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ABSTRACT

Many basic skills are chains of cognitive operations. For teaching such skills, two questions have not been adequately investigated: (1) how the operations comprising the skill should be sequenced, and (2) the relationships among the operations that need to be taught. This investigation entailed four studies on different types and lengths of basic skills in either math or English, and the students were college freshmen. Four types of sequencing were investigated (forward chaining, backward chaining, hierarchical, and elaboration), as well as two types of relationships that might be important to teach (contextual synthesis and performance synthesis). The results indicate that neither sequence nor synthesis makes much difference for teaching a short skill, but that the longer the skill (or set of related skills), the more difference both sequence and synthesis make. The forward chaining sequence resulted in higher achievement than the elaboration sequence. Based on both theoretical prescriptions and common curriculum sequences in K-12, it is proposed that an elaboration sequence may be effective only for considerably larger chunks of interrelated content (rules) than had been previously proposed, and that within each of those chunks a forward or backward chaining sequence is likely to be optimal. (Author/RP)

FINAL REPORT ON

AN INVESTIGATION ON THE EFFECTS OF ALTERNATIVE STRATEGIES FOR SEQUENCING INSTRUCTION ON BASIC SKILLS

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ABSTRACT

Many basic skills are chains of cognitive operations. For teaching such skills, two questions have not been adequately investigated: (1) how should the operations comprising the skill be sequenced and (2) what relationships among the operations need to be taught? Four sequences have been advocated for teaching such skills: forward chaining, backward chaining, hierarchical, and elaboration; and two types of relationships have been advocated to be taught: contextual synthesis, which precedes the instruction, and performance synthesis, which follows it.

This investigation entailed four studies on different types and lengths of basic skills. The skills were either math or English, and the students were college freshmen. The results indicate that neither sequence nor synthesis makes much difference for teaching a short skill, but that the longer the skill (or set of related skills) the more difference both sequence and synthesis make. The forward chaining sequence resulted in higher achievement than the elaboration sequence. Based on both theoretical prescriptions and common curriculum sequences in K-12, it is proposed that an elaboration sequence may be effective only for considerably larger chunks of interrelated content (rules) than had been previously proposed, and that within each of those chunks a forward or backward chaining sequence is likely to be optimal.

FOREWORD

This research project was conducted in support of contract N00123-81-C-1263 under the sponsorship of the Navy Personnel Research and Development Center. This is the final report for said project.

Appreciation is expressed to Dr. Meryl Baker of NPRDC for her sound advice throughout the project, and to Dr. Eric Hemingsen of Syracuse University's Mathematics Department and Randall Brune of Syracuse University's English Department for their cooperation and support with respect to the data collection phase of the project. Appreciation is expressed to the Math and English instructors who volunteered to cooperate with us: Iqbal Abdul-latif, Ann Hoey, Susan Jacobson, Ann Martin, Faith Plvan, George Rowker, Steve Sharp, Pat Soper, Shobha Tharoor, Steve Thompson, and Mike Zanolli; and to David Boeshaar, whose advice and assistance with the data analysis were of great help. I would also like to express deep appreciation to my graduate student assistants, who contributed much to the success of this project: Allen Jenkins, Bonnie Keller, Fulya Sari, and Faith Stein. Finally, I am deeply indebted to Ann Craft, whose dedication, conscientiousness, and fast turn-around time enabled us to produce the instructional materials with the desired production quality and within the allotted time.

CHARLES M. REIGELUTH
Project Manager

SUMMARY

Problem

Basic skills instruction is becoming an increasingly important aspect of Navy training because of the low levels of basic skills that characterize many new recruits. Unfortunately, there are some important gaps in our knowledge about this aspect of training. Such gaps include a lack of knowledge about the best ways to sequence and synthesize instruction in basic skills.

Objective

The purpose of this investigation was to compare the currently viable approaches to sequencing and synthesizing instruction in basic skills of a variety of sizes.

Approach

Many basic skills are chains of cognitive operations that are performed to achieve some goal. Such basic skills are rules or procedures. A review of the literature revealed that four sequences have been advocated for teaching such procedural cognitive skills: forward chaining, backward chaining, hierarchical, and elaboration. A review of the literature also revealed that two types of relationships might be important to teach: contextual synthesis, which shows (on a memorization level) where each part fits within the whole skill, and performance synthesis, which facilitates the smooth chaining (on a performance level) of the steps for performing the complete skill. Because it was believed that neither sequence nor synthesis would make much of a difference for short tasks, four tasks of different lengths were used to look for a trend that could be extrapolated to larger skills than could be investigated in this project. The skills were either math or English, and the students were college freshmen.

Findings

1. The results support the hypothesis that neither sequence nor synthesis makes much difference for teaching a short skill, but that the longer the skill (or set of related skills) the more difference both sequence and synthesis make.

2. However, the sequence differences were not as predicted: the forward chaining sequence resulted in higher achievement than did the elaboration sequence.

3. An interaction between sequence and contextual synthesis indicated that the forward chaining sequence was better without contextual synthesis, whereas the backward chaining sequence was better with contextual synthesis. Forward chaining without was about the same as backward

chaining with contextual synthesis. However, this result did not obtain on all four tasks.

Conclusions

Based on both theoretical prescriptions and common curriculum sequences in K-12 (which tend to be elaboration sequences), it is proposed that an elaboration sequence may be effective only for considerably larger chunks of interrelated content (rules) than had been previously proposed. Secondly, within each of those chunks a forward chaining sequence without contextual synthesis and a backward chaining sequence with contextual synthesis are likely to be equally preferable, and either is likely to be preferable to the hierarchical and the elaboration sequence. However, additional research is needed to confirm both of these very tentative conclusions.

Recommendations

1. For curriculum-level sequencing (primarily the sequencing of related skills, versus the sequencing of operations within a single skill), use an elaboration sequence.

2. Within each chunk of the curriculum (primarily the sequencing of operations within a single skill), use a forward chaining sequence without contextual synthesis or a backward chaining sequence with contextual synthesis.

CONTENTS

SECTION 1

INTRODUCTION

There has been a growing concern with basic skills over the past ten years, due largely to the steadily lower skill levels of an increasingly large portion of adolescents and young adults. In the armed services this concern has reached mammoth proportions, both because the voluntary enlistment program has led to a higher percentage of enlistments by people whose skills are too poor to secure a job in the private sector, and because the increasing sophistication of military equipment requires more highly educated and trained personnel.

Although the teaching of basic skills is not new to the armed services, never before has such a scale of effort been required. This increased scale means that any improvement in the instruction on those skills will result in greater benefits than was previously possible. First, improvements in the effectiveness and efficiency of basic skills instruction will result in significant savings in the _total expenditure_ for such instruction. Second, improvements in the effectiveness and appeal of the instruction in those skills is likely to result in greater _job satisfaction_ among enlisted personnel, which in turn is likely to result in an improved retention rate and lower recruiting and training costs. Third, improvements in the effectiveness of the instruction is likely to improve both the effectiveness and efficiency of any _subsequent training_ and of subsequent _job performance_, thereby increasing the overall effectiveness and efficiency of military operations. All of this means that front-end activities, such as research on the teaching of basic skills and such as the systematic design and development of basic skills instruction, can have considerable pay-offs for the armed services.

Aspects of Basic Skills Instruction

There are many aspects of basic skills instruction that need to be investigated. It may be useful to classify those aspects as the organization, delivery, and management of instruction (Reigeluth & Merrill, 1979). The organization of instruction is concerned with the particular strategies that are used to select and format the information that will be presented to the learner. It includes the use of various kinds of examples, practice, instructional sequences, and mnemonics. The delivery of instruction is concerned with the particular media and methods that are used to convey the instruction to the learner. It includes the use of such things as teachers, blackboards, overhead projectors, workbooks, textbooks, computers, simulators, and on-the-job equipment. The management of instruction is concerned with how the other two aspects of the instructional process will be used. It includes such things as scheduling, grouping, individualizing, giving of rewards, and other aspects of the control of the instructional process. Of these three general aspects of instruction in basic skills, we suspect that the organization of instruction will have the greatest impact on the effectiveness of basic skills instruction, followed closely by the management of the instructional process. This study investigates several different strategies for organizing instruction on basic skills.

Within the general area of the organizaton of instruction, two major types of strategies have been identified: those that are used in the teaching of a single concept or principle or rule, and those that relate to the teaching of more than one concept or principle or rule (Gropper, 1974; Reigeluth & Merrill, 1979). Strategies for teaching a single idea, which are often called "micro" strategies, include the use of such things as examples, practice, feedback, visuals, and mnemonics. On the other hand, strategies that relate to more than one idea, which are often called "macro" strategies, include such things as the selection of ideas, the sequencing of those ideas, the teaching of interrelationships among those ideas, and the systematic preview and review of those ideas. This study is confined to the macro level, and within the macro level it is concerned primarily with sequencing, but also to some extent with synthesis and summary.

The Nature of Basic Skills

Some basic skills are facts that are merely memorized, such as addition facts for finding the sum of single digit numbers. However, the vast majority of basic skills are what have been referred to as "cognitive operations" or "cognitive skills", both of which are rules. A rule is a sequence of steps or operations that a person uses to achieve some prespecified goal. The Author Training Course (Courseware, n.d.) and the Instructional Quality Inventory (Ellis & Wulfeck, 1979) both distinguish between "rules" and "procedures". A rule is "a sequece of steps and decisions which apply in a variety of situations," and a procedure is "a sequence of steps which apply to a single situation" (Ellis & Wulfeck, 1979, p. 4). In this report we will use the term "rule" to refer to both of these kinds of skills (rules and procedures). A rule usually contains two types of operations: cognitive operations, which are unobservable, and motor operations, which are observable (Landa, in press). For example, subtraction usually entails writing numbers on a piece of paper (a motor skill) as well as figuring out the difference between two numbers (a cognitive skill). These rules are often quite complex, being comprised of a number of decisions and branches, and hence entailing ~~a~~ considerable variation from one application to another.

Given that most basic skills are rules that contain a number of motor and cognitive operations or steps, then it becomes readily apparent that some basic skills are much larger than others. Landa (in press) has proposed that if a rule (or algorithm) is relatively small, then it can be taught as a single entity; whereas if it is relatively large, then it should be taught piece by piece. This is very consistent with Merrill's Component Display Theory (Merrill, in press) and its evaluation instrument, the Instructional Quality Inventory (Ellis et al, 1979), which requires breaking the content into bite-sized segments. One characteristic of those "bite-sized" segments is that its generality (or statement of the rule), each of its examples, and each of its practice items span all the content in that segment. The segment is usually a single concept or principle or step of a rule, but if it contains more than one step of a rule, then the generality describes <u>all</u> of those steps, each example illustrates <u>all</u> of those steps, and each practice item requires the use of <u>all</u> of those steps.

It can readily be seen that, in the case of a rule, it is more difficult to decide how much of it should constitute a segment, primarily because what constitutes a step of a rule is not very clear. As a rule can be broken down into steps, so a step can be broken down into substeps, and so on. Landa (1976) deals with this problem by advocating that steps be broken down until they are at a degree of simplicity and specificity that will "control" the learner's behavior. This is similar to Gagne's (1977) call for continuing to analyze an intellectual skill into simpler component skills (which are prerequisites for the initial skill) until you reach the level of student entering knowledge. Then, each skill on the first level above entering knowledge is a segment of instruction in the sense that both Landa and Merrill use.

This means that in some cases, a basic skill may be teachable as a single segment, because all of its subskills have already been mastered by the learners. But in other cases, a basic skill will need to be broken down into bite-sized pieces in order for the instruction to be most effective. If you take a skill that is too far from entering knowledge and try to teach it as as single segment, the learners will not have consolidated their knowledge on one part of it before the generality or the example moves on to another part, and the first part will be forgotten, as will each of the subsequent parts as the instruction moves on.

If a skill can be taught as a single segment, then macro-level sequencing is only of concern with respect to when it is taught in relation to related skills. (Of course, micro-level sequencing of examples and practice within that single segment is also important, but micro-level sequencing is beyond the scope of this investigation.) However, if a skill cannot be taught as a single segment, then it becomes important to decide (1) what pieces to break the skill into (which is the purpose of task analysis), (2) what sequence in which to teach those pieces (which is one of the purposes of design), and (3) how to integrate and review all the pieces (which is another purpose of design). A variety of prescriptions have been proposed by theorists and investigated by researchers. They will now be reviewed.

Breaking a Skill into Subskills

Although many methodologies for task analysis have been developed (see e.g., Gibbons, 1977; Resnick, 1976), there are only two major approaches to task analysis: hierarchical and information processing. The hierarchical approach was pioneered by Robert Gagne (1962, 1968, 1977). It is based on the premise that any intellectual skill can be broken down into simpler skills, which can in turn be broken down into even simpler skills, and so on. In dealing with basic skills, it is likely that Gagne's "rule using" and "concept classification" will be the two types of simpler skills most often identified in the analysis. Our experience in reviewing hierarchical task analyses that were performed by and for the Army (Reigeluth & Merrill, 1980) has shown that the most common pattern is for the skill, which is a rule, to be broken down into steps (also rules) at the first level of analysis, for those steps to be broken down into substeps (also rules) at the next level or two or three, and finally for the sub-sub-...-steps to be analyzed as to their prerequisite concepts at the last level. The results of the hierarchical task analysis process are a learning hierarchy such as that shown in Figure 1-1.

Insert Figure 1-1 about here

On the other hand, the information processing approach to task analysis has been developed by a number of theorists, including Landa (1974), P. Merrill (1971), Resnick (1973), and Scandura (1973); and it seems to have its foundations in the work of several behaviorists, such as Gilbert (1962, see below). This approach entails observing an expert's performances of the task and cataloguing all of the expert's operations in chronological order from beginning to end. Since many of the expert's operations are unobservable, it is necessary to have the expert explain what his or her thought processes are at any given point in the performance of the task. Some theorists, such as Landa (1974) and Reigeluth and Merrill (1980), have included in their task analysis rules some steps for making sure that the resulting description is at the level of entering knowledge. The result of an information

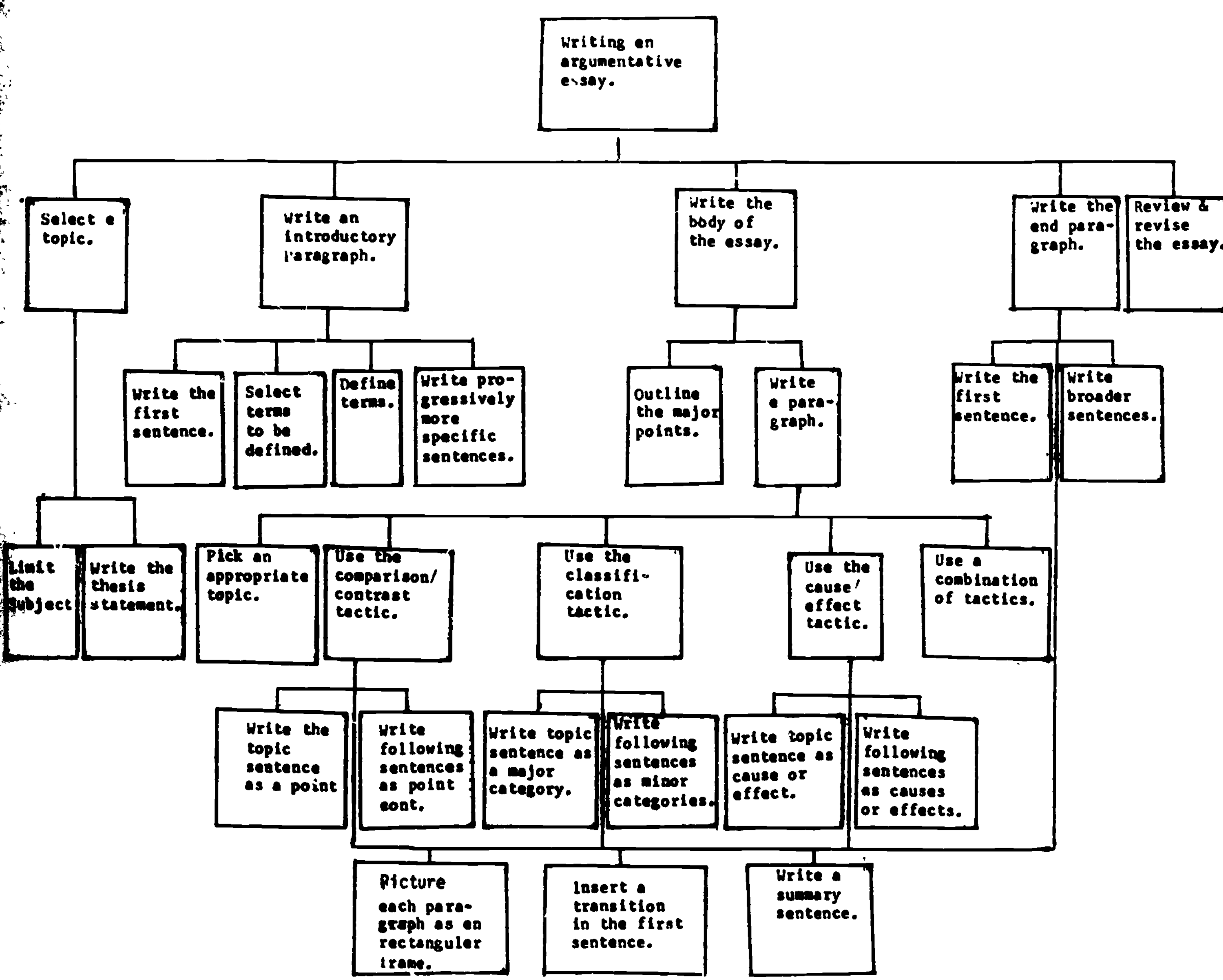

FIGURE 1-1. An example of a learning hierarchy, the product of a hierarchical task analysis.

processing task analysis is a flow diagram such as that shown in Figure 1-2.

Insert Figure 1-2 about here

By way of comparison, it can be seen that, unlike the hierarchical approach, the information processing approach does not identify any of the *concepts* that need to be taught. It can also be seen that, unlike the information processing approach, the hierarchical approach does not indicate the *order* in which the various steps should be performed. We were not able to identify any empirical studies which compared the relative merits of these two approaches to task analysis.

Sequencing the Subskills

A number of theorists have proposed that sequencing is not important for all types of instruction. For example, Branson et al. (197) propose that sequencing effects are long range and that sequencing is most important (1) for low-aptitude students, (2) with unfamiliar materials, and (3) with non-redundant materials. Also, Reigeluth (1979) proposes that sequencing is only likely to make a difference for fairly large amounts of interrelated instructional content. Such qualifications are important to keep in mind during any discussion of instructional sequences.

There are two major levels on which instruction can occur: the *remember* level, which requires the learner to memorize what is being taught, and the *application* level, which requires the

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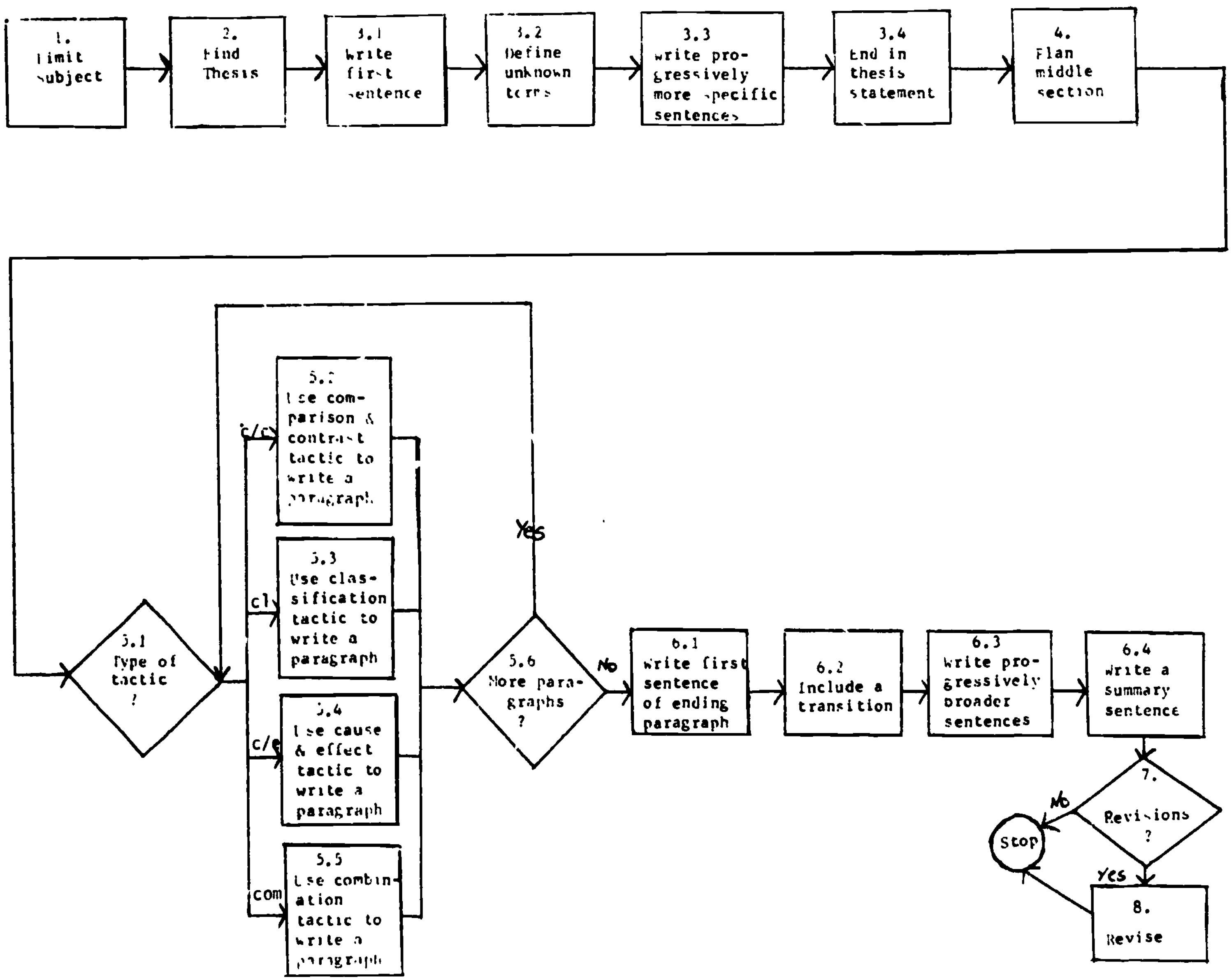


FIGURE 1-2. An example of a flowchart, the product of an information processing task analysis.

learner to apply generalizable knowledge -- such as all of Gagne's "intellectual skills" -- to new cases. Most general-to-detailed sequences are at the remember level. For example, in a general-to-detailed sequence the instruction may start with a general-level description (i.e., one that is way above student entering level) of the whole rule, followed by a slightly more detailed description, and so on, until the level of entering knowledge is reached. All of the instruction that is more than one level above entering knowledge can only occur at the remember level, because the prerequisite skills have not yet been learned. Application level instruction can only take place on the first level above the entry level.

However, just because the instruction is at the remember level does not mean that it must entail <u>rote</u> learning. Meaningful learning (Ausubel, 1968) can also occur at the remember level. The general-to-detailed sequence may be useful, but its usefulness lies in that it provides a meaningful context (via an overview) that can provide "ideational scaffolding" for the subsequent application-level learning. Hence, it is really a summarizing or synthesizing strategy, not a strategy for sequencing the application-level instruction in each of the operations that comprise the cognitive skill.

We have been able to identify four different sequences that have been advocated for application-level instruction in the subskills of a cognitive skill: forward chaining, backward chaining, hierarchical, and elaboration sequences. Each of these sequences is defined below.

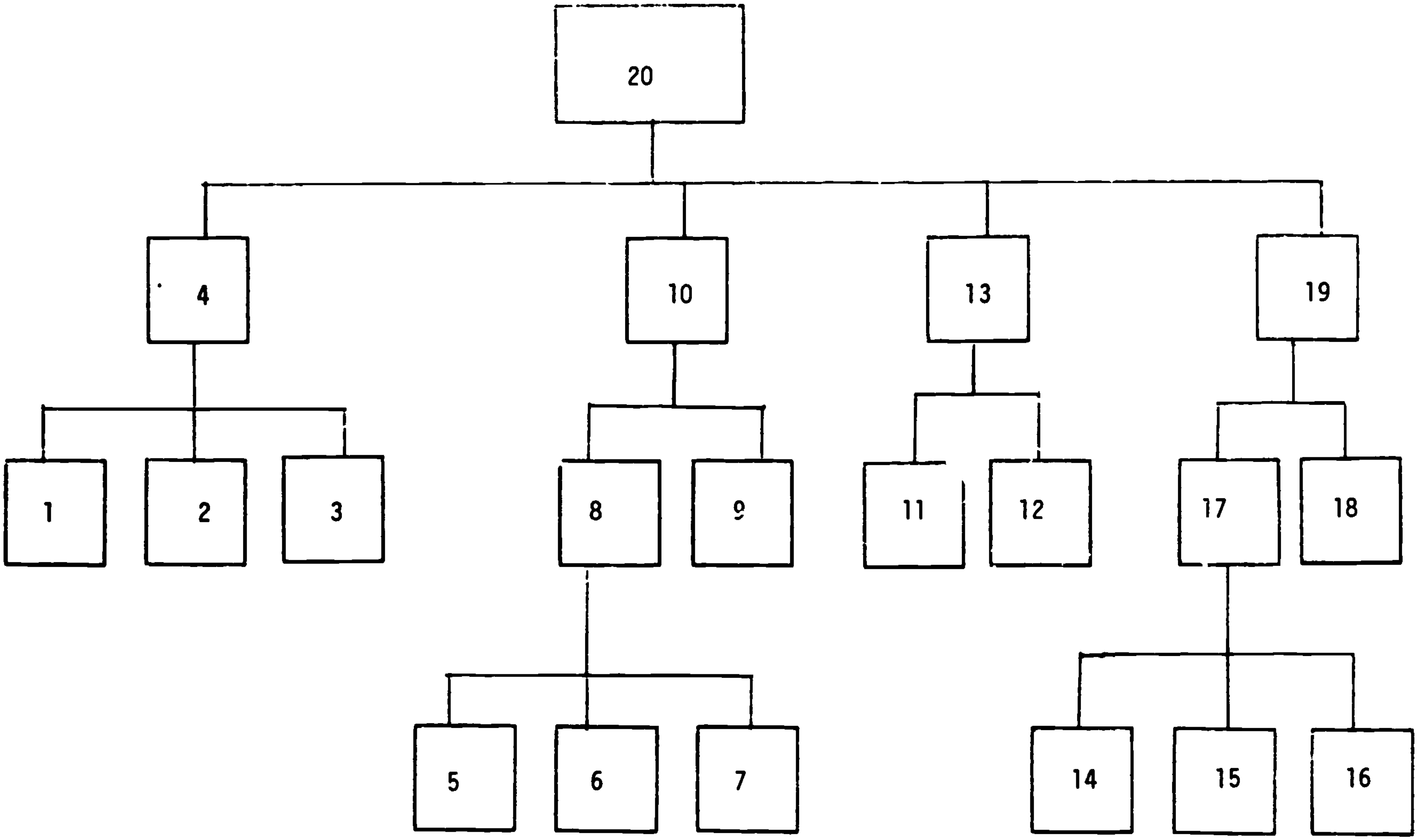
The <u>forward chaining</u> sequence takes the results of an information processing task analysis and sequences the steps in the order in which they are performed. In other words, the step which is performed first is the step which is taught first. The rationale for this sequence is the logic of the correspondance between the performance sequence and the learning sequence.

The <u>backward chaining</u> sequence (Gilbert, 1962) also takes the results of an information processing analysis, but it sequences the steps in the opposite order from that in which they are preformed. In other words, the step which is performed last is the step which is taught first. Of course, all the necessary inputs from prior steps (which have not been taught yet) are provided so that the student can actually practice performing that step. The rationale for this sequence is that the completion of the task is far more intrinsically rewarding than the completion of some intermediate step. Hence, a backward chaining sequence should result in greater reinforcement, which in turn should improve learning. It also seems likely that a constant awareness of the goal or purpose or outcome of what one is learning should improve both meaningfulness and motivation.

The <u>hierarchical</u> sequence, in contrast to the previous two sequences, takes the results of a hierarchical task analysis and sequences them in a bottom-up order. Ordinarily, the sequence starts with the left-most skill on the bottom of the hierarchy and proceeds to the right until all of the skills that are subordinate to a single higher-level skill have been taught. (Notice that, since the substeps in a hierarchy are usually listed from left to right in the order of their performance, the hierarchical sequence can be merely a more complex version of the forward chaining sequence. We return to this issue in the Methods sections below.) Then that higher-level skill is taught before returning to the next skill on the bottom of the hierarchy. In this way, a hierarchical sequence goes as high as possible as soon as possible in the hierarchy, while never teaching a skill before all of its subordinate skills have been taught (see Figure 1-3). The rationale for the hierarchical sequence is that lower-level skills are components of the the higher-level skills and therefore must be learned before the higher-level skills can be learned.

Insert Figure 1-3 about here

Finally, the <u>elaboration</u> sequence is based on the results of both an information processing analysis and another form of analysis called path analysis (see e.g., P. Merrill, 1978; Reigeluth & Rodgers, 1980). This kind of sequence is only used for a rule that has at least one decision step and hence at least two or more branches, such as the rule shown in Figure 1-4. Path analysis entails identifying all the possible "paths" (or distinct combinations of steps) that could be used in performing the rule. Then the shortest path is taught first, usually in a forward chaining sequence (see Figure 1-4). Also, each step in that path is always preceded by any



Note: The numbers indicate the order in which the subskills are taught.

FIGURE 1-3. An illustration of a hierarchical sequence.

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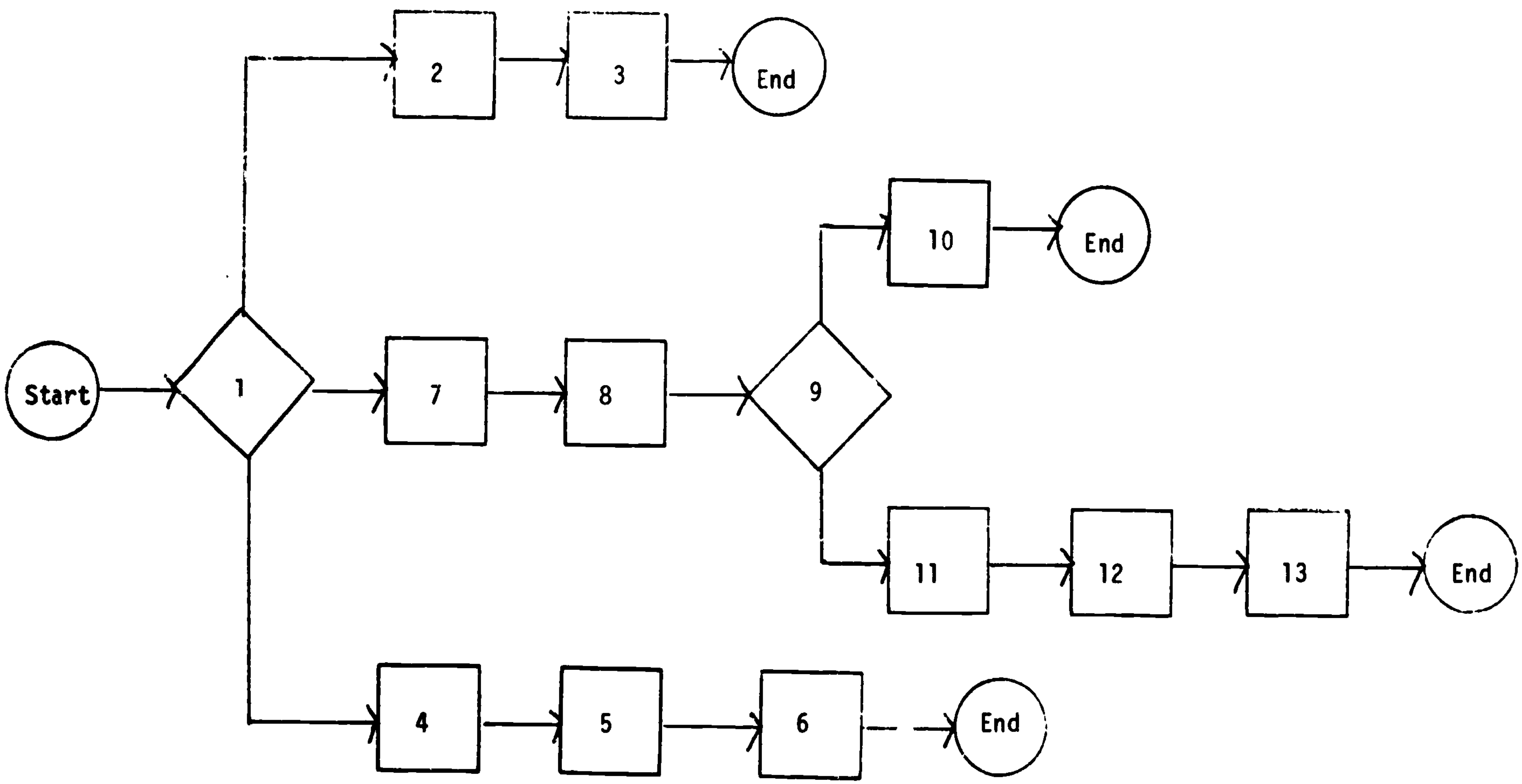
prerequisites that are revealed by a hierarchical analysis of it. Then the next shortest path is taught in the same manner, and so on until all of the paths have been taught (see Figure 1-4). The rationale for this sequence is that the learner is actually able to perform the whole task (albeit under the simplest possible circumstances) from the very first lesson. Hence, its reinforcement and motivational advantages should perhaps be greater than those of the backward chaining sequence. In addition, it does not violate the learning prerequisite notion of the hierarchical approach. In fact, it requires a hierarchical analysis of the steps that are taught in any given lesson, but the number of unmastered prerequisites that will be identified will be very few, because the information processing analysis already describes the steps at the first level above entry level. A final rationale is that by building knowledge from the simple to the complex, stable, subsumptive cognitive structures are formed, and the simpler paths provide "conceptual anchorage" for the more complex operations that follow.

Insert Figure 1-4 about here.

<u>Synthesizing and Summarizing the Subskills</u>

Summarizers are concise statements of the content (in this case, primarily steps or operations) that is taught in the instruction. There are two major kinds of summarizers:



Lesson 1:

2, 3

Lesson 2:

1, 4, 5, 6

Lesson 3:

1, 7, 8, 10

Lesson 4:

9, 11, 12, 13

FIGURE 1-4. An illustration of an elaboration sequence.

previews and reviews. Previews summarize what is about to be taught; they seldom include either examples or practice, and they are always studied at the remember level. Reviews summarize what has just been taught, and may include a typical example and even a self-test practice item or two.

We have identified two kinds of synthesis or integration for procedural content: contextual synthesis and performance synthesis. Contextual synthesis shows how the various pieces of content fit together. In the case of rules, it shows the order among the steps or operations. Contextual synthesis is usually presented before the related application-level instruction, but it may come after. At the very beginning of the instruction, it may show the relationship between the rule that is about to be taught and similar rules that have already been taught, in which case it is usually called an "external" synthesizer. Otherwise, it shows where the step (or set of steps) that is about to be taught fits within the whole rule that is being taught. In this case, it is usually called an "internal" synthesizer.

Performance synthesis, on the other hand, is intended to help the student to perform the whole rule smoothly, without hesitating or forgetting which step comes when. It is not enough for students just to learn all the individual steps; it is also essential for them to know when to use and when not to use each step in relation to all the other steps. And this can not just be memorized -- it must become a habit through practice. Hence, performance synthesis always comes after the application-level instruction, and it always includes "integrated" generalities, examples, and practice. Integrated generalities describe the order in which to use all the steps taught so far in the instruction, including when to use and not to use each. Integrated examples show the use of all those steps to solve a specific problem, and it shows them all being used back-to-back. Similarly, an integrated practice item requires the use of all those steps to solve a specific problem, and it requires that they be used back-to-back.

It is probably evident to the astute reader that there is not a clear distinction between summarizers and synthesizers. Any summary of numbered steps will help the learner to remember the context of each step and the order in which each step should be performed. Hence, for rules a preview (i.e., presummarizer) contains most of the same elements as a contextual synthesizer, and a performance synthesizer contains most of the elements of a review (i.e., postsummarizer). The following is a description of synthesizers and summarizers that have been advocated by various theorists.

For the forward chaining sequence, Landa (in press) has advocated what he refers to as the "snowball approach," which entails application-level review and integration of all previously taught steps immediately after each step is taught. More specifically, after each step is taught (complete with a generality, some examples if the step is observable, and some practice), integrated practice is provided -- practice that requires the use of all the steps that have been taught so far. Landa makes no specific mention of presenting either an integrated generality or some integrated examples -- ones that cover the use of all steps that have been taught so far. Nevertheless, Landa's prescriptions call for some measure of performance synthesis and review after each step is taught.

SECTION 2

REVIEW OF RESEARCH

Sequencing Strategies

Much of the research on sequencing has investigated different sequences of examples or practice (a micro-level strategy), and hence is irrelevant to our present concern. With respect to macro-level sequencing, suprisingly little research has compared any of the four sequences described above with each other. Hence, much of this review will focus on tangentially related sequencing issues.

Random and Logical Sequences

Research on macro-level sequences gained its first major visibility with studies of random vs. logical ordering of instructional content. Gauverin and Donnahue (1961) conducted a study in which a random-ordered program and a logical-ordered program were given to students. As expected, the random-order students made more errors during the program, yet both groups showed no difference on post program achievement measures. It was reasoned that a longer program might prove more difficult for the students to "organize as they go", so Roe, Case and Roe (1962) and Roe (1962) repeated the logical vs. random sequence study of Gauverin & Donnahue (1961) with a longer program. The Roe (1962) study was the only one of the two to find significant sequence effects on posttest achievement measures.

The logical sequence was found to be superior to the random sequence in that study.

These results initiated a long series of "scramble" studies designed to prove the superiority of logical sequences in instruction. However, these studies have had limited success in finding sequence effects. In reviewing this literature, Andersen (1967), Niedermeyer (1968), and Heimer (1969) all drew the same conclusion: that if sequencing is to make a difference, there must be a _theory of sequencing_ which can operationally define "logical" or "correct" sequences. This theory would have to take into consideration such factors as the inherent "interrelatedness" of the content, the length of the instructional unit, and the age and ability of the learner.

Whole and Part Sequences

Behavioral theorists developed three patterns for sequencing a rule: the "whole" method, which entails teaching the whole rule as a single instructional unit, and two "part" methods, one with a forward chaining sequence and one with a backward chaining sequence. Blake and Williams (1969) tested the effects of the "whole" method and two types of forward chaining "part" methods in a nonsense syllable task. The part methods were: "pure part", where the subjects learned steps A, B, C, and D then ABCD (performance synthesis), and "progressive part", where the subjects learned steps A, B, AB, C, ABC, D, ABCD. The "whole" method taught ABCD, ABCD. On a posttest for acquisition, the "whole" group outperformed both "part" groups, but it is important to note that the instruction was on the remember level and the task was quite small. These results confirmed earlier findings by McGuigan (1960) and McGuigan and MacCaslin (1955), both of which also found superior performance for "whole" teaching sequences.

However, with purely manipulative types of tasks, such as rudimentary sorting and assembly of objects or with retarded subjects, the "part" methods have been shown to be superior (Benny, 1966; Gold, 1968; Nettlebeck & Kirby, 1976). The earlier cited Blake and Williams (1969) study also used retarded subjects in one treatment group, and confirmed that the use of "part" methods with retarded subjects and manipulative tasks is superior to "whole" methods. It has often been maintained that sequencing, summarizing, and synthesizing strategies are only likely to make a difference for relatively large amounts of interrelated content, such as a semester course's worth. However, it seems likely that for retarded students the minimum size to make a difference would be considerably less content than for normal students. Hence, the above-cited results for retarded students may be interpreted as lending support to the contention that sequencing strategies are in fact important for relatively large amounts of interrelated content. This is an important issue for basic skills, because many months and even years of instruction are required to develop many basic reading, writing, and math skills.

Forward and Backward Sequences

In a study comparing forward "whole" sequences and forward and backward "part" sequences, Walls, Zare and Ellis (1981) found that retarded subjects made fewer errors learning manipulative assembly tasks to criterion with the "parts" methods than with the "whole" method. However, there were no differences between the forward and backward "part" sequences. Thisrcent of the essays. In all such cases (of the two ratings differing by more than 3 points), another rater provided a third "blind" rating. By "blind" we mean that none of the raters was aware of the ratings of any of the other raters. Considering that 72-step rule was taught to criterion in three different ways:

Method 1: Small Operant Spans (parts), Backward Chaining

Method 2: Small Operant Spans (parts), Forward Chaining

Method 3: Whole Task, Forward Sequence.

In measures of time to criterion, there were no differences between the three treatment groups. These results were discussed in relation to Gilbert's (1962) theory of mathetics, which advocates backward chaining as a method of increasing the efficiency of the instruction because of the reinforcement supplied by constant awareness of the goal of the rule. "Humans," say Cox and Boren, "can (and do) hold a goal in mind" (p. 273), therefore negating any advantage of backward chaining over forward chaining.

Related to the "part" versus "whole" sequences, Gilbert (1962) recommends a middle-of-the-road solution: the use of intermediate "spans" (i.e., amounts of a rule). The size of these "operant spans" varies according to the requirements of the learners. Their use, says Harless (1967), has the major result that "the physical bulk of the programs has been drastically reduced," leading to instructional economy, quicker terminal reinforcement, time savings for the student, and reduced boredom (Harless, 1967, p. 92).

To test the effects of these sequencing patterns with different operant sizes, Balson (1971) used forward and backward chaining sequences with the operant spans and a traditional forward sequence program with small steps. Using 54 normal fourth grade students and the cognitive task of division, Balson found no differences on an achievement posttest but a significant difference on time for learning in favor of operant spans. This finding provides some indication that the optimum size for a "segment" of instruction (discussed earlier) may often be more than one step of the rule being taught. No differences were found between the forward and backward chaining sequences.

Research in the area of spaced and massed practice of tasks, which is similar to the "part" and "whole" methods reviewed above, provides support for spaced practice -- that is, for "part" task presentation methods (Leith, 1971).

In summary, research in sequencing based on behavioral principles supports the use of "part" sequences for teaching a rule. However, this support only concerns the efficiency of learning, as no significant effects on achievement have been found. No differences between forward and backward chaining sequences have been found. However, these results should be viewed with caution due to the relatively small amounts of content used in the studies. It is quite possible that some very important differences might be found with larger amounts of interrelated content.

Cognitively Based Instructional Sequences

With the advent of cognitive instructional theories and their additional component of the learner's memory structure, different sequencing patterns were identified, such as "subsumptive," "general to detailed," and "simple to complex" sequences. These sequencing patterns are based on the assumption that the order of the incoming instruction will affect the order of its representation in memory, which in turn will affect retrieval, retention, and transfer.

Ausubel (Ausubel, 1963, 1968; and Ausubel & Fitzgerald, 1961) developed a set of sequencing principles based on the idea that knowledge is organized hierarchically in the human mind, and that each new piece of knowledge, in order to be meaningfully assimilated, must be "subsumed" by the most appropriate, more general piece of knowledge in that hierarchical organization. Hence, Ausubel called for a "subsumptive" sequence of instructional content -- a special type of general-to-detailed sequence.

Unfortunately, almost all of Ausubel's sequencing prescriptions have been concerned with the teaching of <u>concepts</u> and <u>principles</u>, and not with the teaching of <u>rules</u>. Yet there is no reason to assume that a subsumptive sequence is either impossible or inappropriate for a rule. In fact, recent work on information processing task analysis has resulted in the development of "path analysis" techniques and prescriptions for teaching the shortest "path" first (see, e.g., P. Merrill, 1978). Reigeluth and Merrill have expanded these ideas into their notion of an "elaborative" sequence for teaching a rule or a set of related rules (see, e.g., Reigeluth & Rodgers, 1980), which has much in common with Ausubel's basic notion of a subsumptive sequence.

The bottom-up hierarchical sequences proposed by Gagne (1968) and validated by Gagne and Paradise (1961) have been found quite effective in teaching intellectual skills . However, their use in teaching rules has not been rigorously investigated, and what research there is has not compared hierarchical sequences with any of the other three sequences identified above. Similarly, the elaborative sequence proposed by Reigeluth and Merrill has not been compared with any of the other three sequences, largely due to the recency of the development of that sequencing pattern.

In conclusion, what little research does exist on the macro-level sequencing of rules has not compared the major sequencing strategies that have been developed to date. The only exception is that forward and backward chaining sequences have been compared, but only to a very limited extent with respect to cognitive rules that are learned at the application level.

Synthesizing Strategies

Knowledge of the structure of a subject matter is thought to have a number of beneficial effects, including an increase in the "meaningfulness" of the content and an improvement in problem-solving capabilities. However, "structure" has been defined and operationalized in many different ways. Brunner (1960) states that "Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully" (p. 7). Schwab (1962) states, "The structure of a discipline consists, in part, of the body of imposed conceptions which define the investigated subject matter of that discipline and control its inquiry" (p. 199). In other words, the structure of a subject matter is the concepts which are used in the productive manipulation of the content area.

Further insight is provided by Greeno (1976):

> "When a problem is understood, the person perceives certain structural relations among components of the problem. However, the structural pattern is not complete, and that is why there is a problem. Thus, problem-solving can be seen as a process of modifying a structure in order to complete a pattern." (p. 141)

Thus, problem solving, meaningful learning, and the structure of a subject matter exist in some analogous fashion.

Yet, how is meaningful learning accomplished in a classroom? Ausubel (1962, 1968) states that a general-to-detailed sequence of instruction provides for the construction of a "framework" within the memory of students.

This framework, he assumes, gradually approximates the "framework" used by experts in the subject matter. Bruner (1966) also mentions this progression of "naive-to-expert" cognitive structures.

However, a second method of teaching the structure of a subject matter has been identified -- that is, the direct teaching of it. Early work in such direct teaching of structure was conducted by Ausubel under the rubric of <u>advance organizer</u>. However, advance organizers were primarily constructed to provide a meaningful context for learning based on a learner's cognitive structure, not on the structure of the discipline. Nevertheless, advance organizers have been shown to improve the learning of content in a way which implies greater knowledge of the structure of the content but without directly teaching any of the content itself (Mayer, 1980).

However, it appears that advance organizers not only do not directly teach the content itself, but also do not directly teach the structure. In a series of 9 studies, Mayer (1979) found compelling evidence that advance organizers <u>do</u> facilitate meaningful learning, and he suggests that the effects of advance organizers can be attributed to their ability to provide "a means of generating logical relationships among the elements in the to-be-learned information" by "influencing the learner's encoding process" (Mayer, 1979, p. 382). Advance organizers, then, provide a means of learning the structure of a subject matter without providing the structure of the subject matter itself.

In related research, Mayer (1978), Lesh (1976), and

Schumacher, Liebert and Fass (1975) have found that advance organizers can compensate for poorly organized text. Mayer (1978) believes this is due to the fact that the organizers "provide an assimilative context for organizing the incoming information" (p. 886). The incoming information, and not the organizer, therefore, is seen as primarily responsible for providing the needed structure of the subject matter.

However, if advance organizers can compensate for poorly organized text, could it be possible for organizers to facilitate higher-order skills, while the instructional sequence facilitates retention and lower order skills? This seems to be the case. In a more direct method of providing the structure of the subject matter, Reigeluth (1979) proposes that a "synthesizer" be used to explicitly teach the structure of the subject matter, rather than using an advance organizer to provide a more implicit means of learning that structure. The types of synthesizers he proposes are generated by several task and content analysis methodologies that have been incorporated into the Elaboration Theory's design procedures (see e.g., Reigeluth & Darwazeh, 1982; Reigeluth & Rodgers, 1980; Sari & Reigeluth, 1982).

In one study, Frey and Reigeluth (1981) combined synthesizer position (before and after instruction) with presentation sequence (general-to-detailed and detailed-to-general) for instruction in a set of 12 interrelated concepts. They found that the position of the synthesizer interacted with presentation sequence on a test on students' understanding of the relationships among the concepts that had been taught. A presynthesizer most facilitated such understanding in a detailed-to-general sequence, whereas a postsynthesizer contributed most in a general-to-detailed sequence. Although such significance was quite unexpected for a half hour's worth of instructional content, it is important to note that there were no significant differences on the concept classification test. Hence, the significance was on learning the structure of the concepts, not on learning the concepts themselves. However, as with advance organizers, these results have not been tested with rules.

Conclusions

In conclusion, studies on the effects of presentation sequence support a "part" rather than "whole" approach. There seems to be no difference between forward and backward chaining methods with respect to either learning efficiency or learning potency. Synthesizers have traditionally been constructed from information about the cognitive structure of the learner. However, it has been proposed that a more efficient method of providing knowledge of the structure of the subject matter is to construct synthesizers which explicitly teach that structure. Although such synthesizers have been found to improve students' understanding of the structure of conceptual subject matter, we are aware of no research to date on the use of synthesizers for instruction on rules.

The purpose of this study is to extend the previous research into the area of rules, and more specifically the area of basic skills. However, the Elaboration Theory hypothesizes that sequencing and synthesis are only likely to make an important difference on relatively large amounts of interrelated content. The rationale is that the smaller the amount of interrelated content, the easier it is for the human mind to compensate for deficiencies in these aspects of the instruction (sequencing and synthesis). But one unknown is how much interrelated content is required before one can expect to detect a statistically significant difference. It is beyond the resources of the current project to use more than about 10 hours worth of instructional content, and it is quite possible that this is not enough to yield significant differences. Therefore, we have decided to use a number of tasks of varying lengths. In this manner, even if none of the results reaches significance for the range of amounts of content that are feasible for this project, a trend in the direction of higher F values (and hence lower *p* values) as the amount of content increases would lend some support, albeit tentative, for the contention that sequencing and synthesis are important instructional variables for large amounts of interrelated content.

Hypotheses

Sequence

1. For a relatively short rule, no sequencing strategies will have any effects on either learning or affect.
2. For a relatively long rule, the elaboration sequence will

result in better learning and affect than the other three sequencing strategies.

Contextual Synthesis

1. For a relatively short rule, contextual synthesis will have no effects on either learning or affect.
2. For a relatively long rule, the presence of contextual synthesis before the application-level instruction will result in better learning and affect than its absence.

Performance Synthesis

1. For a relatively short rule, performance synthesis will have no effects on either learning or affect.
2. For a relatively long rule, the presence of performance synthesis after the application-level instruction will result in better learning and affect than its absence.

SECTION 3

EXPERIMENT 1

SHORT UNITARY RULE

Methods

Design

This study investigated sequencing, contextual synthesis, and performance synthesis for a short unitary rule. By unitary, we mean that the rule had no branches. (See *Task and Materials* below for details about the rule.) Since the rule was unitary and very short, the hierarchical sequence turned out to be identical to the forward chaining sequence. More specifically, a hierarchical analysis identifies the same five subskills as an information processing analysis reveals (see Figure 3-2 below), and proceeding from the left to the right in the hierarchy results in the same sequence as proceeding from beginning to end in the flowchart. This supports the notion mentioned in Section 1 above that, for rules, a hierarchical sequence can often be viewed merely as a more complex version of a forward chaining sequence. Also, the rule was not long enough for an elaboration sequence to be used -- the whole rule took only about one quarter of the learning time that the epitome lesson in an elaboration sequence should take.

This left only two sequences to be investigated: forward chaining and backward chaining. Hence, the statistical design was a 2x2x2 factorial design in which the factors were (1) sequence (forward chaining and backward chaining), (2) contextual synthesis (absence and presence), and (3) performance synthesis (absence and presence). The two sequences tested each had four versions, one without any synthesis, one with contextual synthesis only, one with performance synthesis only, and one with both contextual and performance synthesis (see Figure 3-1). Hence, the method of statistical analysis was ANOVA, with SAT scores being used as a covariate whenever the appropriate criteria were met (see Results section).

Insert Figure 3-1 about here

The experimental design was a posttest-only design, with a regular course test as the posttest.

Subjects

Our original intention was to use Navy JOBS students as subjects, but a sufficient number of students was not available. Students at Syracuse University represented the only large number of subjects readily available to us. Since we wanted to be able to generalize to Navy JOBS students, we decided to use freshman math students in Syracuse University's Math 103, a remedial basic Algebra course. This course had three tracks, and assignment of students to those tracks was based solely on each student's numerical score on the Freshman Math Placement Test. The three tracks were:

(1) The <u>fast</u> track, which was comprised of 106 students who were marginally in need of remedial instruction. Hence,

		CONTEXTUAL SYNTHESIZER			
		Absent		Present	
		PERFORMANCE SYNTHESIZER		PERFORMANCE SYTHESIZER	
		Absent	Present	Absent	Present
SEQUENCE	Forward	FAA	FAP	FPA	FPP
	Backward	BAA	BAP	BPA	BPP

FIGURE 3-1. The eight treatment groups for experiment 1.

these students were the least representati of JOBS students and were not included in the study.

(2) The slow track, which was comprised of 58 students whose skill levels were extremely low, in some cases due merely to low aptitude or lack of adequate prior instruction, but in other cases due to serious motivational problems. These students were not included in the study because of the low number of students available.

(3) The regular track, which was comprised of 948 students who represented a broad cross-section of students in need of remediation in basic mathematical skills. This group was used in the study because it contained a large enough number of students.

Most, if not all, students in the regular track of Math 103 had studied this material before and had not done well in it. By and large, they had poor math SAT scores (a mean of 487), and their scores on the Freshman Math Placement Test indicated that they needed remedial work on what is usually considered ninth grade alegbra. Most of the students were 18 or 19 years old. Although these students were remedial students of relatively low ability, it is important to note that there were still considerable differences between this sample and the population of Navy JOBS students. Perhaps the two most notable differences are a considerably lower average ability level and considerably more severe learning disabilities and motivational problems.

Within the regular track, three instructors (with a total of four sections) volunteered to use our instructional materials to teach the regular course material during the regularly scheduled course time. The 157 students in those four sections represented our initial sample for this study. Due to absences either on the day the materials were handed out or on the day of the test, the final sample was 113 students.

The students were randomly assigned to treatments _within_ each section to control for any possible differences between sections.

Instructional Task and Materials

The task for this study was the rule for adding and subtracting algebraic expressions. It consisted of five steps (see Figure 3-2), and it was a unitary rule because there were no branches. However, as can be seen from Figure 3-2, there were two decision steps, each of which permitted the elimination of one of the three operations that comprised the rule. It was a very short rule, taking only about a minute to perform, on the average; and the instruction took about 15 minutes to complete.

Insert Figure 3-2 about here

All micro-level strategies within each step were held constant across all treatment groups. The following are the micro strategies used in the learning module (see Figure 3-3 for an example of each):

WHAT TO DO: This strategy component was the generality, a general description of what the student was to do. By

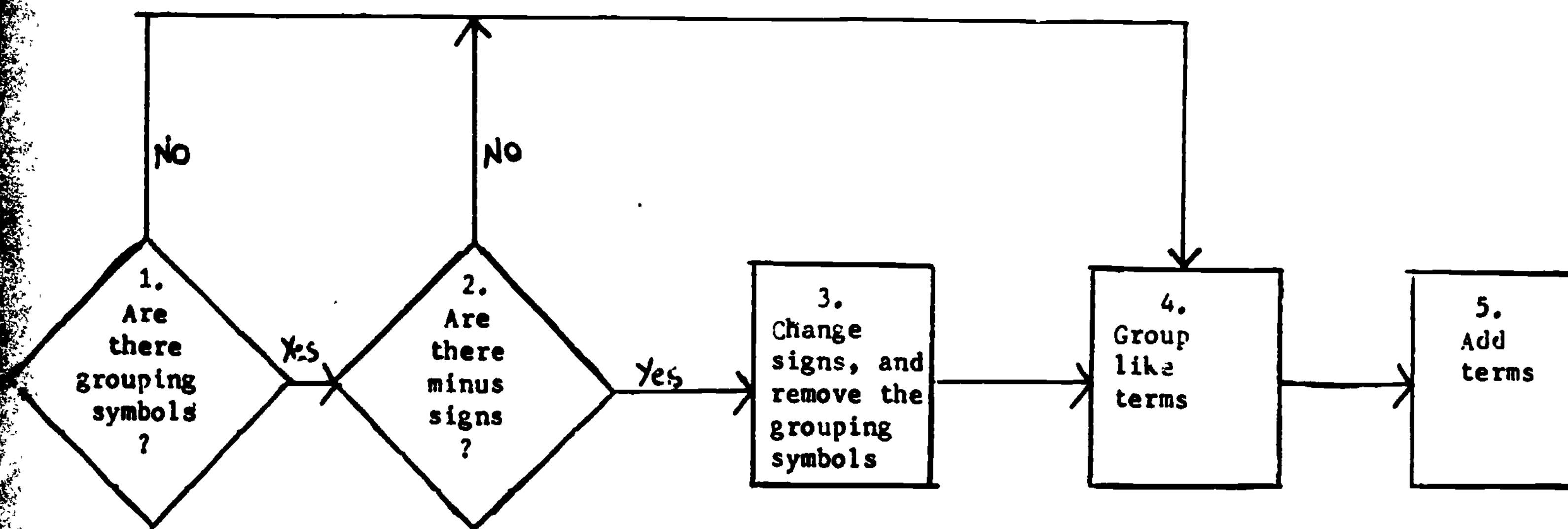


Figure 3-2. A flowchart of the procedure for adding and subtracting algebraic expressions.

"general" description, we mean a description that did not include any reference to a specific problem, or example. This component described a single step, but that step was occasionally presented as a set of substeps.

Definition: This strategy component was also a generality, but it was not the generality for one of the steps of the rule. Rather it defined key terms that appeared within the "WHAT TO DO" component.

Examples: This strategy component showed examples of the concept that was defined in the Definition.

Non-Examples: This strategy component was used, when deemed necessary, to point out cases that would otherwise often be confused with examples of the concept that was defined in the Definition. A non-example was always presented beside an example that was as similar as possible to it.

EXAMPLES: This strategy component illustrated the step that was described in the WHAT TO DO by showing how that step is used in solving specific problems. Usually several examples were provided, and they were arranged in order of increasing difficulty.

PRACTICE: This strategy component presented problems that required the student to use the step that was described in the WHAT TO DO, but the student was only required to use that one step. The problems were arranged in order of increasing difficulty.

ANSWERS: This strategy component provided the answers to the practice problems. It was given to the students after they had done the problems.

Insert Figure 3-3 about here

An experienced Math 103 teacher rated each step on a scale of 1 to 5 as to its anticipated difficulty level for the sample of students. The instruction on steps that were expected to be fairly difficult for the students included more examples and practice items than did the instruction on steps that were expected to be fairly easy to learn. But whatever level of richness was chosen for a step, that same level of richness was used in all treatments, so that all of the micro-level strategies were held constant across all groups. Also, the wording of each of the strategy components was identical except in those few cases where the sequence required a different transition statement or direction to the students.

The instruction was delivered in self-instructional booklets that replaced both the corresponding portion of Chapter 4 of the course textbook and the corresponding class presentation.

<u>Treatments</u>

The eight treatment groups differed only in the sequence in which the steps were presented and in the presence or absence of synthesis. The eight groups are portrayed in Figure 3-1 above, and the following is a brief description of the characteristics of each.

With respect to <u>sequence</u>, the four forward chaining treatments taught step 1 first, then step 2, and so on until

ADDITION AND SUBTRACTION OF ALGEBRAIC EXPRESSIONS

STEP 1

WHAT TO DO

Decide if there are symbols of grouping separating the terms

If yes, go to step 2.
If no, go to step 4.

Definitions:	Examples:
1. Symbols of grouping are:	$\{\ \}$; $[\ ]$; $(\ )$
parentheses	$4a-(a-3x+2y)$
brackets	$5a-[2a-(3a+6)]$
braces	$18-\{-(a-1)+3a\}-4a$
2. A term is a part of an algebraic expression.	x or $3xy$ or $-2x$
Terms are connected by plus and minus signs and thus make up an algebraic expression.	$x + 3xy - 2x$

EXAMPLES In the following examples, the letters indicate this:

a. parentheses
b. brackets
c. braces

1. $-6y+y^2$ no, there are no grouping symbols
2. $10x+(y-x^2)$ a
3. $x-\{3xy+[7+(y-3)]+(x+y)\}$ a, b, c

FIGURE 3-3. An example of the micro strategies used to teach the individual steps of the rule. (Page 1 of 2 pages)

PRACTICE Do these practice *for your own good*! Use them as a self-test to make sure you can do this step. You will be required to do it on the real test!

Which of the following algebraic expressions contain (a) parentheses, (b) brackets, (c) braces? Put an a, b, or c (or any combination of those letters) beside each expression, as appropriate.

1. $5-(x-3)$
2. $-\left[5x-(3-x)\right]$ ----------
3. $3+\left[5n-(2-n)\right]$ ----------
4. $8-\left\{6xy-\left[7-(2xy-5)\right]\right\}$ ---------- ----------

FIGURE 3-3. (Page 2 of 2 pages)

step 5 had been taught. The four backward chaining treatments taught step 5 first, then step 4, and so on until step 1 had been taught. With respect to contextual synthesis, the four treatments in which it was present provided a brief summary (in generality form) of the five steps. This summary appeared before the instruction in each step, and it indicated which step was about to be taught. An example of the contextual synthesizers is shown in Figure 3-4. Finally, with respect to performance synthesis, the treatments in which it was present provided an integrated generality, integrated examples, and integrated practice. More specifically, it presented a summary generality of all the steps which had already been taught, followed by three examples illustrating the use of all of those steps in solving specific problems, followed by two problems requiring the student to use all of those steps. The answers to these integrated practice items were handed out along with the answers to the regular practice items after the practice had been done by the students. The performance synthesizer was presented after each step, except for the first step that was taught. An example of the performance synthesizers is shown in Figure 3-5.

Insert Figures 3-4 and 3-5 about here

It should be noted that the groups which received synthesis received more instruction than did the other groups. Although this might be considered to be a confounding variable, the rationale for this decision is as follows. In

WHAT'S AHEAD?

Welcome to your lesson on how to add and subtract algebraic expressions. There is a series of activities that you need to learn to do in order to learn how to add and subtract algebraic expressions. These are:

* 1. Decide if there are symbols of grouping separating the terms.
   If yes, go to step 2.
   If no, go straight to step 4.

2. Is a grouping symbol (e.g. parenthesis) preceded by a minus sign?
   If yes, just go to step 3.
   If no, remove the grouping symbols and go to step 4.

3. Given a grouping symbol with a minus sign in front of it,

   a) Change the minus sign to a plus sign.
   b) Change the sign of each term within the grouping symbols.
   c) Remove the grouping symbols.

4. Group like terms under one another.

5. Add the terms.

* Now you will learn how to do this.

FIGURE 3-4. Contextual Synthesizer.

PUTTING THE STEPS TOGETHER

WHAT TO DO

You have learned the first two steps in adding and subtracting algebraic expressions. They are:

1. Decide if there are <u>symbols of grouping</u> separating the terms.
   - If yes, go to step 2.
   - If no, go straight to step 4.
2. Is a grouping symbol (e.g. parenthesis) preceded by a minus sign?
   - If yes, just go to step 3.
   - If no, remove the grouping symbols and go to step 4.

EXAMPLES of Steps 1 and 2 done together:

1. $4a+(3-2a)$

   $4a+3-2a$

   (1) There are parentheses.

   (2) None is preceded by a minus sign, so we remove the grouping symbols.

2. $-[5x+(3-x)]$

   $-[5x+3-x]$

   (1) This has brackets and parentheses.

   (2) The parentheses are not preceded by a - sign, so they are removed. The brackets are, so they remain.

3. $8-6xy-[7-(2xy-5)]-6-(xy-8)$

   (1) There are grouping symbols.

   (2) All are preceded by - signs.

IGURE 3-5. A performance synthesizer.

conversations with the students after the experiment ended, the vast majority (about 85 per cent) indicated that the instruction on each step included too many examples and practice and therefore that they did not study all of the ones that were provided. Hence, any additional examples and practice would not influence achievement. Also, it seemed likely that, in the real world to which we would like to generalize, synthesis is an extra component that would be added to the basic instruction rather than an element that would replace part of the basic instruction.

Tests and Measures

The posttest was the regularly scheduled course test on the rule. It was given the Monday following the week of instruction, and all students were required to take it. There were four versions of the test, but each version contained the same number of problems, and the corresponding problem on each version was identical except for the actual digit or letter that appeared at any given place in each algebraic expression. All versions of the test had undergone several years of development and revision by the Math Department and Syracuse University's Testing Services. The test was administered and graded by the Math department. The students were allowed a full class period to complete the test, and no prompting was given to any student. The test is shown in Figure 3-6.

Insert Figure 3-6 about here

Math 103 - Basic algebraic operations

I.

Simplify and collect like Terms:

a) $(2x-3) + [5x + (3x + 1)]$

b) $- [4x + (2x^2-3)-5x^2] + 7x$

c) $- (3x^2+3) - [4x^2-(2x^2+3)]$

d) $(7x-2) - [6x -(x-2)]$

II.

Perform indicated operation:

a) $(7xy^2)(-3x^2y)(-y^3)$

b) $(3a^2-2bc)(2a^2-3bc)$

c) $(-18y^2+30y^3-12y^4) \div (-6y)$

d) $(20x^2+11xy-3y^2) \div (4x+3y)$

III.

Solve for x: $a^3(x+c^2) - (4x-6) = 2(x-a)$

IV

The psychological theory of learning utilizes the expression (1-p)91+p-r). Perform the indicated multiplication.

FIGURE 3-6. The course exam. Only items which required addition or subtraction of algebraic expressions were scored for this experiment, and even then, only the addition or subtraction parts of those items.

Note: Items circled ◯ have been scored for this experiment.

After the tests had been graded by the instructors, we photocopied all tests and, for the posttest for this task, scored only those items which required addition and/or subtraction of algebraic expressions. Also, each such item was only scored for the correctness of the addition and/or subtraction operations that it entailed. Hence, even if the answer on the item was wrong, the student received credit if he or she had performed the addition or subtraction operation correctly. It an item required more than one subtraction and/or addition operation, each such operation was scored separately. A percentage score was obtained by dividing the total of correct addition and subtraction operations by the total number of addition and subtraction operations that were required by the test.

In addition to the posttest, which measured achievement, a questionnaire was developed to measure the students' attitudes about the sequence (see Figure 3-7). In order to try to reduce any "halo" effect from their attitudes about the instruction as a whole, the questionnaire first asked questions about the examples, practice, thoroughness of the materials, and self-instructional nature of the booklets. None of these questions were analyzed -- their function was solely to reduce the "halo" effect.

Insert Figure 3-7 about here

QUESTIONNAIRE ON YOUR NEW MATERIALS

--------------- Booklet number

--------------------- Name

This questionnaire is intended to help us to improve the new materials that you used recently. There are five aspects of the materials on which we would like your opinion. Please try not to let you opinion of one aspect influence your opinion of another aspect. Please rate each of your booklets separately.

Circle the appropriate number for each of the following:

How helpful were the examples?

no help 1 2 3 4 5 6 very helpful

How helpful were the practice exercises?

no help 1 2 3 4 5 6 very helpful

How much did you like the thoroughness of the materials?

disliked 1 2 3 4 5 6 liked a lot

How much did you like the independence of the booklets (e.g. being able to work at your own speed, etc.)?

disliked 1 2 3 4 5 6 liked a lot

How much did you like the sequence in which the steps were taught?

disliked 1 2 3 4 5 6 liked a lot

Any other comments or suggestions?

FIGURE 3-7. The attitude questionnaire. Only the last question was of interest for this study.

Procedure

The experiment began on a Monday (all four sections met on Mondays, Wednesdays, and Fridays) when Chapter 4 would have been introduced by the instructor. The students were provided with a brief notice explaining that a study was being conducted and providing some brief directions for the use of the materials (see Figure 3-8). Then the booklets containing the learning materials were randomly distributed within each section. Three-by-five cards were also distributed, and each student recorded his or her name and booklet number (treatment number) before returning the card to the instructor. The students completed their instructional materials during that class period, at which point they raised their hands and the materials for Experiment 2 were distributed in the same manner.

Insert Figure 3-8 about here

Either the principal investigator or an assistant watched the students during the class period to make sure that the booklets were studied in the proper order. When the class was over, the students took their booklets with them so that they would have them for review before the test the following Monday. The answers to the practice items were handed out at the next class (Wednesday). All classes were held in the regular classrooms, but the teacher did not make any presentations. Class time was used exclusively for studying the self-instructional materials. Students who were absent on

NOTICE TO STUDENTS

These are some learning materials that have been designed to make it easier for you to learn how to work algebraic problems using basic operations. But we want something from you in return.

We are collecting data on different ways of sequencing the instruction. This means that your classmates have booklets that are sequenced differently from yours, but all booklets contain all the same instruction. We anticipate that all sequences will result in your learning more than with the regular text.

Please ...

Do not look at anyone else's booklet until after the next two weeks are over.

Do not look at Chapter 4 in the text until after the next week is over. (These booklets contain all you need.)

Do not skip around in your booklets! Progress from front to back regardless of the way the steps are numbered.

You can can play an important role in improving this course. Please help us!

FIGURE 3-8. The notice provided to all students participating in the study.

that day were excluded from the study, but all other students in each class were included. If the instructor provided any special help to any students, either during class or outside of class, the nature of that help was recorded on the student's 3x5 card.

Some initial confusion was expressed by students who received the backward sequence, but it seemed to be mostly a problem of surprise and unfamiliarity with such an instructional sequence. This problem is discussed in more detail under Discussion below.

The posttest was administered on the following Monday during the regular classtime and in the regular classroom. The test contained items on other rules that they had learned during the same week. After the test, the students were asked to fill out an attitude questionnaire.

Results

1. Short Unitary Rule

On this rule, SAT was significantly correlated with posttest scores, $F\ (1,75) = 4.51$, $p=.037$, but was not significantly correlated with affect, $F\ (1,53) = 0.06$. SAT also met the homogeneity of slopes criterion with posttest scores, hence it was used as a covariate in the the analysis of the posttest data but not in the analysis of the affect data. Since this was such a short rule, we expected no differences on all three factors. Tables 1 and 2 show that there were in fact no significant main effects, but we were surprised to find a significant interaction on sequence x contextual synthesis for the posttest scores, $F(2,75) = 5.29$, $p < .025$. This interaction is shown graphically in Figure 3-9.

Insert Tables 1 and 2 and Figure 3-9 about here

TABLE 1

SUMMARY STATISTICS

for posttest scores for short unitary task

Factor	Adjusted Means, (Standard Deviations), and n's								F	p
Sequence	Forward 77.5 (2.97) 60				Backward 82.3 (2.25) 54				0.19	
Contextual Synthesis	Absent 79.4 (2.97) 56				Present 82.4 (2.36) 58				0.40	
Performance Synthesis	Absent 82.3 (2.41) 56				Present 81.3 (2.88) 58				0.05	
Sequence X Contextual Synthesis	Forw x Abs 73.0 (5.00) 29		Forw x Pres 86.0 (3.11) 31		Back x Abs 85.9 (2.77) 27		Back x Pres 78.8 (3.44) 27		5.29	0.024
Sequence X Performance Synthesis	Forw x Abs 78.9 (3.77) 27		Forw x Pres 80.1 (4.45) 33		Backw x Abs 82.1 (3.11) 29		Backw x Pre 82.6 (3.27) 25		0.01	
Contextual X Performance Synthesis	Abs x Abs 79.6 (3.67) 28		Abs x Pres 79.3 (4.68) 28		Pres x Abs 81.4 (3.17) 28		Pres x Pres 83.4 (3.49) 30		0.07	
Sequence X Contextual X Performance Synthesis	FAA 72.6 (6.74) 12	FAP 73.3 (7.22) 17	FPA 85.1 (3.89) 15	FPP 86.9 (4.87) 16	BAA 86.5 (3.89) 16	BAP 85.2 (3.92) 11	BPA 77.6 (4.95) 13	BPP 80.0 (4.93) 14	0.02	
								SAT	4.51	0.037

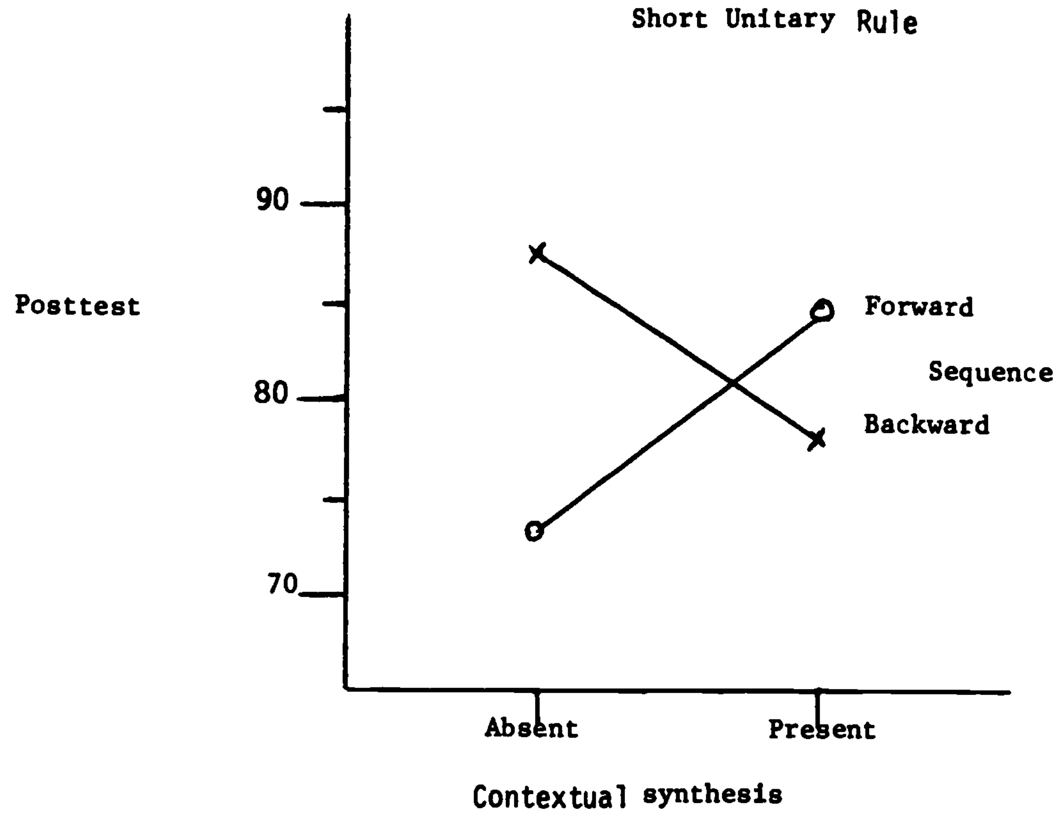
TABLE 2

SUMMARY STATISTICS

for affect scores for short unitary task

Factor	L.S. Means, (Standard Deviations), and n's								F	p
Sequence	Forward 2.71 (0.27) 43				Backward 2.37 (0.23) 40				0.04	
Contextual Synthesis	Absent 2.23 (0.23) 43				Present 2.42 (0.28) 40				0.36	
Performance Synthesis	Absent 2.30 (0.24) 44				Present 2.34 (0.27) 39				0.03	
Sequence X Contextual Synthesis	Forw x Abs 2.21 (0.39) 2[illegible]		Forw x Pres 2.33 (0.38) 22		Back x Abs 2.25 (0.27) 22		Back x Pre 2.50 (0.41) 18		0.06	
Sequence X Performance Synthesis	2.16 (0.36) 21		2.38 (0.40) 22		2.44 (0.32) 23		2.31 (0.34) 17		0.18	
Contextual X Performance Synthesis	Abs x Abs 1.91 (0.26) 25		Abs x Pres 2.55 (0.41) 18		Pres x Abs 2.69 (0.42) 19		Pres x Pre 2.14 (0.36) 21		2.62	
Sequence X Contextual X Performance Synthesis	FAA 1.82 (0.44 11	FAP 2.60 (.65) 10	FPA 2.50 (.58) 10	FPP 2.17 (.52) 12	BAA 2.00 (.23) 14	BAP 2.50 (.46) 8	BPA 2.39 (.63) 9	BPP 2.11 (.51) 9	0.01	

SAT 0.06


Short Unitary Rule
Posttest
90
80
70
Forward
Sequence
Backward
Absent
Present
Contextual synthesis

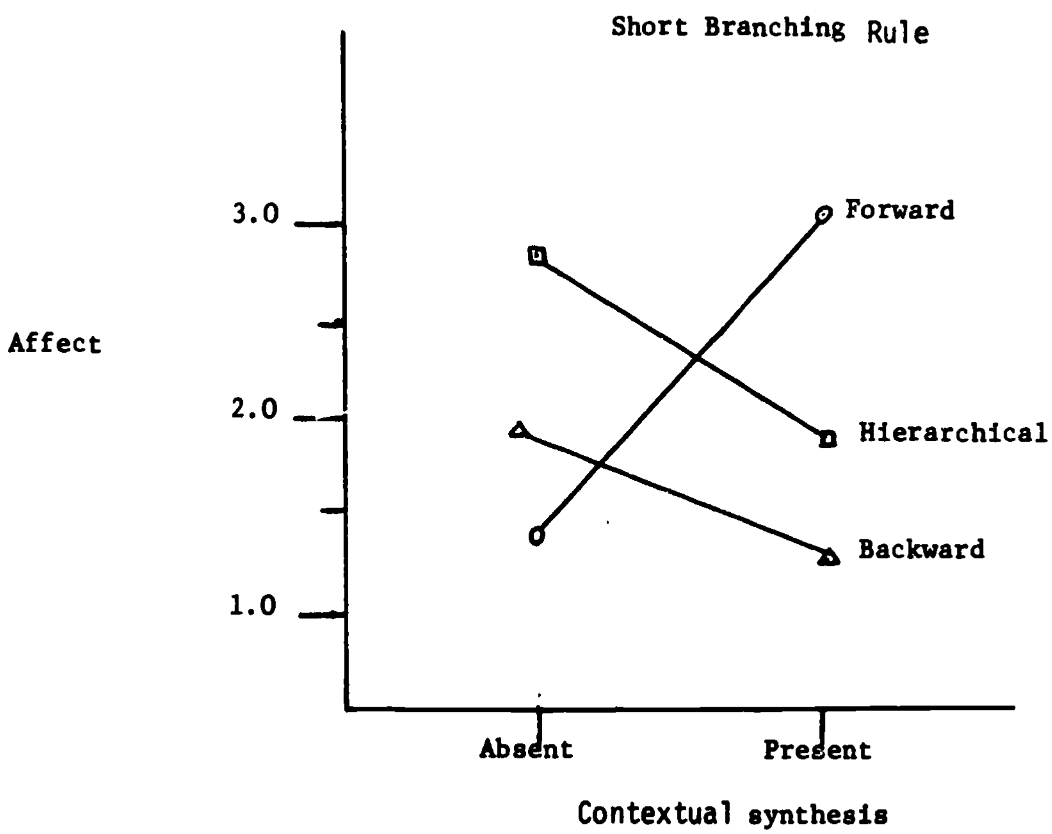

Short Branching Rule
Affect
3.0
2.0
1.0
Forward
Hierarchical
Backward
Absent
Present
Contextual synthesis

Figure 3-9

SECTION 4

EXPERIMENT 2

SHORT BRANCHING RULE

Methods

Design

This study also investigated sequencing, contextual synthesis, and performance synthesis, but it did so for a short branching rule rather than for a short unitary rule. (See Task and Materials below for details about the task.) By branching, we mean that the rule had several independent paths that could be followed from one or more decision steps. Since the task was very short, the hierarchical sequence turned out to be identical to the forward chaining sequence; hence it was not included in the design.

This left three sequences to be investigated: forward chaining, backward chaining, and elaboration. Hence, the statistical design was a 3x2x2 factorial design in which the factors were (1) sequence (forward chaining, backward chaining, and elaboration), (2) contextual synthesis (absence and presence), and (3) performance synthesis (absence and presence). The resulting 12 treatment groups are shown in Figure 4-1). Hence, the method of statistical analysis was ANOVA, but SAT scores were used as a covariate whenever the appropriate criteria were met (see Results section below).

Insert Figure 4-1 about here

The experimental design was a posttest-only design with a regular course test as the posttest.

Subjects

The students comprising the experimental sample were the same as those in Experiment 1 above. However, due to an impending holiday, the number of students who were present totaled only 71.

Instructional Task and Materials

The task for this study was the rule for multiplying algebraic expressions. It consisted of six major steps, one of which was further broken into five substeps, making a total of 10 steps (see Figure 4-2). This was a branching rule with three branches. However, as can be seen from Figure 4-2, three of the six major steps were decision steps. One of those three enabled the selection of the appropriate branch, another made it possible to skip a step, and the third made it possible to loop back to the beginning of the rule to multiply additional terms in the algebraic expression. It was a relatively short rule, requiring about three minutes to perform, on the average; and the instruction took about 50 minutes to complete.

Insert Figure 4-2 about here

		CONTEXTUAL SYNTHESIZER			
		Absent		Present	
		PERFORMANCE SYNTHESIZER		PERFORMANCE SYNTHESIZER	
		Absent	Present	Absent	Present
SEQUENCE	Forward	FAA	FAP	FPA	FPP
	Backward	BAA	BAP	BPA	BPP
	Elaboration	EAA	EAP	EPA	EPP

FIGURE 4-1. The twelvetreatment groups for experiment 2.

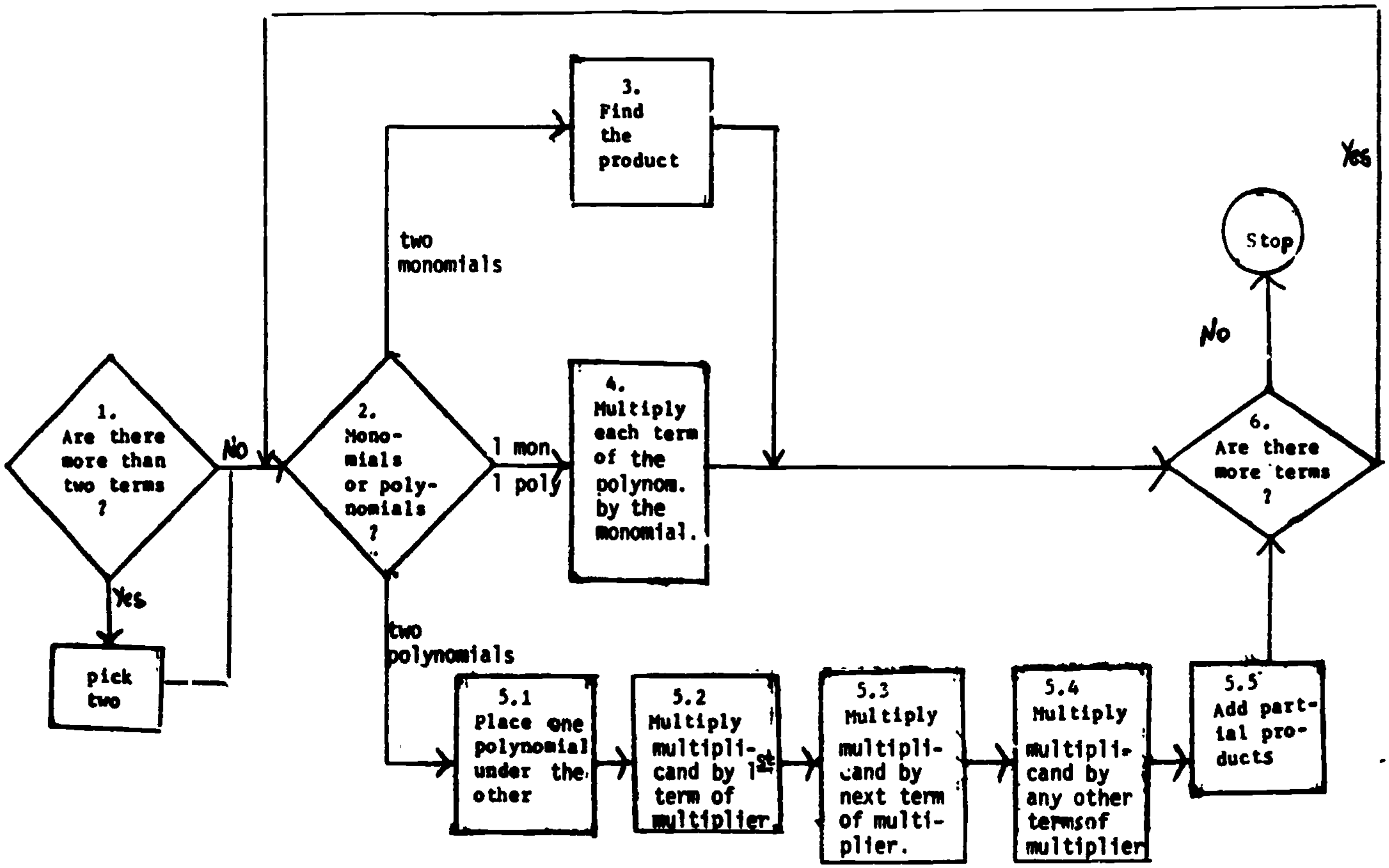


FIGURE 4-2. A flowchart of the rule for multiplying algebraic expressions.

The micro-level strategies within each step were the same as in Experiment 1, and they were held constant across all treatment groups in the same manner as in Experiment 1 (see Figure 4-3 for an example).

Insert Figure 4-3 about here

As in Experiment 1, the instruction was delivered in self-instructional booklets that replaced both the corresponding portion of Chapter 4 of the textbook and the corresponding class presentation.

Treatments

The 12 treatment groups differed only in the sequence in which the steps were presented and in the presence or absence of synthesis. The 12 groups are portrayed in Figure 4-1 above, and the following is a brief description of the characteristics of each.

The four forward chaining treatments taught step 1 first, then step 2, and so on until step 6 had been taught. The four backward chaining treatments taught step 6 first, then step 5.5, then step 5.4, and so on until step 1 had been taught. The four elaboration sequences taught steps 3, 2, and 4 in that order in Lesson 1, followed by steps 5.1, 5.2, and 5.3 in Lesson 2, and finally steps 5.5, 1, 5.4, and 6 in Lesson 3. These sequences are summarized in Figure 4-4.

HOW TO MULTIPLY ALGEBRAIC EXPRESSIONS

STEP 1

WHAT TO DO

Decide if there are more than two terms to be multiplied. (Since they are being used in multiplication, the terms are called <u>factors</u>.)

- If there are just 2 terms, then go to Step 2.
- If there are more than 2 terms, pick 2 of them and then go to step 2.

EXAMPLES

These are algebraic expressions which contain <u>more than two</u> terms to be multiplied:

1. $2 \bullet 4 \bullet 6$
2. $2(3+4)(2+6)$
3. $a \bullet b \bullet c$
4. $a(a+1)(a-1)$

PRACTICE

Do these practice <u>for your own good</u>! Use them as a self-test to make sure you can do this step. You will be required to do it on the real test!

Circle the number of all problems which contain <u>more than two</u> terms to be multiplied:

<u>Example</u>: 1. $4a(3b)(4b^2)$

1. $17 \bullet 35$
2. $(4a^2+2)(a-2)(a^2+1)(a+2)$
3. $7(x+3)(y-2)$
4. $(x+y)(x+z)$

FIGURE 4-3. An example of the micro strategies used to teach the individual steps of the rule.

Insert Figure 4-4 about here

The contextual synthesizer was different for the elaboration sequence than for the other two sequences because the Elaboration Theory calls for grouping the steps into lessons and using each lesson as the amount of instruction between synthesizers, whereas the various theoretical prescriptions related to both forward and backward chaining call for using each step as the amount of instruction between synthesizers (see Section 1 of this report). Otherwise the contextual synthesizers were the same: each presented a brief summary (in generality form) of all the steps before the instruction, and each indicated which step was about to be taught. An example of the contextual synthesizers for the elaboration sequence is shown in Figure 4-5, and the contextual synthesizer for the other two sequences is similar to that shown in Figure 3-4 above.

Insert Figure 4-5 about here

Finally, like the contextual synthesizer, the performance synthesizer was different for the elaboration sequence than for the other two sequences, for the same reason. Otherwise, the performance synthesizers were the same for all sequences: they presented an integrated generality, integrated examples, and integrated practice. An example of the performance

Forward

Step 1
Step 2
....
Step 3
....
Step 4
....
Step 5.1
....
Step 5.2
....
Step 5.3
....
Step 5.4
....
Step 5.5
....
Step 6
....

Backward

Step 5.5
Step 5.4
....
Step 5.3
....
Step 5.2
....
Step 5.1
....
Step 4
....
Step 3
....
Step 2
....
Step 1
....
Step 6
....

Elaboration

Step 3
Step 2
Step 4
....
Step 5.1
Step 5.2
Step 5.3
Step 5.5
....
Step 1
Step 5.4
Step 6
....

*Note: Dotted line indicates position of performance synthesis.

FIGURE 4-4. Summary of the three sequences in experiment 2.

WHAT'S AHEAD?

Welcome to your lesson on how to multiply algebraic expressions. There is a series of activities that you need to learn to do in order to learn how to multiply algebraic expressions. They are:

* 1. Decide if there are more than 2 terms to be multiplied.

   If there are just 2 terms, then go to step 2.
   If there are more than 2 terms, then pick 2 of them and go to step 2.

2. Look at each of the 2 factors (or terms), and decide if it is a monomial or a polynomial.

   If both terms are monomials, go to step 3.
   If there is one monomial and one polynomial, go to step 4.
   If both terms are polynomials, go to step 5.

3. For two monomials: find their product.

4. For one monomial and one polynomial: multiply each term of the polynomial by the monomial, keeping the + or - sign between each term in the product.

5. For two polynomials: multiply each term of the multiplier (the bottom number) by each term of the multiplicand, keeping the + or - sign in between each term in the product.

6. Decide if there are any more terms to be multiplied.

   If yes, take your product as one term and pick another term, and go to step 1 to begin the process of multiplying with those two terms.
   If no, you have finished the problem! Congratulations!

* You are about to learn this step.

FIGURE 4-5. Contextual Synthesizer

synthesizers for the elaboration sequence is shown in Figure 4-6, and the performance synthesizer for the other two sequences is similar to that shown in Figure 3-5 above.

Insert Figure 4-6 about here

Tests and Measures

The posttest was the same regularly scheduled course test as for Experiment 1. The test is shown in Figure 4-7.

Insert Figure 4-7 about here

After the tests had been graded, we photocopied all tests and, for the posttest for this task, scored only those items which required multiplication of algebraic expressions. Also, each such item was only scored for the correctness of the multiplication operations that it entailed. A percentage score was obtained by dividing the total of correct multiplication operations by the total number of multiplication operations that were required by the test.

To measure student attitude toward the sequence, we used a questionnaire identical to that used in Experiment 1 (see Figure 3-7 above).

Procedure

The booklet for this experiment was handed out to each student as soon as he or she completed the booklet for the

LESSON 1

PUTTING THE STEPS TOGETHER

WHAT TO DO

You just learned the three most fundamental steps in the process of multiplying algebraic expressions. They are (don't worry about the missing step no. 1--you don't need it yet):

2. Look at each of the two factors (or factors), and decide if it is a monomial or a polynomial.
   - If both factors are monomials, go to step 3.
   - If there is one monomial and one polynomial, go to step 4.
   - If both factors are polynomials, go to step 5.

3. For two monomials: find their product.

4. For one monomial and one polynomial: multiply each term of the polynomial by the monomial, keeping the + or - sign between each term as it appears in the product.

EXAMPLES of steps 2, 3, and 4 done together:

1. $2a^2 \bullet 4a^3$

   $8a^5$

   (2) Both factors are monomials, so we go to step 3.
   (3) We find the product of the two monomials.
   (4) (We did step 3 instead of this one.)

2. $2a(a^2+2)$

   $2a(a^2+2)$

$$\begin{array}{r} a^2+2 \\ 2a \\ \hline 2a^3+4a \end{array}$$

   (2) 2a is a monomial and a^2+2 is a polynomial, so we go to step 4.
   (3) (Do step 4 instead of step 3.
   (4) Multiply each term of the polynomial by the monomial.

PRACTICE

Do steps 2, 3, and 4 on the following problems:

1. $9x^2y(2x+1)$

2. $2mn \bullet m^2n^4$

FIGURE 4-6. Performance Synthesis

Math 103 - Basic algebraic operations

I.

Simplify and collect like Terms:

a) $(2x-3) + [5x + (3x + 1)]$

b) $- [4x + (2x^2-3)-5x^2] + 7x$

c) $- (3x^2+3) - [4x^2-(2x^2+3)]$

d) $(7x-2) - [6x -(x-2)]$

II.

Perform indicated operation:

a) $(7xy^2)(-3x^2y)(-y^3)$

b) $(3a^2-2bc)(2a^2-3bc)$

c) $(-18y^2+30y^3-12y^4) \div (-6y)$

d) $(20x^2+11xy-3y^2) \div (4x+3y)$

III.

Solve for x: $a^3(x+c^2) - (4x-6) = 2(x-a)$

IV

The psychological theory of learning utilizes the expression $(1-p)(1+p-r)$. Perform the indicated multiplication.

FIGURE 4-7. The course exam. Only items which required multiplication of algebraic expressions were scored for this experiment, and even then, only the multiplication parts of those items.

Note: Items circled have been scored for this experiment.

first experiment. Otherwise the procedures were identical for this study as for Experiment 1. No attempt was made to give any students the same treatment as in Experiment 1 -- the booklets were randomly distributed within each section as in Experiment 1.

Results

On this task, SAT was significantly correlated with posttest scores, $F\ (1,58) = 5.47$, $p=.023$, but was not significantly correlated with affect, $F\ (1,39) = 1.68$. SAT also met the homogeneity of slopes criterion with posttest scores, hence it was used as a covariate in the the analysis of the posttest data but not in the analysis of the affect data. Since this was such a short task, we also expected no differences on all three factors. Tables 3 and 4 show that there were in fact no significant effects for either achievement or affect.

Insert Tables 3 and 4 about here

TABLE 3

SUMMARY STATISTICS

for posttest stores for shortbranching task

Factor	Adjusted Means, (Standard Deviations), and n's												F	p
Sequence	Forward				Backward				Elaboration					
	89.1 (2.70) 30				81.5 (2.79) 31				78.3 (3.69) 37				0.98	
Contextual Synthesis	Absent						Present							
	86.0 (2.91) 49						80.0 (2.31) 49						0.53	
Performance Synthesis	Absent						Present							
	83.3 (2.72) 55						82.1 (2.41) 43						0.03	
Sequence X Contextual Synthesis	Forw x Abs		Forw x Pres		Back x Abs		Back x Pres		Elab x Abs		Elab x Pres			
	93.4 (6.49) 8		84.8 (2.93) 22		88.2 (2.60) 19		74.8 (5.91) 12		76.3 (5.64) 22		80.3 (3.97) 15		1.24	
Sequence X Performance Synthesis	Forw x Abs		Forw x Pres		Back x Abs		Back x Pres		Elab x Abs		Elab x Pres			
	89.5 (3.98) 17		88.7 (3.58) 13		80.3 (5.40) 10		82.7 (3.29) 21		80.0 (4.40) 28		76.7 (6.87) 9		0.06	
Contextual X Performance Synthesis	Abs x Abs			Abs x Pres			Pres x Abs			Pres x Pres				
	88.3 (4.83) 24			83.6 (3.41) 25			78.3 (3.12) 31			81.7 (3.17) 18			0.69	
Sequence X Contextual X Performance Synthesis	FAA	FAP	FPA	FPP	BAA	BAP	BPA	BPP	EAA	EAP	EPA	EPP		
	96.6 (10.07) 3	90.2 (9.23) 5	82.5 (4.49) 14	87.1 (1.66) 8	91.8 (3.11) 6	84.6 (3.4) 13	68.8 (8.96) 4	80.7 (6.96) 8	76.6 (7.37) 15	76.0 (8.77) 7	83.4 (4.55) 13	77.3 (5.0) 2	0.37	
SAT													5.47	0.023

81

TABLE 4

SUMMARY STATISTICS

for affect scores for shortbranching task

Factor	L.S. Means, (Standard Deviations), and n's												F	p
Sequence	Forward 2.55 (0.37) 20	Backward 1.50 (0.20) 23	Elaboration 2.14 (0.31) 28										2.92	0.062
Contextual Synthesis	Absent 2.24 (0.24) 34	Present 1.83 (0.26) 37											0.87	
Performance Synthesis	Absent 2.38 (0.24) 40	Present 1.85 (02.6) 31											0.84	
Sequence X Contextual Synthesis	Forw x Abs 1.50 (0.50) 4	Forw x Pres 2.82 (0.42) 16	Back x Abs 1.83 (0.28) 14	Back x Pres 1.17 (0.22) 9	Elab x Abs 2.78 (0.40) 16	Elab x Pres 1.50 (0.44) 12							2.40	0.0995
Sequence X Performance Synthesis	Forw x Abs 2.80 (0.48)	Forw x Pres 2.17 (0.58)	Back x Abs 1.50 (0.38)	Back x Pres 1.50 (0.24)	Elab x Abs 2.41 (0.34)	Elab x Pres 1.88 (0.75)							0.11	
Contextual X Performance Synthesis	Abs x Abs 2.59 (0.35) 17	Abs x Pres 1.97 (0.32) 17	Pres x Abs 1.93 (0.32) 23	Pres x Pres 1.72 (0.44) 14									0.01	
Sequence X Contextual X Performance Synthesis	FAA -- -- 0	FAP 1.50 (.50) 4	FPA 2.80 (.47) 10	FPP 2.83 (.87) 6	BAA 2.00 (.55) 5	BAP 1.67 (.33) 9	BPA 1.00 (.00) 3	BPP 1.33 (.33) 6	EAA 2.82 (.44) 12	EAP 2.75 (1.03) 4	EPA 2.00 (.52) 10	EPP 1.00 (.00) 2	0.69	

SAT 1.68

SECTION 5

EXPERIMENT 3

LONG UNITARY RULE

Methods

Design

This study also investigated sequencing, contextual synthesis, and performance synthesis, but it did so for a relatively long unitary rule. (See Task and Materials below for details about the task.) Again, because the rule was unitary and relatively short, the hierarchical sequence turned out to be identical to the forward chaining sequence; thus it was not included in the design.

Hence, the statistical design was also a 3x2x2 factorial design in which the factors were (1) sequence (forward chaining, backward chaining, and elaboration), (2) contextual synthesis (absence or presence), and (3) performance synthesis (absence or presence). The resulting 12 treatment groups are shown in Figure 5-1). The method of statistical analysis was ANOVA, but SAT scores were used as a covariate whenever the appropriate criteria were met (see Results below).

Insert Figure 5-1 about here

The experimental design was a posttest-only design (Campbell and Stanley, 1963), with a regular course test as the

		CONTEXTUAL SYNTHESIZER			
		Absent		Present	
		PERFORMANCE SYNTHESIZER		PERFORMANCE SYNTHESIZER	
		Absent	Present	Absent	Present
SEQUENCE	Forward	FAA	FAP	FPA	FPP
	Backward	BAA	BAP	BPA	BPP
	Elaboration	EAA	EAP	EPA	EPP

FIGURE 5-1. The twelve treatment groups for experiment 3.

posttest.

Subjects

The students comprising the experimental sample were the same as those in Experiments 1 and 2 above. However, due to an impending holiday, the number of students who were present totalled only 61.

Instructional Task and Materials

The task for this study was the rule for performing operations with exponential expressions. It consists of fourteen steps (see Figure 5-2). This is a unitary rule because it has no independent branches. However, as can be seen from Figure 5-2, it does contain 8 decision steps, each of which can result in the elimination of one of the 6 operations that comprise the rule. Although it is long for a unitary rule, this is still a relatively short rule, requiring an average of about ten minutes to solve a moderately sized problem; and the instruction took about 100 minutes to complete.

Insert Figure 5-2 about here

The micro-level strategies within each step were the same as in Experiments 1 and 2, and they were held constant across all treatment groups in the same manner (see Figure 5-3 for an example).

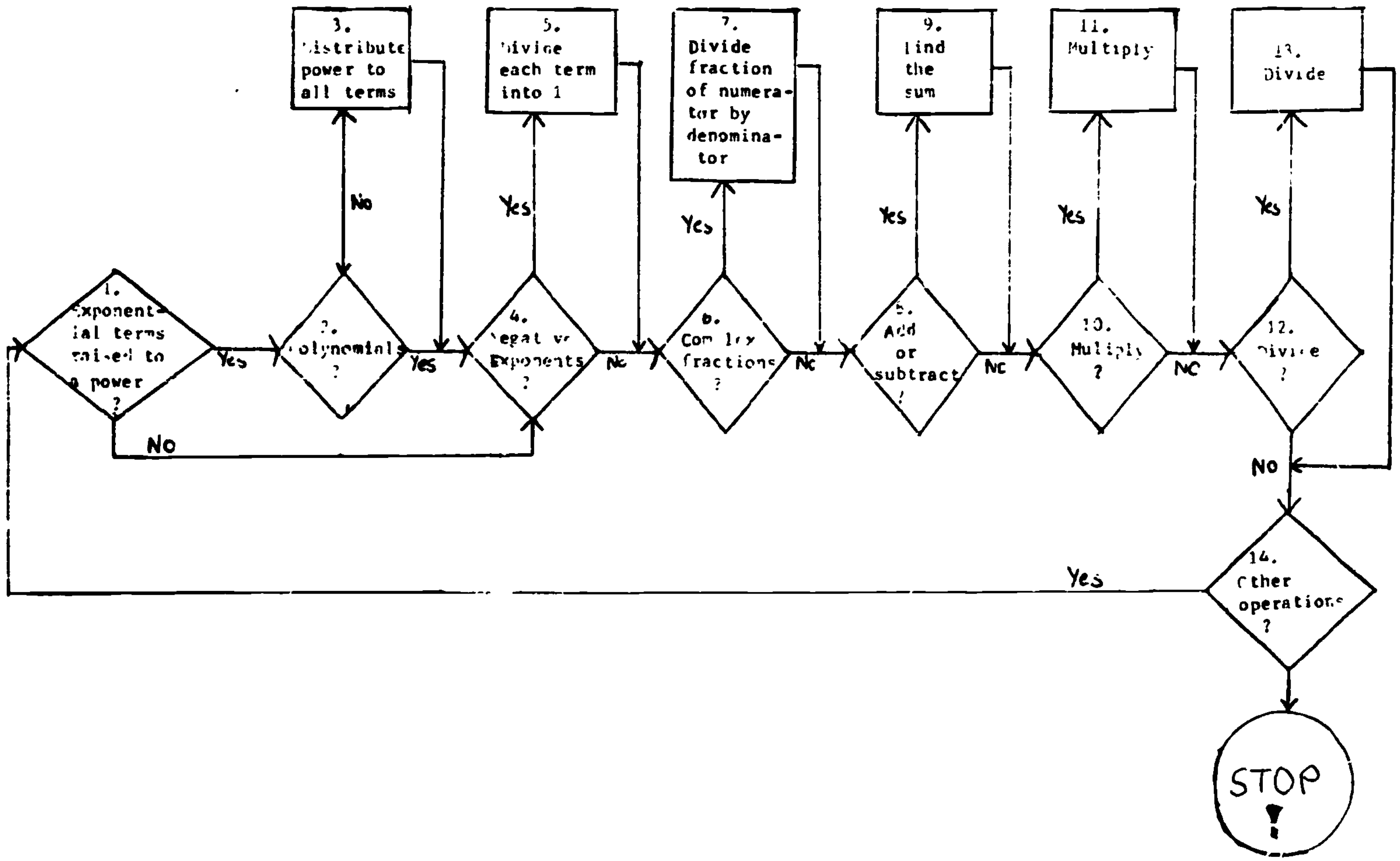


FIGURE 5-2. A flowchart of the rule for performing operations with exponential expressions.

Insert Figure 5-3 about here

As in Experiments 1 and 2, the instruction was delivered in self-instructional booklets that replaced both the corresponding portion of Chapter 4 of the textbook and the corresponding class presentation.

Treatments

The 12 treatment groups differed only in the sequence in which the steps were presented and in the presence or absence of synthesis. The 12 groups are portrayed in Figure 5-1 above, and the following is a brief description of the characteristics of each.

The four forward chaining treatments taught step 1 first, then step 2, and so on until step 14 had been taught. The four backward chaining treatments taught step 14 first, then step 13, and so on until step 1 had been taught. The four elaboration sequences taught steps 8-11 in that order in Lesson 1, followed by steps 4, 5, 12, and 13 in Lesson 2, steps 1-3 in Lesson 3, and finally steps 6, 7, and 14 in Lesson 4. These sequences are summarized in Figure 5-4.

Insert Figure 5-4 about here

As in Experiment 2, the contextual synthesizer was different for the elaboration sequence than for the other two

STEP 6

WHAT TO DO

Determine if there are any complex fractions.

- If yes, go to step 7.
- If no, go to step 8.

<u>Definition</u>: A COMPLEX FRACTION is a fraction in which the numerator or denominator (or both) has a fraction as a term.

EXAMPLES

$$\frac{a^2}{\frac{c}{d}} \qquad \frac{\frac{x^2}{y^2}}{\frac{x}{y}} \qquad \frac{2p}{\frac{p}{t}} \qquad \frac{x + \frac{a}{b}}{y - \frac{c}{d}}.$$

PRACTICE Do at least the last few of these <u>for your own good</u>! Use them as a self-test.

Circle the number of all problems which have complex fractions.

1. $\dfrac{\frac{3}{4}}{\frac{5}{8}}$

2. $\left(\dfrac{1}{1+i}\right)\left(1 - \dfrac{1}{1+i}\right)$

3. $\dfrac{\frac{1}{1+i}}{1 - \frac{1}{1-i}}$

4. $\dfrac{x + \frac{a}{b}}{y}$

5. $\left[x(x^2y^3z)\right] \div \left[y\;(x^2yz^2)\right]$

6. $\dfrac{x}{y - \frac{a}{d}}$

<u>Note</u>: Check your answers with the ones given on the answer sheet.

FIGURE 5-3. An example of the micro strategies used to teach the individual steps of the rule.

Forward	Backward	Elaboration
Step 1	Step 13	Step 8
Step 2	Step 12	Step 9
....	....	Step 10
Step 3	Step 11	Step 11
....	....	....
Step 4	Step 10	Step 4
....	....	Step 5
Step 5	Step 9	Step 12
....	....	Step 13
Step 6	Step 8	....
....	....	Step 1
Step 7	Step 7	Step 2
....	....	Step 3
Step 8	Step 6	....
....	....	Step 6
Step 9	Step 5	Step 7
....	....	Step 14
Step 10	Step 4	....
....	....	
Step 11	Step 3	
....	....	
Step 12	Step 2	
....	....	
Step 13	Step 1	
....	....	
Step 14	Step 14	
....	....	

*Note: Dotted line indicates position of performance synthesis.

FIGURE 5-4. Summary of the three sequences in experiment 3.

sequences, for the same reason. Otherwise the contextual synthesizers were the same: each presented a brief summary of all the steps before the instruction and each indicated which step was about to be taught. An example of the contextual synthesizers for the elaboration sequence is shown in Figure 5-5, and the contextual synthesizer for the other two sequences is similar to that shown in Figure 3-4 above.

Insert Figure 5-5 about here

Finally, like the contextual synthesizer, the performance synthesizer was different for the elaboration sequence than for the other two sequences, also for the same reason. Otherwise, the performance synthesizers were the same for all sequences: they presented an integrated generality, integrated examples, and integrated practice. An example of the performance synthesizers for the elaboration sequence is shown in Figure 5-6, and the performance synthesizer for the other two sequences is similar to that shown in Figure 3-5 above.

Insert Figure 5-6 about here

Tests and Measures

The posttest was the same regularly scheduled course test as for Experiments 1 and 2. The test is shown in Figure 5-7.

Insert Figure 5-7 about here

SEGMENT 4
WHAT'S AHEAD?

Welcome to Segment 4 of your lesson on operations with exponents. Remember what the whole process is like:

1. Decide if there are any exponential terms or expressions raised to a power.

2. Decide if the exponential expression that is raised to a power is a polynomial.

3. If a monomial exponential expression is raised to a power, then distribute the power to all terms within the grouping symbols that the exponent applies to.

4. Decide if there are any negative exponents.

5. If there are any negative exponents, then rewrite them as positive by dividing each term that has a negative exponent into 1 (or placing 1 over the term).

* 6. Decide if there are any complex fractions.

* 7. If there are any complex fractions, rewrite them by dividing the fraction in the numerator by the fraction in the denominator.

8. Decide if you must add or subtract.

9. If you must add or subtract, find the algebraic sum using the method you have learned in the lesson on addition and subtraction, and write the results in standard format and with proper signs.

10. Decide if you must multiply.

11. If you must multiply, then multiply the terms or expressions as indicated, using the method you have learned in the lesson "Multiplication of Algebraic Expressions."

12. Decide if you must divide.

13. If you must divide, then divide the terms or expressions as indicated, using the methods you learned in the lesson "Division of Algebraic Expressions."

* 14. Decide if there are any other operations to be performed.
    If yes, go back to step 1 to do the next one.
    If not, you are done with this problem. Hurray!

* In Segment 4 you will learn these steps. They represent all the remaining steps.

FIGURE 5-5. Contextual Synthesizer

SEGMENT 1

PUTTING THE STEPS TOGETHER

WHAT TO DO

You have just learned steps 8, 9, 10, and 11 of the process of doing operations with exponents. They are:

8. Determine if you must add or subtract.

9. If you must add or subtract, then find the algebraic <u>sum</u> using the method you have learned in the lesson on addition and subtraction, and write the results in standard format and with proper signs.

10. Determine if you must multiply.

11. If you must multiply, then multiply the terms or expressions as indicated, using the method you have learned in the lesson "Multiplication of Algebraic Expressions."

EXAMPLE of steps 8 - 11 done together:

Problem: $\left\{\left[a^3+a^2-a^3+2a^3+a^2+2a+ab+3a+b+3+2\right]\div\left[a+1\right]\right\}$

$$-\left[\frac{3b(b-1)}{-b+1}\right]+b^{-1}\left[(2^{-1}b^{-1})^{-2}+b\right]$$

<u>Steps</u>:

8. Must you add or subtract?

   Yes ==> $\left[a^3+a^2-a^3+2a^3+a^2+2a+ab+3a+b+3+2\right]$

9. Find the sum:

   $\left[a^3+a^2-a^3+2a^3+a^2+2a+ab+3a+b+3+2\right]$

   ==> $\left[2a^3+2a^2+5a+ab+b+5\right]$

10. Must you multiply?

    Yes

11. Find the product:

    $3b(b-1)$

    ==> $\left[\frac{3b^2-3b}{-b+1}\right]$

FIGURE 5-6. Performance Synthesis (1st Page of 2)

Math 103 - Basic algebraic operations

I.

Simplify and collect like Terms:

a) $(2x-3) + [5x + (3x + 1)]$

b) $- [4x + (2x^2-3)-5x^2] + 7x$

c) $- (3x^2+3) - [4x^2-(2x^2+3)]$

d) $(7x-2) - [6x -(x-2)]$

II.

Perform indicated operation:

a) $(7xy^2)(-3x^2y)(-y^3)$

b) $(3a^2-2bc)(2a^2-3bc)$

c) $(-18y^2+30y^3-12y^4) \div (-6y)$

d) $(20x^2+11xy-3y^2) \div (4x+3y)$

III.

Solve for x: $a^3(x+c^2) - (4x-6) = 2(x-a)$

IV.

The psychological theory of learning utilizes the expression (1-p)91+p-r). Perform the indicated multiplication.

FIGURE 5-7. The course exam. Only items which required operations with exponents were scored for this experiment, and even then, only the exponential parts of those items.

<u>Note</u>: Items circled ◯ have been scored for this experiment.

$\boxed{\text{PRACTICE}}$ Do steps 8 - 11 on the following problems:

1. $(a+2)^3$

2. $b^2(a+b)^2$

3. $\left[4(a^{-1})^{-3}\right]\left[3(a^{-1})^{-2}\right]$

FIGURE 5-6. (2nd Page of 2)

After the tests had been graded, we photocopied all tests and, for the posttest for this task, scored only those items which required operations with exponential expressions. Also, each such item was only scored for the correctness of the operations with exponential expressions that it entailed. A percentage score was obtained by dividing the total of correct operations with exponential expressions by the total number of such operations that were required by the test.

To measure student attitude toward the sequence, we used a questionnaire identical to that used in Experiments 1 and 2 (see Figure 3-7 above).

Procedure

The booklet for this experiment was handed out to each student on a Wednesday, after he or she completed the booklet for Experiment 2. Otherwise the procedures were identical for this study as for Experiments 1 and 2. No attempt was made to give any students the same treatment as in either Experiment 1 or 2 -- the booklets were randomly distributed within each section as in Experiments 1 and 2.

Results

On this task, SAT was significantly correlated with posttest scores, $F\ (1,48) = 5.09$, $p = .029$, but was not significantly correlated with affect, $F\ (1,31) = 0.49$. SAT also met the homogeneity of slopes criterion with posttest scores, hence it was used as a covariate in the the analysis of the posttest data but not in the analysis of the affect data. Since this was a moderately short rule, we expected moderate, or barely detectable, differences on all factors. Tables 5 and 6 show that there was a barely detectable difference on sequence, $F\ (2,48) = 3.37$, $p=.043$. However, contrary to expectations, the forward chaining sequence resulted in the best test scores and the elaboration sequence resulted in the worst. There were no significant differences on posttest scores for either type of synthesis, and there were no significant differences on affect scores for any of the effects.

Insert Tables 5 and 6 about here

TABLE 5

SUMMARY STATISTICS

for posttest scores on long unitary task

Factor	Adjusted Means, (Standard Deviations), and n's												F	p
Sequence	Forward 91.2 (1.89) 31				Backward 86.5 (3.91) 26				Elaboration 77.1 (4.67) 25				3.37	0.043
Contextual Synthesis	Absent 87.5 (2.65) 38						Present 82.4 (3.36) 44						0.71	
Performance Synthesis	Absent 89.6 (2.85) 43						Present 80.3 (3.36) 39						2.58	0.11
Sequence X Contextual Synthesis	Forw x Abs 91.3 (3.37) 13		Forw x Pres 91.1 (2.21) 18		Back x Abs 88.8 (3.27) 13		Back x Pres 84.2 (7.16) 13		Elab x Abs 82.3 (6.13) 12		Elab x Pres 72.0 (7.05) 13		0.28	
Sequence X Performance Synthesis	Forw x Abs 91.6 (2.85) 16		Forw x Pres 90.8 (2.42) 15		Back x Abs 94.0 (2.97) 15		Back x Pres 79.1 (8.08) 11		Elab x Abs 83.2 (7.54) 12		Elab x Pres 71.1 (5.96) 13		1.26	
Contextual X Performance Synthesis	Abs x Abs 91.7 (3.86) 19			Abs x Pres 83.2 (3.68) 19			Pres x Abs 87.4 (4.11) 24			Pres x Pres 77.4 (5.63) 20			0.00	
Sequence X Contextual X Performance Synthesis	FAA 95.9 (4.59) 7	FAP 86.8 (5.41) 6	FPA 87.2 (3.78) 9	FPP 94.9 (1.43) 9	BAA 92.9 (3.09) 8	BAP 84.7 (6.89) 5	BPA 95.0 (5.53) 7	BPP 73.5 (14.1 6	EAA 86.4 (13.71 4	EAP 78.2 (6.69) 8	EPA 80.0 (9.68) 8	EPP 63.9 (10.99) 5	1.07	
												SAT	5.09	0.029

TABLE 6

SUMMARY STATISTICS
for affect scores for long unitary task

Factor	Means, (Standard Deviations), and n's												F	p
Sequence	Forward 2.31 (0.33) 23				Backward 1.83 (0.36) 19				Elaboration 1.73 (0.23) 19				0.98	
Contextual Synthesis	Absent 2.02 (0.27) 27						Present 1.89 (0.25) 34						0.04	
Performance Synthesis	Absent 1.91 (0.29) 29						Present 2.00 (0.23) 32						0.07	
Sequence X Contextual Synthesis	Forw x Abs 2.60 (0.54) 10		Forw x Pres 2.02 (0.41) 13		Back x Abs 1.50 (0.38) 8		Back x Pres 2.17 (0.[illegible]) 11		Elab x Abs 1.95 (0.37) 9		Elab x Pres 1.50 (0.31) 10		1.22	
Sequence X Performance Synthesis	Forw x Abs 2.46 (0.56) 11		Forw x Pres 2.16 (0.40) 12		Back x Abs 1.50 (0.50) 10		Back x Pres 2.17 (0.52) 9		Elab x Abs 1.77 (0.38) 8		Elab x Pres 1.69 (0.31) 11		0.54	
Contextual X Performance Synthesis	Abs x Abs 1.98 (0.43) 13			Abs x Pres 2.06 (0.36) 14			Pres x Abs 1.84 (0.41) 16			Pres x Pres 1.94 (0.32) 18			0.00	
Sequence X Contextual X Performance Synthesis	FAA 2.60 (.93) 5	FAP 2.60 (.68) 5	FPA 2.33 (.72) 6	FPP 1.71 (.47) 7	BAA 1.00 (.00) 5	BAP 2.00 (1.0) 3	BPA 2.00 (1.0) 5	BPP 2.33 (.67) 6	EAA 2.33 (.88) 3	EAP 1.33 (.33) 6	EPA 1.20 (.20) 5	EPP 1.80 (.58) 5	0.73	
												SAT	0.49	

SECTION 6

EXPERIMENT 4

LONG BRANCHING RULE

Methods

Design

This study investigated sequencing, contextual synthesis, and performance synthesis for a long branching rule in the area of English composition. Initially, four sequences were planned, but one of the four sequences, backward chaining, was dropped from the study, and the students originally receiving that treatment were randomly assigned to one of the other three treatments. It was found during the first class period that students were confused by the backward sequence and angered by it, and to insist that they continue would have caused the entire experiment to be dropped by the instructors. The problem originated in the fact that the proper inputs for backward chaining weren't provided for all steps, so that students were not given enough prior information to be able to complete some steps successfully, and because the steps were labeled with their forward numbers, so that backward chaining students felt that they were working in an inferior or illogical order.

Hence, the statistical design was a 3x2x2 factorial design. The factors were (1) sequence (forward chaining, hierarchical, and elaboration), (2) contextual synthesis (absence and presence), and (3) performance synthesis (absence and presence). Thus, for any single sequence there were four versions -- one without synthesizers, one with only a contextual synthesizer, one with only a performance synthesizer, and one with both types of synthesizer (see Figure 6-1). Hence, the method of statistical analysis was ANOVA, with English SAT scores being used as a covariate whenever the appropriate criteria were met (see Results below).

Insert Figure 6-1 about here

The experimental design was a posttest only design, with each student writing a final essay as the posttest.

Subjects

Subjects in the study were students enrolled in thirteen sections of Freshman English at Syracuse University, whose instructors volunteered to allow their students to participate. The 224 students thus selected were freshmen who had (1) scored below 550 on their English SAT tests, (2) failed the Freshman English Exemption exam (taken if their scores were over 550) or (3) did not enter with advanced placement credit. Out of a class of approximately 3,000 freshman, only 180 students were not required to take Freshman English.

Those required to take Freshman English have to attend at least four weeks of the class, after which time, if they write two consecutive "pass" essays, they may transfer out. In any

	CONTEXTUAL SYNTHESIZER			
	Absent		Present	
	Performance Synthesizer		Performance Synthesizer	
	Absent	Present	Absent	Present
Forward	FAA	FAP	FPA	FPP
Elaboration	EAA	EAP	EPA	EPP
Hierarchical	HAA	HAP	HPA	HPP

FIGURE 6-1. The twelve treatment groups for experiment 4.

successfully written the two consecutive essays or they must take the course over again. At the time of this study, the students had completed two and one half weeks of work in the class. Some students had already written one pass essay, while others had not.

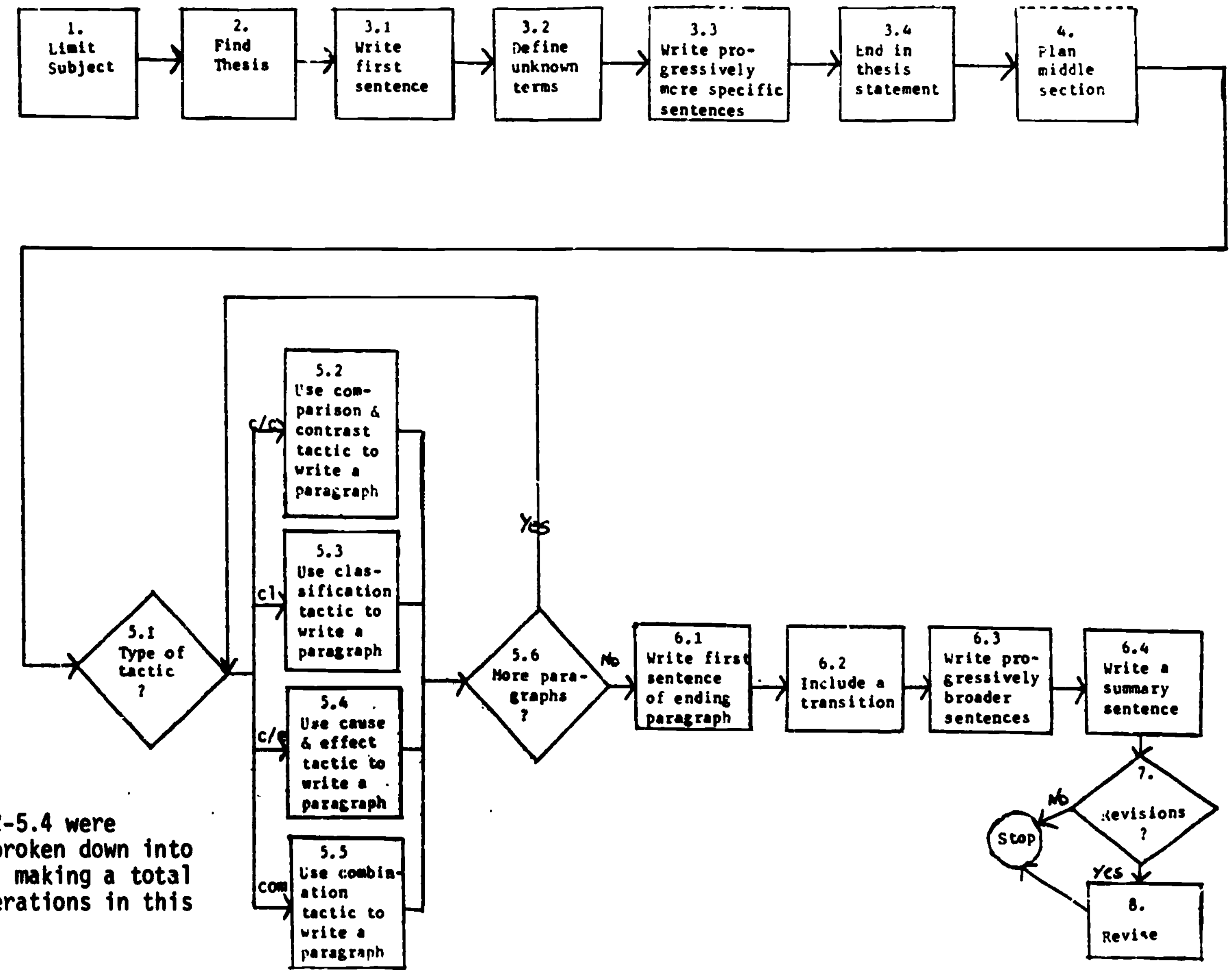
The students within each section were randomly assigned to one of sixteen different treatment groups.

Instructional Task and Materials

The task for this study was how to write an argumentative essay. It required using the elements of beginning, middle and concluding paragraphs and both choosing and using argumentative tactics, such as classification, comparison and contrast, and cause and effect. The rule contained a total of 24 operations, including 3 decision steps and 4 distinct branches (see Figure 6-2). The rule is moderately long, taking about 40-60 minutes to perform and, according to the instructors' estimation, about 7 1/2 hours (in class and as homework) to learn, on the average.

Insert Figure 6-2 about here

All of the treatment groups were provided with self-instructional booklets, which replaced both the textbook -- *The Practical Stylist* by Sheridan Baker -- and in class presentations by the instructor. Each booklet used the same steps on how to write an argumentative essay, and the



<u>Note</u>: Steps 5.2-5.4 were further broken down into substeps, making a total of 24 operations in this rule.

FIGURE 6-2. A flowchart of the rule for writing an argumentative essay.

treatment groups. The instruction on each step contained the following components in the indicated order: (1) a generality, which explained what to do and how to do it in terms that applied to the writing of all argumentative essays, (2) two examples, each of which illustrated the use of the step in one specific case, (3) two practice items, each of which required the student to use the step in a new case, and (4) sample answers for each practice item, so that the instructors did not have to grade extra papers, yet the students would receive corrective feedback on the practice items. See Figure 6-3 for a sample of these strategy components. Also, the wording of each of the components was identical for each step except in those few cases where the sequence required a different transition statement or direction to the students. Therefore, the instruction on each individual step was the same in each treatment group. The aspects that varied among the groups -- the sequence of the steps and the presence or absence of synthesis -- are described under "Treatments" below.

Insert Figure 6-3 about here

The instructors did not make any class presentations during the two-week experimental period, but they did answer questions individually for students as they worked through materials during the class periods. They also spent about 1/2 hour each of the two weeks in giving the students information on topics which they could write on during the essay-writing periods. These involved issues and supporting ideas, but did

STEP 5.3.2

WHAT TO DO

Make your topic sentence cover the major point of your paragraph.

Note A: The topic sentence is the first sentence of the paragraph.

EXAMPLES of topic sentences:

1. For a middle paragraph of an essay on problems encountered in building the Panama Canal:

<u>The first problem encountered was political in nature.</u> A French company, organized in 1881 to dig, had already begun...

The topic sentence covers the major point of the paragraph.

2. For a middle paragraph of an essay on the advantages of a broad liberal education:

<u>One of the first benefits is that such an education prepares you for a world of changing employment possibilities and opportunities.</u> The economic sphere can radically alter the job market...

The topic sentence covers the major point of the paragraph.

PRACTICE

For each of the following major points, write a topic sentence for each one.

1. Prohibiting the sale of marijuana in the United States.

2. The main signs of our present economic crisis.

FIGURE 6-3. An example of the micro strategies used to teach the individual steps of the rule.

not include elements of how to write beginning, middle or end paragraphs, nor tactics to use in argumentation.

Treatments

The twelve treatment groups differed only in the sequence in which the steps were presented and in the presence or absence of synthesis. The twelve groups are portrayed in Figure 6-1 above, and the following is a brief description of the characteristics of each.

With respect to sequence, the four forward chaining treatments taught the steps in the order in which an argumentative essay is written; the four hierarchical treatments followed Gagne's theory of working from simpler component skills to more complex higher-level skills, and the four elaboration treatments followed the Elaboration Theory's notion of beginning with the simplest level of writing an argumentative essay, and elaborating on this "epitome" with progressively more complexity. These sequences are summarized in Figure 6-4.

Insert Figure 6-4 about here

There were four possible versions of each sequence, depending upon the presence or absence of contextual and performance synthesizers. As in the previous experiments, the contextual synthesizers provided a preview in the form of a short-form generality of all eight steps in the rule. If the step that was about to be taught was divided into substeps, the

Forward

Step 1
Step 2
....
Step 3.1
Step 3.2
Step 3.3
....
Step 4
Step 5.1
Step 5.2.1
Step 5.2.2
Step 5.2.3
Step 5.2.4
Step 5.2.5
....
Step 5.3.1
Step 5.3.2
Step 5.3.3
Step 5.3.4
Step 5.3.5
....
Step 5.4.1
Step 5.4.2
Step 5.4.3
Step 5.4.4
Step 5.4.5
....
Step 5.5
Step 6.1
Step 6.2
Step 6.3
....
Step 7
Step 8
....

Elaboration

Step 1
Step 2
....
Step 3.1
Step 3.2
Step 3.3
....
Step 4
Step 5.1
....
Step 5.3.1
Step 5.4.1
Step 5.2.3
Step 5.3.3
Step 5.4.3
Step 6.2
Step 5.2.5
Step 5.3.5
Step 5.4.5
Step 5.2.2
Step 5.2.4
....
Step 5.3.2
Step 5.3.4
....
Step 5.4.2
Step 5.4.4
....
Step 5.5
....
Step 6.1
Step 6.3
....
Step 7
Step 8
....

Hierarchical

Step 1
Step 2
Step 5.3.1
Step 5.3.2
Step 5.3.3
Step 5.3.4
Step 5.3.5
Step 7
Step 8
....
Step 5.1
Step 5.4.1
Step 5.4.2
Step 5.4.3
Step 5.4.4
Step 5.2.1
Step 5.2.2
Step 5.2.3
Step 5.2.4
Step 5.2.5
Step 5.5
....
Step 3.1
Step 3.2
Step 3.3
Step 4
Step 6.1
Step 6.2
Step 6.3
....

Note: Dotted line indicates position of performance synthesis.

FIGURE 6-4. Summary of the three sequences in experiment 4.

contextual synthesizer also provided a concise generality for all of those substeps; and if the substep that was about to be taught was divided into sub-substeps, it also provided a concise generality for all of those sub-substeps. An example of the contextual synthesizers is shown in Figure 6-5. The performance synthesizers, as in the previous studies, provided a review of the steps that had been taught. This review took the form of a concise generality for all those steps, integrated examples illustrating all those steps, and integrated practice in applying all those steps. In the forward chaining sequence, the performance synthesizer was presented after each step except for the first step. But in the hierarchical and elaboration sequences, it was only presented after each lesson (see dotted lines in Figure 6-4). An example of the performance synthesizers is shown in Figure 6-6.

Insert Figures 6-5 and 6-6 about here

Tests and Measures

The posttest was the essay given during the sixth class meeting, and it required the students to write an argumentative essay on one of the subjects on which their instructors had prepped them during a previous class session. For example, the topic might have been arguing for or against experimental or trial marriage. Thus, the students were asked to use in a new situation the skills they had learned during the instruction.

WHAT'S AHEAD?

Now that you are about to learn step 5.3, you might like to know that it is made up of five major activities:

5.3.1 Think of each middle paragraph as a rectangular frame containing approximately five sentences.
5.3.2 Make your topic sentence cover the major point of your paragraph.
5.3.3 Insert a transition (from the paragraph above) into your topic sentence.
5.3.4 Continue to develop your paragraph using the tactic of classification.
5.3.5 End your paragraph in a sentence which summarizes what has been covered in the paragraph.

Remember how step 5.3 fits into step 5:

5.1 Pick the first (next) entry in your outline and decide which type of paragraph is appropriate.
5.2 Use the tactic of comparison and contrast to develop your middle paragraph.
5.3 Use the tactic of classification to develop your middle paragraph.
5.4 Use the tactic of cause and effect to write your paragraph.
5.5 Use a combination of tactics to develop your middle paragraphs. Choose the most appropriate tactic, and refer back to the section on each.

Also, remember how step 5 fits into the whole process of writing an argumentative essay:

1. Limit your subject.
2. Find a thesis for your essay by taking a stand on your subject.
3. Write the beginning paragraph by structuring it like a funnel.
4. Plan the middle section, outlining your major points.
5. Write each of your middle paragraphs, structuring each like a miniature essay.
6. Write the end paragraph by structuring it like an upsidedown funnel.
7. Review the essay to determine if revisions are needed.
8. Revise.

FIGURE 6-5. Contextual Synthesizer

Lesson 1 (Cont.)

PUTTING THE SUBSTEPS TOGETHER

WHAT TO DO

This is a summary of what you need to do to write a mini-essay (a single paragraph):

1. Limit your subject.
   (You studied this earlier in this course.)

2. Find a thesis for your essay (paragraph) by taking a stand on your subject.
   (You also studied this earlier in the course.)

5.3 Use the tactic of classification to develop your middle paragraph. This is done as follows:

  5.3.1 Think of each middle paragraph as a rectangular frame containing approximately five sentences.

  5.3.2 Make your topic sentence cover the major point of your paragraph.

  5.3.4 Continue to develop your paragraph using the tactic of classification, and arrange your points from least to most important.

  5.3.5 End your paragraph in a sentence which summarizes what has been covered in the paragraph.

7. Review the essay (paragraph) to determine if revisions are needed.

8. Revise, if necessary.

EXAMPLES Here are some examples of all the above steps being used together:

Comments:

1. Problems with building the Panama Canal

Step 1. The subject was limited to problems with building the Panama Canal.

Building the Panama Canal was very difficult for three reasons:
   a) Political problems
   b) Geological problems
   c) Human survival

Step 2. The thesis was developed by taking a stand on the subject.

FIGURE 6-6. Performance Synthesis (1st Page of 3)

Step 5.3.1 We then think of the essay (paragraph) as containing approximately five sentences.

Step 5.3.2 We then write the topic sentence to cover the major point of the paragraph.

Building the Panama Canal posed problems of politics, geology, and human survival.

A French company was organized in 1880 to dig the canal. Uneasy about the French, the United States made treaties with Nicaragua and Costa Rica to dig along the other most feasible route. This political threat, together with the failure of the French and the revolt of Panama from Colombia, finally enabled the United States to buy the French rights and negotiate new treaties, which continue to cause political problems to this day. Geology also posed its ancient problems: how to manage torrential rivers and inland lakes; whether to build a longer but more enduring canal at sea level, or a shorter but cheaper and safer canal with locks. But the problem of yellow fever and malaria, which had plagued the French, remained. By detecting and combatting the fever-carrying mosquito, William Gorgas, solved these ancient health problems.

Step 5.3.4 We continue to develop the paragraph using the tactic of classification.

Step 5.3.5 Next, we end the paragraph (essay) with a sentence which emphasizes what has been covered in the paragraph (essay).

Without him, the political and geological solutions would have come to nothing.

Step 7. We review the essay (paragraph) to determine if revisions are needed.

The section from "Geology also posed its ancient problems ..." to "but the problem of yellow fever ..." is found to be in need of revision, because it represents an economic decision and not a real problem in the building of the Panama Canal.

Step 8. We make the necessary revisions.

so it is revised to read "Geology also posed the problem of how to manage torrential rivers and inland lakes. But the problem of yellow fever ..."

FIGURE 6-6. (2nd Page of 3)

2. Benefits of a broad liberal education

Step 1. The subject was limited to benefits of a broad liberal education.

A broad liberal education is beneficial because
a) It prepares for a world of changing employment
b) It enables you to function well as a citizen
c) It enables you to make the most out of your life

Step 2. The thesis was developed by taking a stand on the subject.

Step 5.3.1 We then think of the paragraph (essay) as containing approximately five sentences.

In a world where technology is drastically and rapidly changing, a liberal education gives a person the foundation to be able to change with the times. And quickly develop the new skills needed to keep abreast. It also provides the solid basis in western philosophy that allows one to function as a useful citizen. The greatest benefit, though, is that it permits one to live a full, rewarding life both at work and at leisure. For all these reasons, young people should be strongly encouraged to seek a liberal education.

Step 5.3.2 The topic sentence covers the major point of the paragraph (essay).

Step 5.3.4 Notice the classifications used to develop the rest of the paragraph (essay).

Step 5.3.5 Next, we end the paragraph (essay) with a sentence which emphasizes what has been covered in the paragraph (essay).

Careful review reveals a sentence fragment after the first sentence.

Step 7. We review the essay (paragraph) to determine if revisions are needed.

Hence, the first and second sentences are joined: "... with the times, and quickly develop ...."

Step 8. We make the necessary revisions.

PRACTICE

Write an essay (paragraph) on each of the following general subjects:

1. Cases where abortion is clearly necessary.

2. The main signs of our present economic crises.

FIGURE 6-6. (3rd Page of 3)

While the essays were usually graded as pass/fail by the instructors, for the purposes of this experiment they ranked the essays on a scale from 1 to 10. The instructors were directed to rank the essays only on the basis of the criteria that were taught in the booklets. To help assess reliability, each instructor was asked to blind-rank the essays from one of the other instructor's sections. In the case of poor inter-rater reliability (which was fairly frequent), a third rating was obtained from an English content expert. Then the two (or three) ratings were averaged to create the data point for each student. Validity was increased by using only raters who were English instructors and/or English content experts to judge the quality of the essays and to rank them according to this judgment.

<u>Procedure</u>

During the first two weeks of class, all students had been asked to read the first four chapters in the textbook, <u>The Practical Stylist</u>, by Sheridan Baker. Class presentations, however, dealt only with the first two chapters -- choosing a topic, dealing with the opposition, and ordering arguments. At the beginning of the third full week of class, this study was initiated.

Students received the booklets on either the Monday or the Tuesday (depending upon whether their section met for fifty minutes on Monday/Wednesday/Friday or for seventy-five minutes on Tuesday/Thursday) of the beginning of their third week of class. Some religious holidays occurred during their second week of school, and, therefore, they had completed only two and a half weeks of actual class time. During the experiment another religious holiday occurred, and the Tuesday/Thursday sections did their final essay four days later than they would have otherwise. However, no extra class instruction occurred during that time.

The students were told by their instructors that they could use class time to work on the booklets, and that they could take them home to work on them. The students were also told that they could consult individually with the instructor if they were confused or had a question. None required exorbitant help, as reported by the instructors, with either interpreting the booklet instructions or in completing the exercises.

The students spent one and a half class periods each week working on the booklets, with one-half hour each week being taken up by the instructor to prep students for the essays by presenting issues and ideas. One class period each week was used for writing essays. The first week's essay served as practice and was graded and returned to the students as usual. The second week's essay served as the posttest.

After writing the posttest essays, the students filled out an attitude questionnaire on their perceptions of the instructional sequence each had received.

Results

On this task, SAT was significantly correlated with both posttest scores, $F\ (1,153) = 13.60$, $p<.0005$, and affect, $F\ (1,126) = 4.60$, $p=.034$. SAT also met the homogeneity of slopes criterion with both posttest scores and affect, hence it was used as a covariate in the analysis of both dependent variables.

Since this was the largest rule that we used, we would have expected the largest differences; but we recognized that the poor inter-rater reliability on the essay ratings would make it very difficult to detect any real differences. Tables 7 and 8 show that there were no significant effects on the achievement measure but that there was a significant sequence effect on the affect measure, $F\ (2,126) = 6.57$, $p<.0025$, with the hierarchical sequence resulting in the lowest affect.

Insert Tables 7 and 8 about here

TABLE 7

SUMMARY STATISTICS

for postest scores for longbranching task

Factor	Adjusted Means, (Standard Deviations), and n's												F	p
Sequence	Forward 5.47 (0.23) 52				Elaboration 5.25 (0.26) 53				Hierarchical 5.34 (0.25) 51				0.22	
Contextual Synthesis	Absent 5.29 (0.20) 74						Present 5.41 (0.20) 82						0.14	
Performance Synthesis	Absent 5.56 (0.20) 75						Present 5.14 (0.20) 81						2.11	
Sequence X Contextual Synthesis	Forw x Abs 5.38 (0.30) 25		Forw x Pres 5.56 (0.34) 27		Elab x Abs 5.26 (0.44) 23		Elab x Pres 5.23 (0.32) 30		Hier x Abs 5.24 (0.33) 26		Hier x Pres 5.44 (0.39) 25		0.06	
Sequence X Performance Synthesis	Forw x Abs 5.68 (0.32) 34		Forw x Pres 5.25 (0.33) 31		Elab x Abs 5.44 (0.34) 32		Elab x Pres 5.05 (0.40) 29		Hier x Abs 5.55 (0.37) 28		Hier x Pres 5.12 (0.34) 32		0.00	
Contextual X Performance Synthesis	Abs x Abs 5.50 (0.26) 46			Abs x Pres 5.09 (0.31) 43			Pres x Abs 5.62 (0.30) 48			Pres x Pres 5.19 (0.27) 49			0.00	
Sequence X Contextual X Performance Synthesis	FAA 5.67 (.42) 17	FAP 5.09 (.42) 14	FPA 5.70 (.49) 17	FPP 5.41 (.49) 17	EAA 5.47 (.49) 14	EAP 5.06 (.79) 12	EPA 5.42 (.48) 18	EPP 5.04 (.42) 17	HAA 5.36 (.48) 15	HAP 5.12 (.45) 17	HPA 5.75 (.60) 13	HPP 5.12 (.52) 15	0.11	
												SAT	13.60	0.0003

TABLE 8

SUMMARY STATISTICS

for affect scores for longbranching task

Factor	Adjusted Means, (Standard Deviations), and n's												F	p
Sequence	Forward 3.49 (0.22) 52				Elaboration 3.32 (0.23) 53				Hierarchical 2.37 (0.21) 51				6.57	0.0019
Contextual Synthesis	Absent 2.58 (0.19) 74						Present 3.27 (0.19) 82						2.63	
Performance Synthesis	Absent 3.03 (0.18) 75						Present 3.09 (0.20) 81						0.13	
Sequence X Contextual Synthesis	Forw x Abs 3.18 (0.31) 25		Forw x Pres 3.80 (0.32) 27		Elab x Abs 2.94 (0.35) 23		Elab x Pres 3.70 (0.30) 30		Hier x Abs 2.44 (0.31) 26		Hier x Pres 2.31 (0.29) 25		0.98	
Sequence X Performance Synthesis	Forw x Abs 3.46 (0.28) 25		Forw x Pres 3.52 (0.35) 27		Elab x Abs 3.29 (0.31) 28		Elab x Pres 3.35 (0.36) 25		Hier x Abs 2.34 (0.27) 22		Hier x Pres 2.41 (0.31) 29		0.00	
Contextual X Performance Synthesis	Abs x Abs 2.84 (0.25) 38			Abs x Pres 2.87 (0.29) 36			Pres x Abs 3.22 (0.25) 37			Pres x Pres 3.32 (0.27) 45			0.01	
Sequence X Contextual X Performance Synthesis	FAA 3.24 (.37) 13	FAP 3.12 (.51) 12	FPA 3.68 (.43) 12	FPP 3.92 (.46) 15	EAA 2.84 (.44) 13	EAP 3.04 (.59) 10	EPA 3.74 (.41) 15	EPP 3.66 (.45) 15	HAA 2.43 (.44) 12	HAP 2.44 (.44) 14	HPA 2.25 (.29) 10	HPP 2.37 (.45) 15	0.12	
											SAT		4.60	0.034

SECTION 7

DISCUSSION

Discussion of Methodological Concerns

Before we begin our discussion of the results, it may be helpful to discuss some methodological concerns that may impact on any interpretation of the results. With respect to the math experiments (Experiments 1, 2, and 3), we will discuss problems associated with the nature of the students, the test, and the experimental situation.

With respect to the nature of the students, two factors are worthy of discussion. First, they were primarily *remedial* learners rather than first-time learners. In other words, the purpose of the course was to *review* skills that the learners had already been exposed to, rather than to teach completely new skills. This difference may influence the effects of both contextual synthesis and sequence. Since the students needed review but received primary instruction, the results of this study may be entirely different from what they would have been if the students had been first-time learners. However, for purposes of generalizing the results of this study to Navy JOBS students, who are remedial learners, this problem is of no concern.

Another problem related to the remedial nature of the learners is the appropriate level of description of the rule -- that is, the appropriate level to which the steps are broken down. Conversations with the students indicate that they felt that the the steps were broken down to too fine a level of description. This may have hurt some sequences more than others. It is possible that forward chaining would be the least hurt by this problem. If in fact one only wishes to generalize the results of this study to remedial learners, then only the second of these two problems would be of concern; but if one wishes to generalize the results to first-time learners, extra caution should be observed in interpreting the results.

The second aspect of the students that deserves some comment is their prior familiarity with different instructional sequences. Some students expressed considerable initial confusion over the backward sequence. This could have had a negative impact on both achievement and affect which would not have occurred if the students had had some prior familiarity with such a sequence. The same may also have been a factor for the elaboration sequence and to a lesser extent for the hierarchical sequence.

With respect to the nature of the test, two factors are worthy of comment. First, the number of items for each task was quite small, thereby impeding its ability to discriminate among levels of achievement. Second, it did not test the full range of the skills that had been taught. Many types of problems, particularly the more difficult ones to which the rule applied, were not included on the test. This also reduced the test's ability to discriminate among different levels of achievement. It was unfortunate that our experimental situation did not permit us to administer a test of our own.

Finally, with respect to the experimental situation, there was a considerable time gap between the administration of the treatments and the test. During that time gap, students were allowed to take their booklets home and study them. It is also possible that they compared their booklets with those of other students. But perhaps even more important is that a student could reread his booklet in any sequence. Even if he reread it from front to back, the student would not have been receiving a true implementation of his instructional sequence because he had already read steps that appear later in the booklet. It would have been far superior if we had been able to administer our own test immediately after the students had first studied their booklets from beginning to end.

It can readily be seen that the last two of these problems -- the nature of the test and the experimental situation -- worked to reduce any differences that might otherwise result from the treatment effects. On the other hand the first problem -- the nature of the students -- were likely to have differential effects across the treatments, to the particular detriment of all sequences but forward chaining.

Our final set of methodological concerns relates to the English experiment (Experiment 4). The task was "how to write an argumentative essay", and the achievement measure was a student essay. All essays were blind rated on a scale of 1 to 10 by at least two experts -- the section instructor and the instructor of another section of English 101. The two ratings differed by more than 3 points in over 50 percent of the essays. In all such cases (of the two ratings differing by more than 3 points), another rater provided a third "blind" rating. By "blind" we mean that none of the raters was aware of the ratings of any of the other raters. Considering that the only criteria that were to be used in the ratings were those that were taught by the treatment materials, the ratings were disappointingly poorly correlated. We also found that the instructor of each section rated his or her class's essays consistently higher than did the outside rater. This lack of an objective and reliable measure of achievement would make it very difficult indeed for any differences to be detected.

It is important to note that the general ability level of Navy JOBS students is probably somewhat lower than that of our students. However, it should also be noted that there were no interactions between ability level and any of the factors investigated in this study. Since the range in SAT scores in our sample was considerable (300-710), this lack of interaction provides some evidence that the difference in mean SAT scores between the two sets of students is probably not a sufficient reason to limit the generalizability of the results to the Navy JOBS students.

Discussion of Results

The results of Experiments 1 and 2 (the short unitary and short branching rules, respectively) were generally as expected: the rules were too short for either sequence or synthesis to have any effects on achievement or affect. However, there was one surprising result. On the short unitary rule, a significant interaction effect (see Figure 3-9 above) revealed that the forward chaining sequence was most effec .

when it was preceded by contextual synthesis, whereas the backward chaining sequence was most effective when such synthesis was not provided.

In retrospect, this result makes a lot of sense. Given that contextual synthesis shows the whole rule at the beginning of the instruction and thereby provides perspective about its goal, then it stands to reason that a forward chaining sequence, which gives no advance indication of the goal, could benefit by that synthesizer, whereas the backward chaining sequence, which has been advocated because of its clear indication of the goal, would not stand to benefit from such synthesis. Hence, this result lends support to Gilbert's (1962) contention that any advantage of a backward sequence over a forward sequence would be attributable to the greater saliency of the goal in a backward sequence. However, this result also indicates that a forward chaining sequence may be just as effective as a backward chaining sequence as long as it is accompanied by contextual synthesis. It also seems likely that some other means of providing a clear perspective on the goal may make a forward sequence equally as effective.

In Experiment 2 the same interaction effect approached, but did not reach, significance on the affect measure. If the significance level had been established at $p=.07$ instead of .05, then adding a contextual synthesizer would have been found to result in improved affect for the forward chaining sequence, whereas its removal would have been found to result in improved affect for the backward chaining sequence. However, it should also be noted that there was no significant interaction for affect in Experiment 1 and none for achievement in Experiment 2. This may be partly due to the shortness of the rules studied, but no such interaction was found in either Experiment 3 or 4. Clearly, this is a result that should be viewed with caution until further research can substantiate it.

As was mentionned earlier in this report, one of our long-time beliefs is that neither sequencing nor synthesis would make any difference in the teaching of relatively short amounts of content, but that as the amount of interrelated content increased, so too would the effects of sequence and synthesis increase. We did not really expect that any of the rules investigated in this study would be large enough to make <u>important</u> differences in instructional outcomes, but we did hope to find a trend in the direction of higher F levels and lower probability levels as the size of the rules increased. This trend in fact occurred for the sequence factor on both achievement and affect.

With respect to <u>achievement</u>, the shortest rule -- the short unitary -- obtained an F of 0.19; the next shortest rule -- the short branching -- yielded an F of 0.98; and the next shortest rule -- the long unitary -- obtained an F of 3.37. The long branching (English) rule, for reasons of very poor reliability of the achievement measure (see discussion above), did not reveal any significant differences. With respect to <u>affect</u>, the shortest rule obtained an F of 0.04, the next shortest rule obtained an F of 2.92, the next shortest rule obtained an F of 0.98, and the longest rule obtained an F of 6.57. The fact that the affect measure did reveal a very highly significant difference on sequence with the long branching rule, and hence a fairly reliable trend in significance levels across tasks, lends some (albeit small) support to the interpretation that it was an insensitive measure of achievement that was responsible for the lack of significance on the English task.

In all of the above cases of trends with respect to sequencing main effects, the means were surprisingly consistent, but not exactly as predicted. The forward sequence yielded the highest means, followed by the backward sequence, and finally by the hierarchical sequence and the elaboration sequence. This lends further support to our belief that reliable sequencing effects will be found as the amount of interrelated instructional content increases.

But the unpredicted direction of the means leaves us with the uncomfortable problem of having to assess the implications of those findings for our sequencing prescriptions and theory. Bruner's "spiral curriculum", Ausubel's assimilation theory, and Norman's "web learning" all advocate an instructional sequence that proceeds from the simple to the complex, or from the general to the detailed, but none of them provided clear prescriptions for sequencing instruction in highly procedural tasks. The notion of path analysis has provided a breakthrough with respect to the articulation of a technology for creating such a simple-to-complex sequence for procedural tasks. And an analysis of curricula in which the content is highly procedural (such as the K-12 mathematics curriculum) shows that this kind of a simple-to-complex sequence is in fact widely used by virtually all schools. For example, the simplest case of addition (adding single-digit whole numbers) is taught first, followed at some point by the next most simple case (two-digit whole numbers without carrying), and so on through carrying, carrying to a 9, decimals, fractions, algebraic expressions, and whole equations. Addition is often thought of as a single skill, and in fact a single rule can be identified that will allow one to add any numerical expression. But such a rule is far too large and complicated for anyone to even consider teaching it in a forward chaining or backward chaining or even standard hierarchical sequence. Educators intuitively select an elaboration approach for curriculum-level sequencing.

So how should we interpret the results of this set of studies? First, it seems likely that there is a certain minimum quantity of interrelated procedural content, above which an elaboration approach is the only viable way to go, but below which the elaboration approach does not function as well as alternatives. Then the question arises as to why it does not function well below that minimum quantity of procedural content. There could be several factors involved. One is that students are confused when, say, four steps are taught as a stand-alone rule in the first lesson and other intermediate steps are taught in later lessons, such that what was step 3 in lesson 1 becomes step 7 in lesson 2, and so forth. This awkwardness in numbering is unavoidable in an elaboration approach, unless no steps are numbered at all.

Another factor may be the nature of human learning. Spacial and chronological cues can be powerful aids to learning. For example, when a person wishes to find some information which has been read fairly recently, he or she may remember that the information was in the top of a right-hand page. It is likely that such a spacial cue was encoded in what Gagne and White (1980) refer to as the image memory store. In a similar way, a sequence of events (which is charcteristic of any rule) is believed by the same theorists to be stored in the episodic memory store. These are in contrast to intellectual skills which are believed to be stored mainly in the propositional memory store. It seems quite possible that episodic memory may have a limit in terms of the size of a rule which it can comfortably handle at a given time. When that size is exceeded, then it becomes necessary to "internalize" that rule by passing it to propositional memory store, which is organized hierarchically (or subsumptively) and hence benefits from a subsumptive or elaborative sequence (i.e., a simple-to-complex or general-to-detailed sequence).

If this interpretation is correct, then an important area for future research would be to determine the critical size below which a forward or backward sequence would be optimal and above which an elaborative sequence would be optimal. But given our current state of knowledge, the major implications of this research for designing instruction on intellectual skills in general and on basic skills in particular are as follows:

1. Identify (through an information processing, or preferably ETAP, task analysis) all of the rules that need to be taught. Be sure to combine all related rules into a single large rule. You may end up with several large rules.

2. Decide if the total amount of instruction required to teach each single large rule exceeds, say, something like 20 hours. If not, then use forward chaining (with contextual synthesis) or backward chaining (without contextual synthesis) to sequence the instruction.
3. If the total amount of instruction exceeds that relatively large cut-off point, then use an elaboration sequence. However, the Elaboration Theory currently proposes making each "lesson" in the elaboration sequence about one hour's worth of instruction. Instead of making it so short, this research indicates that you should make each "lesson" at least 10 hours worth of instruction, and perhaps a good bit more. This will probably allow you to teach entirely independent branches of the rule in each "lesson", such that you will not encounter the problem of having to renumber steps as we had to in our studies.
4. Within each "lesson" (10 hours worth of instruction or more), use a forward chaining (with contextual synthesis) or backward chaining (without contextual synthesis) sequence.
5. Do not bother to use either contextual or performance synthesis within any of those "lessons". Rather, use them at the beginning and end of each such "lesson".

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