Buckland, 1968; Cartwright, 1971; Conley, 1968; Hamilton, 1964; Harrington, 1966; Hegedus, 1971; Levin & Baker, 1963; Maier & Jacobs, 1966; Payne, Krathwhol, & Gordon, 1967; Roe, 1962; Rose, Case, & Roe, 1962; Reichert, 1971; and Stolurow, 1964) only three (Conley, 1968; Hegedus, 1971, and Roe, 1962) showed significant differences in performance that favored the logical sequence.

Methodological considerations. Two characteristics are shared by all of the studies cited above.

1. The original intra-sequence (prior to reordering) was "logically" ordered.
2. A criterion other than mastery was used.

The methodological concerns involved in point 2 were discussed earlier in this paper. Point 1 raises a concern unique to this set of studies. In all of the studies the proper sequence was "logically" arranged, yet none of the studies provided an elaboration of the criterion used to determine the "logical order". There was no statement similar to the list of events of instruction provided by Gagne. There was no process described to determine the "logicalness" of the intra-sequence analogous to Gagne's process of task analysis used to determine the dependency of learning tasks.

The doubt that such objective criteria exist is fostered by the statements of proponents of programed instruction. Skinner (1968) in describing the requirements of a teaching machine states:

> A second requirement of a minimal teaching machine also distinguishes it from earlier versions. In acquiring complex behavior the student must pass through a carefully designed sequence of steps, often of considerable length. Each step must be so small that it can always be taken, yet in taking it the student moves somewhat closer to fully competent behavior. The machine must make sure that these steps are taken in a carefully prescribed order (pp. 34-35).

Yet the "carefully designed sequence" and the "carefully prescribed order" are not defined. In Lysaught's (1963) text on programmed learning he states as one of the characteristics of a successful program:

> <u>Logical sequence of small steps</u>. Subject matter, broken down into fragments of information, is arranged in an orderly sequence of growing difficulty so that the student may progress from one point in the program to the next (p. 17).

Again, there lacks an objective description of what constitutes a logical sequence.

The statements cited above are sufficiently vague that a programmer's interpretation would represent a large subjective factor in the program design. Subjective factors minimize the generalizability (and interpretability) of the effects of such programs.

A methodological consideration that this group of studies shares with the group of studies reviewed on sequencing of learning sets is that of program effectiveness. Some of the studies examining the sequencing of communications, notably Payne, <u>et al</u>. (1967), and Levin and Baker (1963), used instructional programs of dubious effectiveness even in the logical form. Payne, <u>et al</u>. showed only a mean score of 37.5 out of a 56 item criterion test for the logical group. In the discussion of their results Levin and Baker conclude:

> Probably the most important limitation of the present study was the failure of the program to teach the material presented thoroughly to most of the subjects, as indicated in post-test performance (p. 143).

The lack of difference between logical and scrambled frame instruction can be explained, in general, by two factors: A lack of empirical validation for the sequence termed "logical"; and the lack of effectiveness in the instruction used.

Inter X Intra-sequence interaction. The theory of Gagne reviewed previously indicated that both inter and intra-sequencing play crucial roles in learning. If either the inter or intra-sequencing of instruction are drastically altered, learning would occur only with great difficulty, if at all. However Gagne does not take a position on the relative importance of inter or intra-sequencing for the learning of intellectual skills.

A study of Miller (1969, 1967) showed the possible inter-relationship between the inter and intra-sequencing of instruction. In his study Miller divided an instructional program into what he termed macro (topics) and micro (frames) order. The results indicated that students using the program where micro order was random but macro order was preserved performed better on criterion measures than those students using a program where the micro order was preserved and the macro order was random. Furthermore, the random micro ordered program took longer than the program which preserved the micro order even though there was no difference between the groups on post-tests.

Conley (1968) reported results for a unit in Nursing which was arranged into four sequences: i.e. logical block-logical item, logical block-random item, random block-logical item, and random block-random item. The students following the logical block-logical item sequence performed reliably better on both achievement and retention tests than learners from other groups. However, a relative effect between logical block-random item and random block-logical item was not indicated as it was in the Miller study.

Neither the theory or research on sequencing provide a clear indication of the expected direction of any interaction between inter and intra-sequence. The fact that the same pattern did not recur in the Conley and Miller studies does not provide a foundation for a hypothesized interaction. Therefore, the investigation of the interaction between inter and intra-sequence is phrased in question form.

The literature reviewed suggests the following questions:

Does the order of the inter-sequence have more of an effect on time spent to master skills than the order of the intra-sequence?

Is there an interaction between inter and intra-sequence?

Learner variables.

Although the cumulative learning theory is very emphatic about the desirability (if not necessity) of learning subordinate learning sets prior to learning of superordinate skills, Gagne (1970a) concedes that there are learners who can "skip over" skills. He does not say that these learners do not acquire the subordinate skill (this would contradict the theory), what he does say is that they "acquire both the subordinate and superordinate skill in one intellectual jump (p. 241)." Gagne refers to the students who can do this as "bright" students.

A number of studies examining hierarchies and sequence have encountered interaction between sequence and some measure of intelligence or ability. Buckland (1968); Levin & Baker (1963); and Stolurow (1964) showed that whereas bright (high IQ) learners did well in either the logically or scrambled sequence, the low IQ students did well only on the logically sequenced program. Oliver (1971) showed a similar interaction between treatment groups and the factored ability test of induction.

Studies by Brown (1970) and Niedermeyer, Brown, and Sulzan (1969) showed no such interaction. The fact that both of these studies used populations with above average mean IQ's (Brown: mean IQ 120; Niedermeyer et al., mean IQ 111) on the same program (Number Series) may partially explain the conflict between their results and those of other studies.

A learner variable termed "learning rate" was used to examine Treatment X Aptitude interactions in the present study. Carroll (1970) defines learning rate as "... amount of skill learned or knowledge gained per unit time (p. 38)." The learning rate task used in this study, topographically similar to the experimental task, was the amount of time used to master a reading comprehension task. The researcher felt that because the learning rate task required the same type of behaviors (i.e. decoding, comprehension, etc.) and was measured in the same units of measure (time in minutes) as the experimental task it would extract more variance than an IQ measure.

Although a learner variable was used in this study primarily to extract error variance, interactions among learning rate and inter and intra-sequence were examined. An answer to the following question is posed: Is there an interaction between either inter or intra-sequence and learning rate?

Hypotheses and questions. The following hypotheses and questions were examined in this study.

With regard to determining the effects of inter-sequencing on learning it was hypothesized that:

In a situation of learner option to reorder the inter-sequence:

H 1 Learners presented with an empirically validated inter-sequence take less time on each level of tasks to acquire the terminal skill than those learners presented with a reordered inter-sequence.

In a situation of no learner option to reorder the inter-sequence:

H 2 Learners following an empirically validated inter-sequence master more skills than those learners following a reordered inter-sequence.

H 3 Of those learners mastering a superordinate skill, more learners also master all relevant subordinate skills than will have not mastered lower skills.

With regard to determining the effect of intra-sequencing on learning, it is hypothesized that:

In a situation of learner control of the intra-sequence:

H 4 Learners presented with an empirically validated intra-sequence take less time on each level of tasks to acquire the terminal skill than those learners presented with an inverted intra-sequence.

With regard to both inter and intra-sequencing, answers to the following questions were sought:

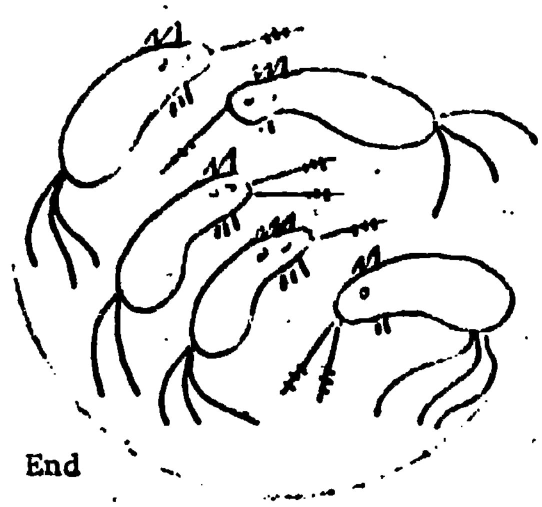
Q 1 Does the order of the inter-sequence have more of an effect on time spent on each level of learning sets to master the terminal skill than the order of the intra-sequence?
Q 2 Is there an interaction between inter and intra-sequence?

With regard to the relationship between individual differences and sequencing, answers to the following questions were sought:

Q 3 Is there an interaction between either inter or intra-sequencing and learning rate?

Procedures

Developing the learning hierarchy. As was discussed previously Tobias (1972) noted that whereas the learning of subject content that was familiar to learners was not affected by reordering, the learning of unfamiliar subject content was susceptible to a reordered sequence. To avoid confounding the effects of prior learning and sequencing, a contrived terminal rule-using task was created. Figure 2 is an example of this task in which the learner must pick the best poison to use on the group of germs.



End

Stop

Underline the best poison

Figure 2. Example of item from test of mastery of the terminal skill of selecting the best poison for a given group of germs. Learners must know which poison will kill all the deadly germs and the fewest helpful germs. At least four correct responses to five items were required for mastery.

In order to solve the terminal task it is necessary for the student to learn to use the rule: The best poison is the one that kills all the deadly germs and the fewest helpful germs. In order to use this rule it is theorized that the learner must also have learned a number or prerequisite skills.

A hierarchy of skills subordinate to the terminal task was derived by a process of task analysis described by Gagne (1962). The analysis was begun by asking what would an individual have to know how to do in order to achieve successful performance of this class of task, assuming he were given only instructions? By examining the terminal task it was determined that it was necessary for the learner to know: what a deadly germ is, what a helpful germ is, which germs End kills, and which germs Stop kills. These concepts compose the second level of the learning hierarchy. A third level of skills requiring the discrimination of the conceptual attributes of "tap", "blik" and "dod" completed the hierarchy.

The hierarchy shown in Figure 3 does not include such concepts as: germ, kill, helpful, deadly, fewest, all, and poison, which were also derived as subordinate skills by task analysis. It was the assumption of the researcher that these skills were universally held by the learners used in the study (8-12 graders).

Pilot study I - validating the inter-sequence. Walbesser (1968) Eisenberg and Walbesser (1971) has developed a procedure for validating the proposed interdependencies of the skills in a learning hierarchy. The procedure begins by teaching the skills in the hierarchy to a number of learners then testing them on their mastery of each skill. This data is used in computing a "consistency ratio". The consistency ratio provides a numerical criterion for testing the dependency among learning sets. The consistency ratio tests the assumption which the constructed hierarchy makes. The assumption is that "if after instruction the student has acquired the terminal behavior of the hypothesis, then he should also have acquired all subordinate behaviors (Eisenber and Walbesser, 1971, p. 248)."

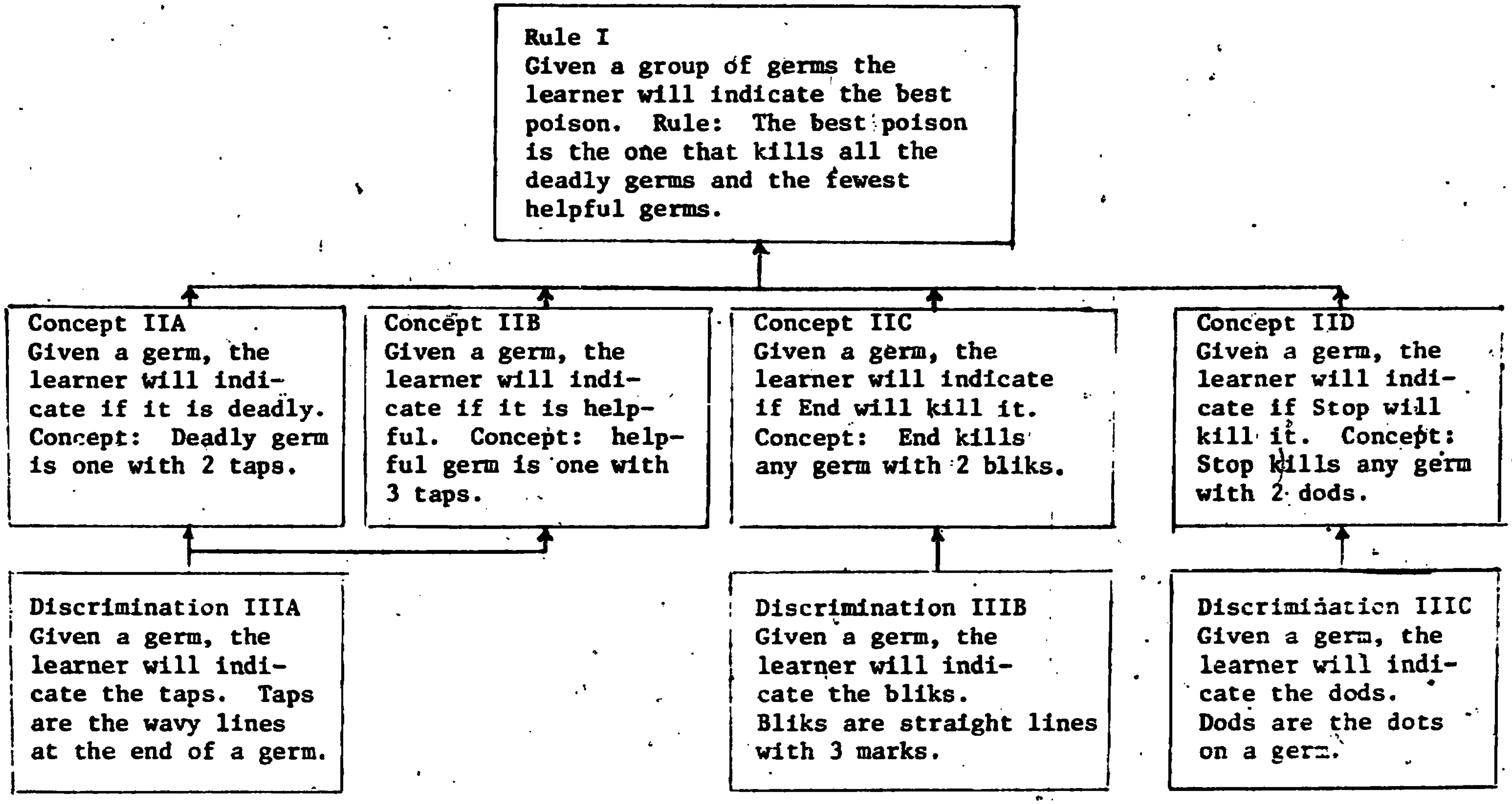
The consistency ratio is the number of learners who mastered both the superordinate skill and all relevant subordinate skills (expressed as the ordered pair: 1,1), divided by the number plus the number of students who mastered the superordinate skill without mastering all the subordinate skills (expressed as the ordered pair: 1,0). The result is the percentage of those learners who ~~mastered~~ superordinate skills who also mastered all relevant subordinate skills. The consistency ratio formula is written as:

$$\frac{f\ (1,1)}{f\ (1,1) + f\ (1,0)}$$

Ratios computed for each superordinate skill and its relevant subordinate skills indicate the degree to which the assumption stated above is valid. The "relevance" of a subordinate skill is indicated by the lines connecting one skill to another in the diagram of a hierarchy. So that the relevant subordinate skills to Skill I in the hierarchy used in this study (see Figure 3) are Skills IIA, IIB, IIC, and IID; the skill subordinate to Skill IIA is Skill IIIA, and so on.

Figure 3

Hierarchy of Learning Sets
Used in the Experiment



However, the consistency ratio would be of little practical value if all of the students in the sample tested mastered all of the skills, both superordinate and subordinate. Although the ratio would be 1.00 (maximum value) for all learning sets, the ratio would become more an indication of the effectiveness of the instruction than a test of the dependency of the skills. A researcher interested in validating a hierarchy is interested in knowing that if a subordinate skill is not mastered, no adjacent subordinate skill will be mastered. For this reason the researcher is as interested in non-mastery as in mastery during the hierarchy validation phase. In order to obtain a distribution of nonmastery among the learners the instruction must be less than thoroughly effective.

The students in Pilot Study I were given instruction for all of the learning sets in the hierarchy. However, in order to get less than 100% effectiveness, the instruction was presented verbally and in a less thorough manner than in the written material used during the second Pilot Study and the experimentation.

Pilot Studies I and II were conducted with 28 available junior high school students (grades 7-9) from the Wayne-Westland summer school program. Fourteen of the students were assigned to Pilot I, and fourteen were assigned to Pilot Study II.

The students in Pilot Study I were presented with the instruction. After the lecture the learners were given a test identical to that which was used in the experiment (see Appendix A). The test consisted of five items for each learning set. The tests were corrected and scored on a mastery basis using an 80% criterion (4 out of 5) for each learning set. The resulting distribution of mastered skills is shown in Table 2. The 1's indicate mastery while the 0's show that mastery was not achieved. Consistency ratios of 1.00, IIA; .93, IIB; .92, IID; and 1.00 for task I were obtained. This indicates that the hypothesized hierarchy was interdependent in the way expected.

Only one case (student #11) out of fourteen was inconsistent with the supposed interdependency. In only three instances out of a total of seventy adjacent subordinate-superordinate pairs (or 4%) was there mastery of a superordinate skill without mastery of the relevant subordinate skill. This percentage is close to the 3% recorded by Gagne & Paradise (1961) in their study of hierarchical learning.

The hierarchy displayed in Figure 3 was accepted as empirically validated. The sequence of learning sets based on this hierarchy was termed the empirically validated inter-sequence. The order of presentation of the instructional lessons for the empirically validated inter-sequence is: IIIA, IIIB, IIIC, IIA, IIB, IIC, IID, and Lesson I is the instruction for the terminal task.

<u>Designing the instructional materials</u>. An instructional lesson was designed by the researcher for each learning set in the hierarchy. The instruction was based on the nine events described by Gagne (1970a) Gagne

Table 2

Results of Pilot Study I: Showing Pass-Fail Pattern on Each Learning Set in the Hierarchy

	Learning Sets							
Student #	IIIA	IIIB	IIIC	IIA	IIB	IIC	IID	I
1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	0
7	1	1	1	1	1	1	1	0
8	1	1	1	1	1	1	1	0
9	1	1	1	1	1	1	1	0
10	1	1	1	1	1	1	1	0
11	0	0	0	0	1	1	1	0*
12	1	1	1	1	1	1	0	0
13	1	1	1	1	1	0	0	0
14	1	1	1	1	1	0	0	0

Consistance Ratios $\frac{(1,1)}{(1,1) + (1,\ )}$

IIA	IIB	IIC	IID	I
1.00	.93	.92	.92	1.00

1 = mastered
0 = not mastered

* contrary to expected pattern

and Rohwer (1969). Reviewing they are:

1. Gaining and controlling attention.
2. Informing the learner of expected outcomes.
3. Stimulating recall of relevant prerequisite capabilities.
4. Presenting the stimuli inherent to the learning task.
5. Offering guidance for learning.
6. Providing feedback.
7. Appraising performance.
8. Making provisions for transferability.
9. Insuring retention.

The instruction was in the form of a small frame, overtly constructed or multiple choice responding, linear program. The first frame of each lesson presented a picture of a germ or a group of germs that represented the class of stimuli for the task of the particular lesson, and directed the learner's attention to the portion of the example which was relevant to the concept or rule being taught. Event 2 was a statement of the behavioral objective for the lesson.

Because some students in the experiment would be receiving the instruction in a reordered inter-sequence it was a fear of the researcher that an explicit review of prerequisite skills would serve to correct the order by teaching missing skills. In other words a review of Task IA in the instruction for Task IIA would serve to teach Skill IA to the learner who was receiving IIA first in a reordered inter-sequence. Such an occurrence would defeat the purpose of the experiment. Therefore explicit review of relevant prerequisite capabilities (Event 3) was not included in the design of the lessons for the superordinate skills. However, subtle cues were employed to evoke recall of the skill if it had been learned from a previous lesson.

Event 4 was accomplished by presenting an example of items similar to those that would be encountered in the test. Neither response or feedback was required for this frame. For Event 5 the attribute, concept or rule was stated, accompanied by an example of its use. A single test item with feedback functioned as Event 6, followed by a series of items similar to those on the test, and appropriate feedback (Event 7). Transferability was provided for (Event 8) by indicating how the newly learned skill would be used in the following lessons.

Spaced practice was used to insure retention in Event 9. The spaced practice was cumulative as the learner progressed through the lessons for a particular level. Practice for previously learned skills was included only in lessons for skills on the same level of the hierarchy and not in lessons for a superordinate level. Practice for subordinate skills was not included in the higher-order lessons in order to avoid teaching these skills to students who followed a reordered sequence.

The resulting instruction was printed and cut into 8 1/2" x 2 1/2" strips. The pages of the instructional lessons for each learning set were stapled into three booklets, one for each level. Book I included instruction for Skills IIIA, IIIB, and IIIC. Book II covered sets IIA, IIB, IIC, and IID. The terminal skill (I) was the only lesson in Book III.

Pilot study II - validation of the inter-sequence. Two more ratios were developed by Walbesser (1968), Eisenberg and Walbesser, (1971) to measure the effectiveness of the instruction for each learning set in a hierarchy. The adequacy ratio is the number of students who master both superordinate and subordinate skills (1,1), divided by that number plus those students who master the subordinate skills but not the superordinate (0,1). The formula is:

$$\frac{f\ (1,1)}{f\ (1,1) + f\ (0,1)}$$

This tests the degree of effectiveness of the lesson for those students who have the prerequisite skills.

The completeness ratio is the number of students who mastered both subordinate and superordinate skill (1,1) divided by that number plus those who mastered neither the superordinate nor subordinate skills (0,0). The formula is:

$$\frac{f\ (1,1)}{f\ (1,1) + f\ (0,0)}$$

This ratio gives an indication of the cumulation of non-learners at a specific point in the hierarchy. The range for both ratios is 0.0 to 1.0, a higher number indicating a higher degree of effectiveness.

Fourteen junior high students remaining from Pilot Study I received the instructional material in the valid inter-sequence and hypothesized intra-sequence. All students began with Book I at the same time. They were allowed as much time as they felt they needed to complete the material. As each student finished Book I he returned it to the monitor who then gave him Book II. As each student finished Book II they received Book III; and when they finished Book III they took the test used in Pilot Study I and the experiments.

The tests were scored as they were in Pilot Study I. The distribution of mastered skills is shown in Table 3. Adequacy ratios of .86, IIA; 1.00, IIB; .86, IIC; .71, IID; and .86 for task I were obtained. The completeness ratios were: 1.00, IIA; 1.00, IIB;, 1.00, IIC; 1.00, IID, and .67 for I. Note also that there was only one instance (*) where a superordinate skill was mastered without mastering all relevant subordinate skills.

Population. The experimental population consisted of 99 senior high school (grades 10-12) students attending Wayne-Westland, Michigan summer school session. The students were assigned to the two experiments by classroom rather than by random assignment, and therefore each group was considered a separate population for the purpose of the experiments and statistical tests.

Table 3

Results of Pilot Study II: Showing Pass-Fail Pattern on Each Learning Set in the Hierarchy and Effectiveness Analysis

Student #	IIIA	IIIB	IIIC	IIA	IIB	IIC	IID	I
	Learning Sets							
1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1
8	1	1	1	0	1	1	1	1 *
9	1	1	1	1	1	1	1	0
10	1	1	1	0	1	1	1	0
11	1	1	1	1	1	1	0	0
12	1	1	1	1	1	1	0	0
13	1	1	1	1	1	0	0	0
14	1	1	1	1	1	0	0	0

Adequacy Ratios

$$\frac{(1, 1)}{(1, 1)+(0, 1)}$$

IIA	IIB	IIC	IID	I
.86	1.00	.86	.71	.88

Completness Ratios

$$\frac{(1, 1)}{(1, 1)+(0, 0)}$$

IIA	IIB	IIC	IID	I
1.00	1.00	1.00	1.00	.67

1 = mastered
0 = not mastered

* contrary to expected pattern

Experimental design. The design for Experiment A was a 2 X 2 X 2 complete factorial design. For the purpose of control and examination of interactions, learners in Experiment A were divided into high and low learning rate groups based on a time-to-mastery reading comprehension task. Learners were then randomly assigned to either empirical or reordered inter and intra-sequence groups, thus comprising the matrix shown in Figure 4.

The instruction for the learning sets was reordered by interchanging Book I (instruction for Level II) with Book II (instruction for Level III). Those students who followed a reordered intersequence received the books in this order: II I III. Learners receiving this sequence would be in a position of having to learn a superordinate skill without first learning the skills subordinate to it (an accomplishment not likely to happen according to the theory). The learners receiving the empirically validated sequence receive instruction for the subordinate skills followed by instruction for the superordinate skills (Book I, Book II, Book III).

The events of the lessons were reordered for intra-sequence by inverting the order of the frames or sets of frames which corresponded to Gagne's events of instruction. The order of the events for those students who received the inverted intra-sequence was:

9 8 7 5 6 4 3 2 1

The order was inverted around Events 5 and 6 as suggested by Gagne (1970a, p. 305). Hypotheses 1 and 4 contended that learners following either a reordered inter or intra-sequence would require more time to achieve mastery of the terminal task than those students who follow an empirically validated sequence.

Inter-sequence only was manipulated in Experiment B. A modification of the post-test only control group design (Campbell & Stanley, 1963) was used for the second experiment. Two groups (empirically validated versus reordered inter-sequencing) were compared on post-tests at the end of each level of instruction. The pictorial representation of the design is this:

$$\begin{matrix} R & X_{e1} & O_1 & X_{e2} & O_2 & X_{e3} & O_3 \\ R & X_{r1} & O_1 & X_{r2} & O_2 & X_{r3} & O_3 \end{matrix}$$

Students were randomly assigned (R) to each group. Instructional lessons were received in either an empirically validated (Xe) or reordered (Xr) inter-sequence. Reordering for Experiment B was the same as for Experiment A. After each lesson the learner received a test (o); all tests were identical.

Testing Session. The first session of the experiment was a two hour testing session held on a Tuesday morning in place of regularly scheduled classes. The testing was done in each of four classrooms. The researcher did not have the names of the students prior to the testing session, therefore random assignment to the classrooms would have been difficult. Students were assigned to the classrooms by the class that they came from. Members of all treatment groups were in each of the classrooms.

Figure 4

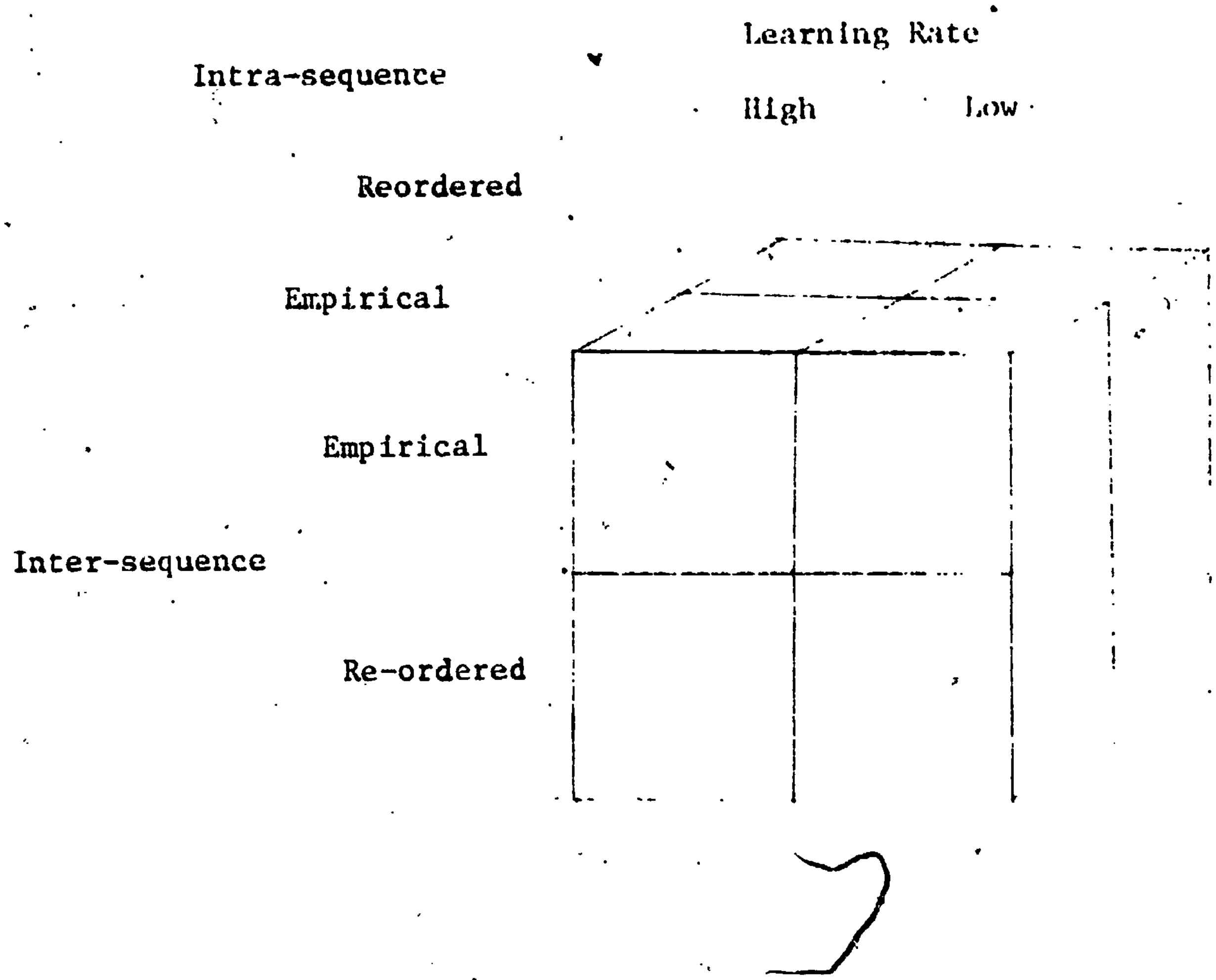


Figure 4. 2 X 2 X 2 matrix of the design used in Experiment B, showing the factors.

Identical directions were given to the monitors and identical directions were read to the students. Procedures were followed in all of the rooms that would minimize disruption and cheating during the session.

During the testing session the learners receive the Learning Rate Test and a set of factored abilities tests. The Learning Rate Test was used to block learners for Experiment A. The ability tests of memory, perception, and induction were used for puposes not reported on in this paper.

Experimental session. The instructional materials were administered two days after the testing session, again in place of regularly scheduled classes. Experiment A was held in four classrooms and Experiment B was held in one other.

In Experiment A monitors for each room were given the same directions. Identical directions were given to each class involved by means of duplicated audio tape recordings. When Book I had been passed out the students were told to begin, and the time was recorded. Although different clocks were used in different rooms, one clock was consistently used in each.

The students were self paced and as each student completed Book I the time was recorded on the cover sheet of his book, and he was given Test I. When Test I was completed, the time was recorded on Book II and instruction began. Test II was taken upon the completion of Book II and Book III and Test III followed. The time was recorded each time a book was requested and returned.

At the time a student turned in Test III the items for the terminal task were checked and if mastery was not scored (criterion of 80%) the student was allowed to review any or all books (one at a time) and retake the test. If mastery was again not scored, the opportunity to review the materials was repeated. This process was continued until mastery on the terminal task was scored. At no time were the students told by the monitors what the correct responses were, or which of their responses were incorrect. As the student mastered the terminal task they were directed to return to their classrooms, so that correct responses could not be passed to other students.

The experiment ended when the last student mastered the terminal task. In no case was a student still working when the two hours that were allotted lapsed.

Experiment B began when the monitor played a tape to the students. The tape introduced the session to the learners and told them what they were to do. When the tape was finished, Book I was passed out and the students were told to begin. The students were self paced in both experiments, though none of the students used the two hours maximum which was allotted for the experiment.

As each of the students completed Book I he turned it in and received Test I. When that was completed he was given Book II. When Book II was finished Test II was taken. Test II was followed by Book III, and that was in turn followed by Test III. As each student finished Test III he was allowed to return to his classroom.

None of the students were allowed to look at any previously taken materials. None of the tests were checked during the experiment, and no feedback was given to the students as to the correctness of their responses on the test. The experiment was terminated when the last student completed Test III.

Results

Experiment A. In Experiment A the effects of both inter and intra-sequencing were measured. The two learning rate groups were each divided into four groups corresponding to the eight cells of the experimental design. Of the 84 students who participated in the testing session, 67 chose to participate in the instructional session. Of those, ten elected to drop out and return to their classrooms before they mastered the terminal task. In addition two more learners were dropped by the researcher, one because he did not receive one of his books, another because the final test was accepted as correct when it was not. A total of 55 students were used in the analysis of the data for Experiment A. Attrition did not seem to be random and may have biases the results.

The dependent variables were the total time spent on the instruction for each level of learning sets to master the terminal task. The grand mean for the time spent on instruction for Level III was 7.127 minutes, and 16.64 minutes for Level II, and 17.64 minutes for Level I. The grand means and standard deviations are shown in Table 8, as well as the means and standard deviations for the inter-sequence, intra-sequence and learning rate groups. The means and standard deviations for each cell of the matrix is displayed in Table 5.

The learners in Experiment A were required to continue reviewing the instructional material until they mastered the terminal task. Each learner received the three books at least once, and after they followed their assigned sequences they were allowed to choose any of the books as often as they needed in order to master the terminal skill. Although they took the same test for each attempt at mastery, no indication of which items were correct or incorrect was given to the learners. Table 6 shows by number the order of books that each student took before mastering the terminal task. As can be seen the initial pattern for those students that received the empirically validated sequence is 1 2 3; while the initial pattern of those students who received a reordered sequence is 2 1 3. The empirical sequence group looked at an average of 4.1 books (the initial three, and review of approximately one of the three books); while 41.2% of the students in this group required no review (they mastered the terminal skill after taking the initial three books only). Students following a reordered sequence required an average of 4.0 books, and 63.6% of them needed no review.

Table

Mean Learning Time in Minutes for
Each Factor on Instruction for
Each Level of the Hierarchy

Factor	Level I	Level II	Level III
Inter-sequence			
Empirical	7.364	16.45	18.70
Reordered	6.773	16.91	16.05
Intra-sequence			
Empirical	7.500	17.57	17.57
Inverted	6.741	15.67	17.70
Learning Rate			
High	6.640	14.64	14.92
Low	7.533	18.30	19.90
Grand Means	7.127	16.64	17.64

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Sequence Inter Intra		Empirical Empirical	Empirical Reordered	Reordered Empirical	Reordered Reordered	Totals
High Learning Rate	Level III	n= 9 M 6.556 SD 2.698	n= 5 M 7.200 SD 3.194	n= 4 M 7.250 SD 3.862	n= 7 M 6.000 SD 5.066	n=25 M 6.640 SD 3.558
	Level II	M 15.778 SD 8.814	M 15.200 SD 5.675	M 14.750 SD 5.560	M 12.714 SD 2.928	M 14.64 SD 6.238
	Level I	M 15.222 SD 8.243	M 19.600 SD 8.243	M 11.000 SD 8.735	M 13.429 SD 5.255	M 14.92 SD 7.325
Low Learning Rate	Level III	n= 9 M 8.667 SD 3.240	n=10 M 7.000 SD 2.539	n= 6 M 7.333 SD 3.266	n= 5 M 6.800 SD 2.387	n=30 M 7.533 SD 2.849
	Level II	M 17.778 SD 4.994	M 16.500 SD 3.894	M 21.833 SD 6.969	M 18.600 SD 7.987	M 18.30 SD 5.706
	Level I	M 21.556 SD 6.966	M 18.800 SD 7.658	M 19.500 SD 7.259	M 19.600 SD 5.941	M 19.90 SD 6.855
Totals	Level III	n=18 M 7.611 SD 3.090	n=15 M 7.067 SD 2.658	n=10 M 7.300 SD 3.302	n=12 M 6.333 SD 4.030	n=55 M 7.127 SD 3.192
	Level II	M 16.78 SD 7.026	M 16.07 SD 4.399	M 19.00 SD 7.118	M 15.17 SD 6.088	M 16.64 SD 6.178
	Level I	M 18.39 SD 8.089	M 19.07 SD 7.741	M 16.10 SD 7.622	M 16.00 SD 6.164	M 17.64 SD 7.440

Table 5. Means and Standard Deviations of Time in Minutes on Each Level of Instruction for Inter and Intra Sequence and Learning Rate

Table 6

Experiment B
Order and Number of Books Taken

Student #	Books						
Empirical Sequence							
1	1	1	2	3			
2	1	2	3	3			
3	1	1	2	3	3	3	2
4	1	2	3	3	2	1	
5	1	2	3				
6	1	2	3				
7	1	2	3	3			
8	1	2	3	1	2	2	
9	1	2	3	2			
10	1	2	3				
11	1	2	3	2			
12	1	2	3				
13	1	1	2	3			
14	1	2	3				
15	1	2	3				
16	1	2	3	2	3		
17	1	2	3	2			
18	1	2	3	2			
19	1	2	3	3			
20	1	2	3				
21	1	2	3				
22	1	2	3	1			
23	1	2	3	2	1	2	
24	1	2	3	2	2		
25	1	2	3				
26	1	2	3	3	3	3	1
27	1	2	3				
28	1	2	3				
29	1	2	3	1	3	2	2
30	1	2	3	3			
31	1	2	3				
32	1	2	3				
33	1	2	3	3			

(continued)

Table 6

(continued)

Student #	Books								
Reordered Sequence									
34	2	1	3	1					
35	2	1	3	1	1				
36	2	1	3	3	3	3	1	2	3
37	2	1	3						
38	2	1	3	3					
39	2	1	3						
40	2	1	3	3	1	2	2		
41	2	1	3						
42	2	1	3						
43	2	1	3						
44	2	1	3	2	1				
45	2	1	3	2	1	3			
46	2	1	3						
47	2	1	3						
48	2	1	3						
49	2	1	3						
50	2	1	3	1	2	3			
51	2	1	3						
52	2	1	3						
53	2	1	3						
54	2	1	3						
55	2	1	3						

Empirical Sequence

Mean Number of Books	4.1
% 1 2 3 Only	41/2

Reordered Sequence

Mean Number of Books	4.0
% 2 1 3 Only	63.6

Experiment B. In Experiment B the students were given empirically validated or reordered sequences according to the group to which they were randomly assigned. Out of a population of 15 who participated in the testing session, only 10 selected to participate in the second session. Of the ten students who were involved in both sessions, five received the empirically validated sequence and five received the reordered sequence. Each student was tested at the end of the instruction for each level of the hierarchy. The tests were scored for mastery of each task using a 80% criterion (4 out of 5 items correct). The students were not allowed to review previously received booklets at any time.

Each learner took Test I after completing the first book he received. Therefore the students following the empirically validated sequence took the test after instruction for the skills in Level III (IIIA, IIIB, and IIIC) of the hierarchy, while the students who followed the reordered sequence took Test I after receiving instructions for the skills in Level II (IIA, IIB, IIC, and IID) of the hierarchy. The pass-fail pattern for each learning set for Test 1 is shown in Table 7. All of the five students following the empirically validated sequence mastered the three skills taught in Book I. Additional skills were mastered by several members of che group. The five students following the reordered sequence mastered all but four of the skills taught by the lessons they received. Only four subordinate skills were mastered by this group.

Table 7 also indicates that four of the students appear to have mastered the terminal skill. It is dubious that this was so, at least for the three learners in the empirical group, because they did not repeat their mastery performance on Test II. Use of constructed responses rather than multiple choice would have virtually eliminated any chance display of mastery such as this.

The Book II received by students following an empirically validated inter-sequence consisted of instruction for Sets IIA, IIB, IIC, and IID. The Book II received by students following a reordered inter-sequence covered Skill IIIA, IIIB, and IIIC. As each student finished Book II he took Test 2. The pass-fail pattern for the skills of the hierarchy for Test 2 are shown in Table 8. The five students following the empirical sequence mastered all but one of the skills for which they had received instruction at this point. Of the five students receiving the reordered sequence, only two failed to learn all of the skills taught in the first two books.

Students from both the empirical and reordered sequence groups received instruction for the terminal skill (Learning Set I) in Book III. After each student finished Book III he took Test III. At the time a student took Test III, he had received instruction for all subordinate learning sets regardless of which group he was assigned to. The pass-fail pattern for the learning sets for Test III are shown in Table 9. All but six skills were mastered by the empirical sequence group. Two students for the empirical sequence group mastered all the

Table 7

Results of Experiment A, Test 1, Showing Pass-Fail Pattern on Each Learning Set in the Hierarchy After First Instructional Book

Student #	IIIA	IIIB	IIIC	IIA	IIB	IIC	IID	I
				Learning Sets				
Empirical Sequence								
1	1	1	1	0	0	0	0	0
2	1	1	1	0	0	0	0	0
3	1	1	1	0	1	0	1	1*
4	1	1	1	1	0	0	0	1*
5	1	1	1	0	0	0	0	1*
Reordered Sequence								
6	1	1	1	1	1	1	1	0
7	0	0	0	0	1	1	0	0*
8	0	0	0	1	1	1	1	0*
9	1	0	0	1	1	0	1	0*
10	0	0	0	1	1	1	0	1*

1 = mastered
0 = not mastered

* Students who learned superordinate skills without learning all relevant subordinate skills.

Table 8

Results of Experiment A, Test 2: Showing Pass-Fail Pattern on Each Learning Set in the Hierarchy After Second Instruction Book

Student #	IIIA	IIIB	IIIC	IIA	IIB	IIC	IID	I
	Learning Sets							
Empirical Sequence								
1	1	1	1	1	1	1	1	0
2	1	1	1	1	1	1	1	0
3	1	1	1	1	1	1	1	0
4	1	1	1	1	1	1	1	0
5	1	1	1	0	1	1	1	0*
Reordered Sequence								
6	1	1	1	1	1	1	1	0
7	1	0	1	0	1	0	1	0
8	1	1	1	1	1	1	1	0
9	1	1	1	1	1	1	1	0
10	1	1	1	1	1	1	0	1

1 = mastered
0 = not mastered

* Student who learned superordinate skills without learning all relevent subordinate skills

Table 9

Results of Experiment A, Test 3: Showing Pass-Fail Pattern on Each Learning Set in the Hierarchy After Third Instructional Book

Student #	IIIA	IIIB	IIIC	IIA	IIB	IIC	IID	I
Empirical Sequence								
1	1	1	1	1	1	0	1	0
2	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	0
5	1	1	1	0	1	0	1	0
Reordered Sequence								
6	1	1	1	1	1	1	1	1
7	1	0	0	1	1	1	1	1*
8	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	0
10	1	1	1	0	1	1	0	1*

Adequacy Ratio $\frac{(1,1)}{(1,1)+(0,1)}$

IIA	IIB	IIC	IID	I
.80	1.00	.77	.90	.71

Completness Ratio $\frac{(1,1)}{(1,1)+(0,0)}$

IIA	IIB	IIC	IID	I
1.00	1.00	1.00	1.00	.71

1 = mastered
0 = not mastered

* Students who learned superordinate skills without learning all relevant subordinate skills.

Table 10

Individual and Group Mean Error Rate in Percent on Instruction for Each Level of the Hierarchy

Student #	Level III	Level II	Level I
	Empirical	Sequence	
1	00%	19%	05%
2	00	00	11
3	00	00	05
4	00	00	21
5	00	00	16
Means	00%	04%	12%
	Reordered	Sequence	
6	00%	06%	00%
7	09	42	68
8	00	10	16
9	(Did not actively respond)		
10	00	39	29
Means	02%	24%	46%

skills, and two students following the reordered sequence mastered all of the skills. Adequacy ratios of .80, IIA; 1.00, IIB; .77, IIC; .90, IID; and .71, I; and completeness ratios of 1.00, IIA; 1.00, IIB; 1.00, IIC; 1.00, IID; and .71, I, computed form the data from Test III show that the instruction under both sequences was effective and complete to the extent indicated.

Error rates were computed for both groups on instruction for each level of learning sets. Individual rates and mean rates are shown in Table 10. Contrary to direction, one of the students following the reordered sequence did not overtly respond. Examination of the rates indicates that the learners in the reordered inter-sequence group had difficulty learning the skills on levels II and I.

Hypothesis 1. Learners presented with an empitically validated inter-sequence take less time on each level of tasks to acquire the terminal skill than those learners presented with a reordered inter-sequence.

Time taken on each level of instruction was examined in Experiment A in preference to total time. A multiple measure avoids an "averaging effect" which makes no distinction between learners who spend differing amounts of time on different levels if their overall times are the same.

A measurement on each level provides a more accurate description of how the learning occured.

Because the multiple measures were taken on the same learners (and therefore not independent), a statistical comparison between the empirical and reordered inter-sequence groups required a multivariate analysis of variance (MANOVA). Table 11 indicates the multivariate F ratio (Wilk's Lambda) of the within groups variance divided by the total variance, as well as the degrees of freedom, and the probability of occurrence of the null hypothesis. Univariate tests for each level are also displayed. The tests show no difference between the amount of time used by the two groups.

Table 11

Multi and Univariate Analysis
of Variance for the Factor
of Inter-sequence

F	DF	p
1.037	3.45	0.385

Table 11 (con.)

	Univariate F		
Level	F	DF	p
III	0.420	1, 47	0.520
II	0.074	1, 47	0.787
I	1.799	1, 47	0.186

A preliminary test of equality of dispersions assumption (analogous to the homogeneity of variance assumption for MANOVA) was not included in the computer program which computed the test means. However, as Cooley and Lohnes (1971) indicate, "Many research workers prefer to ignore the issue of homogeneity of group dispersions on the grounds that the test of H2 (test of the difference of means) is probably fairly robust under departures from its assumptions (p. 228)."

A lack of effect on the learning of the groups following the different sequences is also noted in Table 6. The number and order of books taken by each learner is displayed in this table. As mentioned previously, if the learner did not master the terminal task upon completion of Book 3, he was required to continue selecting books to review until he could master the terminal task. The results indicate that there is essentially no difference in the mean number of books taken by the student of the two groups: 4.1 books for the empirical sequence, and 4.0 books for the reordered sequence. Also of note is the fact that whereas 41.2% of the students receiving an empirical sequence mastered the terminal task without review, 63.6% of the students receiving a reordered sequence did so.

<u>Hypothesis 2</u>. Learners following an empirically validated inter-sequence master more skills than those learners following a reordered inter-sequence.

The distribution of skills, mastered and non-mastered for empirical and reordered sequence groups in Experiment B, is shown in Table 12. This data was collected after the instruction was completed and it indicates the total number of skills that were mastered by each student. Of the 40 skills which the students of each group received instruction for, 34 were mastered by the students following an empirical sequence, while 35 were mastered by the students following a reordered sequence. A chi-square analysis of the number of mastered skills is also shown in Table 12. A chi-square value of .104 indicates no difference between the number of skills mastered by the two groups.

<u>Hypothesis 3</u>. Of those learners mastering a superordinate skill, more learners also mastered all relevant subordinate skills than will not have mastered lower skills.

For each test of skills at each level in the hierarchy all students mastering any superordinate skill were examined to see if they also mastered all subordinate skills relevant to the superordinate skill. (See Tables 7, 8, and 9) Of the students who mastered superordinate skills, Table 13 shows the number who did or did not also master all relevant subordinate skills for each test. Frequencies for Test 1 do

Table 12

Number of Skills Mastered or Not Mastered for Learners in Each Inter-sequence Group in Experiment B

	Mastered	Not Mastered	Totals
Empirical Sequence	34	6	40
Reordered Sequence	35	5	40
Totals	69	11	80

Chi square = 0.104

not include the dubious mastery of the terminal task by some learners. Corrected chi-square values are also displayed for each distribution.

Table 13

Number of Learners Mastering or Not Mastering Subordinate Skills Who Mastered Superordinate Skills for Each Test in Experiment B

	Mastered All Subordinate Skills	Did Not Master All Subordinate Skills	df	Corrected x^2
Test 1	2	4	1	0.16
Test 2	9	1	1	4.90*
Test 3	8	2	1	1.85

* $p < .05$

The chi-square value computed for the distribution resulting from Test 2 was significant at the .05 level indicating that at this point in the learning process more learners mastering superordinate skills also mastered all relevant subordinate skills. The distribution from Tests 1 and 3, however, were not significant.

It must be noted that of the three points in the learning process (Test 1, Test 2, Test 3) that Test 1 was the crucial test of Hypothesis 3. At the point Test 1 was given, learners from the empirical group had received instruction for Level III skills only, while learners from the reordered group had had instruction for Level II skills only. By the time learners of both groups had taken Test 2 and 3 they had received instruction for all subordinate skills (although in different orders, of course). Therefore while Test 1 shows whether or not mastery of subordinate skills is essential, Test 2 and 3 could just as easily be merely testing the accumulation of skills. As indicated in Table 14, the distribution for Test 1 fails to support the hypothesis.

Hypothesis 4. Learners presented with an empirically validated intra-sequence take less time on each level of tasks to acquire the terminal skill than those learners presented with an inverted intra-sequence.

The multivariate test of significance is shown in Table 14 on data collected from Experiment A. A multivariate F Ratio of 0.666 was not significant. Univariate tests for each level also show a lack of differences. There was no difference in the amount of time used by students following empirical or reordered intra-sequences to master the terminal task.

Table 14

Multi and Univariate Analysis
of Variance for the Factor
of Intra-sequence

F	DF	p
0.666	3, 45	0.577

Univariate F Tests

Level	F	DF	p
III	0.632	1, 47	0.431
II	1.424	1, 47	0.239
I	0.036	1, 47	0.851

Question 1. Does the order of the inter-sequence have more of an effect on time spent on each level of learning set to master the terminal skill than the order of the intra-sequence?

Since the ordering of neither the inter nor intra-sequence had a differential effect on the learning time of the students, no statement can be made about the relative effectiveness of these two main effects. Question 1 is moot for this experiment.

Question 2. Is there an interaction between inter and intra-sequence?

The test of significance of the Inter-sequence X Intra-sequence interaction is shown in Table 15. No interaction resulted from either multivariate or univariate tests. Assignment to empirical or reordered inter-sequence had no effect on time for either empirical or inverted intra-sequence, and vice versa.

Table 15

Multi and Univariate Analysis
of Variance for the Interaction
Inter X Intra-sequence.

F	DF	p
0.179	3, 47	0.910

Univariate F Tests

Level	F	DF	p
III	0.004	1, 47	0.949
II	0.298	1, 47	0.588
I	0.053	1, 47	0.818

Question 3. Is there an interaction between either Inter or Intra-sequencing and learning rate?

An examination of the main effect of learning rate on time to mastery of the terminal task, shown in Table 16, indicates a probability of less than .064 for the multivariate test. Univariate tests for Levels II and I were significant beyond the .05 level. Although high learning rate students took less time on Levels II and I than low learning rate students, there was no difference between them on the time spent on Level III instruction.

Table 16

Multi and Univariate Analysis of Vaiance for the Factor of Learning Rate

F	DF	p
2.595	3, 45	0.064

Univariate F Tests

Level	F	DF	p
III	0.944	1, 47	0.336
II	5.234	1, 47	0.027
I	6.066	1, 47	0.017

Tests of significance for the following are shown in Table 17. Intersequence X Learning Rate, Intra-sequence X Learning Rate, and Inter-sequence X Intra-sequence X Learning Rate. None of the interactions were significant by either multivariate or univariate tests.

Discussion

Concerning the effects of inter-sequencing. Commenting on previous studies on sequencing, Briggs (1968) states that:

> ...positive results, showing that mastery of an early skill component does transfer to learning a later one is a supporting argument to the notion of hierarchical structure when viewed in terms of all the kinds of evidence Gagne presents. On the other hand, negative findings, e.g., failure to find transfer from one subtask to another, may simply mean that that task was not hierarchical (p. 66).

Table 17

Multi and Univariate Analysis of Variance for the Remaining Interactions

Inter-sequence X Learning Rate

F	DF	p
0.945	3, 45	0.427

Univariate F Tests

Level	F	DF	p
III	0.122	1, 47	0.728
II	1.992	1, 47	0.172
II	0.945	1, 47	0.336

Intra-sequence X Learning Rate

F	DF	p
0.652	3, 45	0.586

Univariate F Tests

Level	F	DF	p
III	0.342	1, 47	0.562
II	0.072	1, 47	0.790
II	1.678	1, 47	0.202

Inter X Intra-sequence X Learning Rate

F	DF	p
0.408	3, 45	0.748

Univariate F Tests

Level	F	DF	p
III	0.652	1, 47	0.424
II	0.005	1, 47	0.943
I	0.349	1, 47	0.557

Such an argument presumes that the theory concerning hierarchical learning is correct and that negative results of an experiment designed to test the theory merely indicate that such a test is invalid. This would put the researcher in the untenable position of accepting results only if they supported his hypothesis. The scientific approach is to presume against the theory until it is supported by empirical evidence. A well constructed experiment should be presumed to be a valid test of the theory, subject to replication. The researcher does not claim immunity from methodological error but is of the position that negative results should not be rejected on face value. It remains, therefore, to explain why an inter-sequence based on task analysis and empirically validated according to Walbesser's technique did not affect learning differently than a reordered sequence.

A source of obvious concern is the learners in Experiment B (see Table 7) who followed a reordered inter-sequence and mastered Level II skills without showing mastery of Level III skills (students #7, 8, 9, and 10). The position of a learner receiving instruction on concept rule, tests and feedback on examples and non-examples, but not having the attributes identified.

Bruner, Goodnow & Austin (1957) describe two main strategies for attribute identification. In the scanning strategy the subject will test a single hypothesis at a time until he hits the correct concept. When using the focusing strategy the subject finds a positive instance to use as a focus, then makes a sequence of choices, each of which alters an attribute value to test whether the change yields a positive or negative instance.

When asked how he mastered Task IID Student #9 said, "By the process of elimination. By seeing them (examples and corrected responses) over and over I could guess what was right." From the student's comment it sounds as if he was using the focusing strategy described by Bruner et al. This may have been the case with Student #6 who mastered the concept and identified the attributes, but Students #7, 8, 9, and 10 mastered the concept without identifying the relevant attributes.

Whaley and Malott (1971) refer to the case where instances can be correctly identified while defining attributes cannot be described as "intuitive concepts." They illustrate how such concepts can be learned by referring to an experiment by Hernstein and Loveland (1964). In this experiment a straight-forward conditioning procedure was used to teach pigeons the complex concept of "man", involving discriminative stimulus variety in sex, race, age, and pictorial position and background. The stimulus generalization applied as well to instances not used in the original conditioning. The procedure used by Hernstein and Loveland parallels that used in the instructional materials of this study.

It appears that by being conditioned with examples and non-examples of the concept some learners were able to show mastery of the concept without showing mastery of its defining attributes. However, it is doubtful if the instruction gave the concept rule without any accompanying examples, that the learners would have been able to correctly perform on the test item without first passing the subordinate attributes. It becomes apparent that the hierarchical dependence between sets interacts with the form in which information is presented in the instruction. What is hierarchical using one form of instruction does not seem to be so when using another form.

Since this experiment was not designed to test the interaction between forms of instruction and hierarchical learning it is suggested that such an experiment be designed. Subjects could be divided into treatment groups corresponding to a 3x2 factorial using examples/no examples, rule/no rule, and attributes/no attributes. Results would indicate effects and interactions of the variables on concept learning.

Given the data from Experiment B it is possible to interpret the lack of differences in time to mastery resulting from the reordering the sequence in Experiment A. Level II in a sense stood by itself, making the fact that the learners mastered or did not master Level III irrelevant and thus did not effect time to mastery. If a third group had been asked to start with Level I first, it could be expected that they would have had great difficulty. One cannot infer from this study what effect sequencing has on rule using or problem solving since the reordering involved concept learning only.

Concerning the effects of intra-sequencing. Each event in the intra-sequence of this study was intended to function as a facilitator to the corresponding event in information processing of the learner. Presumably, however, the information processing occurs somewhat independently of the intended function of the event. Presumably the information processing is dependent only on there being information to be processed. For example, what was intended by the designer to insure retention in the original sequence may function to gain attention in the reordered sequence. The requisite for facilitation of learning seems to be what is included in the design rather than what order it is in.

In commenting on the nine events of instruction Gagne states that, "Each of these functions is essential; should any one of them be omitted learning would occur only with difficulty (1970a, p. 320)." A study involving the deletion of instructional events from an empirically validated program may shed more light on the relationship between instructional events and learning. Such a study could involve deletion of events or combinations of events and examine the resulting effect on learning.

As for the present study, those learners receiving a reordered intra-sequence took no more time on instruction for each level of learning sets to master the terminal task than learners receiving an empirical sequence. For the hierarchy used the order in which the events of instruction were presented had no effect on learning.

Concerning the effects of learning rate. Learning rate appeared as a significant factor in two (Levels II, and I) of the three levels. There are two ways that these results can be analyzed. First, the effect of learning rate on time to mastery may be influenced by the effectiveness of the instruction used. Data from the pilot studies and Experiment A indicate that instruction for Level III was the most effective of the three instructional books. Also, there was no difference on time to mastery between high and low learning rate groups on this level. Possibly, the more effective the instruction is, the less learning rate will affect learning.

A second analysis of the learning rate data concerns the level of type of learning involved. Quite possibly, the acquisition of higher types of learning depend increasingly on learning rate. Whereas Level III involved discrimination learning, Levels II and I involved the learning of concepts and rules. Distinction between the two analyses cannot be made from the present study because the effectiveness of the instruction decreased for higher types of learning. The three factors of effectiveness, type of learning, and learning rate should be examined separately and in interaction in future studies.

Summary. Sequencing of learning sets may be dependent in part on the type of information presented in the instruction within each level of learning sets. That is, for concept learning extensive use of examples and corrected responses may in fact make the learning of "subordinate skills" unnecessary. Learners seem to be able to go beyond the information given to acquire skills not directly intended by the designer.

The order of instructional events within each learning set does not appear to be crucial if all are used. Although the events may be reordered in a way that does not correspond to the manner in which the learner processes the information, the learner seems to be able to quickly adapt the information to the process.

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