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ABSTRACT

This study investigated the effects of sequence and synthesis prescriptions from the Elaboration Theory by teaching the parts of a microcomputer system based on a parts-conceptual structure. A 2x3 factorial design was used which incorporated two sequences, general-to-detailed and detailed-to-general, and three levels of synthesizer, i.e., no synthesizer, synthesizer first, and synthesizer last. The subjects were 128 eighth-grade pupils who were randomly assigned to the six treatment groups. Each group viewed a slide/tape presentation followed by a paper-and-pencil test on attributes and relationships of 19 concepts. A two-way analysis of variance revealed that the attributes of the concepts were learned equally well by all groups, but relationships were learned better (1) with a general-to-detailed sequence than with a detailed-to-general sequence ($p.<05$), and (2) with the synthesizer last ($p<.01$) or no synthesizer at all ($p.<05$) than with the synthesizer first. Twenty-five references are provided. (Author/RP)

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This study investigated the effects of sequence and synthesis prescriptions from the Elaboration Theory by teaching the parts of a microcomputer system based on a parts-conceptual structure. A 2x3 factorial design was used which incorporated two sequences, general-to-detailed and detailed-to-general, and three levels of synthesizer, no synthesizer, synthesizer first, and synthesizer last. The subjects were 128 eighth grade pupils who were randomly assigned to the six treatment groups. Each group viewed a slide/tape presentation followed by a paper-and-pencil test on attributes and relationships of 19 concepts. A two-way analysis of variance revealed that the attributes of the concepts were learned equally well by all groups, but relationships were learned better (1) with a general-to-detailed sequence than with a detailed-to-general sequence ($p<.05$) and (2) with the synthesizer last ($p<.01$) or no synthesizer at all ($p<.05$) than with the synthesizer first.

Introduction

The structuring of subject matter content is a major concern in the instructional process. Sequence, which refers to the order in which subject matter is presented, gained much attention during the 1960's, primarily because it was an important aspect of programmed instruction materials which were very popular at that time. Synthesizing, which refers to showing the relationships among elements of the subject matter, has also received much attention, since many educators feel that the presence of a synthesizer enhances the quality of the instruction. Although there have been many research studies that have investigated each of these concerns, few have looked at the use of both sequence and synthesizers together in instruction.

The popularity of programmed instruction led to much interest in the effects of instructional sequence, and several studies regarding sequence have been conducted. Many, such as Levin and Baker (1963), Payne, Krathwohl and Gordon (1967), Roe, Case and Roe (1969), and Mayer (1976), found no significant effect when comparing "logically" sequenced instruction with randomly scrambled versions of the same instruction. Roe (1960, p. 409) found that "careful sequencing of items has a significant effect on student performance, at least for programs of some length and complexity". Similar findings made by Brown (1970) revealed that sequencing of complex problem-solving behaviors, which Gagne (1970) describes as intellectual skills, produced a significant effect in longer programs.

Natkin and Moore (1972) proposed that the presence of adjunct questions, use of repetitious material, and lack of evidence of truly logical sequences may have obscured the sequence effects in earlier studies. By removing these detrimental effects, they found that sequence does have a significant effect.

Bruner (1960, p. 31) stated "that the curriculum of a subject should be determined by the most fundamental understanding that can be achieved of the underlying principles that give structure to that subject". He referred to the use of a "spiral curriculum" that develops by revisiting basic ideas repeatedly and builds upon these ideas until the student has grasped the full formal apparatus that goes with them.

Ausubel (1963, p.82) advocated the use of an "advance organizer" which "gives the learner a general overview of the more detailed material in advance of his actual confrontation with it and also provides organizing elements that are inclusive of and take into account most relevantly and efficiently both the particular content contained in this material and relevant concepts in cognitive structure". He (Ausubel, 1960) found that the learning and retention of unfamiliar but meaningful verbal material can be facilitated by the advance introduction of relevant subsuming concepts (advance organizers).

Reviews of the research on the use of advance organizers (Barnes and Clawson, 1975; Hartley and Davies, 1976; Lawton and Wanska, 1977; Mayer, 1979) indicate conflicting claims regarding the efficacy of advance organizers. Although Ausubel (1977) contends that the nature and definition of advanced organizers are described in several of his publications, each of these reviews states that a more acceptable operational definition should be generated. The general nature of Ausubel's definition appears to be a major cause of the confusion in evaluating the effectiveness of advance organizers since researchers differ in their interpretations as to what constitutes an advance organizer.

The Elaboration Theory (Reigeluth, 1979) advocates the use of a special kind of general-to-detailed or simple-to-complex sequence based on epitomizing large amounts of instructional material. Epitomizing is done on the basis of a single type of content (concepts, procedures, or principles), and other types of content are plugged into that overall sequence whenever they are most relevant. The epitomized version of the content is taught as the first lesson, followed by progressively more detailed or complex versions in subsequent lessons.

With respect to a conceptual orientation to the general-to-detailed sequence, the Elaboration Theory proposes that the general-to-detailed sequence be based on subdividing things into kinds or parts. Conceptual structures show superordinate, coordinate, and subordinate relationships among ideas, where the subordinate concept may be either a part or a kind of its superordinate concept. Each lesson begins with "a very general synthesizer (i.e., a very simple or general version of the orientation structure)" which is presented first to show a pervasive relationship among the concepts, even though the concepts themselves are not understood yet (Reigeluth and Stein, in press).

Another approach to sequencing instruction is the use of a learning hierarchy (Gagne, 1970; Gagne and Briggs, 1979) which is based on complex skills being progressively broken down into simpler ones, forming successive levels of prerequisites. Although an Elaboration Theory sequence is different from most "hierarchically-devised" sequences, the Elaboration Theory sequence does not violate the notion of hierarchical learning prerequisites. In an analysis of the Elaboration Theory and the learning hierarchy approaches, Wilson and Merrill (1980, p. 18) found that "learning prerequisite relationships will be in strict agreement with Elaboration Theory when understanding subordinate concepts".

In contrast to Bruner's spiral curriculum and Ausubel's subsumptive theory, the Elaboration Theory provides specific guidelines for sequencing and synthesizing instruction. When the guidelines are followed, a blueprint describing a general-to-detailed sequence of instruction is easily and reliably created. Thus, the Elaboration Theory appears to provide a more promising approach for prescribing these aspect of instruction.

Frey and Reigeluth (1981) were among the first to investigate the effects of sequence and synthesizer using the Elaboration Theory. Their study involved the use of a kinds-conceptual structure. A one-hour session was used to present 16 related concepts using printed booklets and to complete a 39-item paper-and-pencil test. An interaction between synthesizer position and the sequence of instruction was found which indicated that the presentation of a synthesizer before a detailed-to-general sequence was superior to having a synthesizer after that sequence for learning relationships among concepts. In contrast, the synthesizer placed at the end with a general-to-detailed sequence was superior to having the synthesizer at the beginning. This interaction was significant for the learning of relationships among concepts, but there was no support for this same interaction for learning the attributes of concepts.

Among the methodological problems identified by Frey and Reigeluth with their study were:

1) a small sample size of twenty-seven subjects (four or five per treatment group) was used;
2) the instruction was presented in booklet form and strict control of sequence was not assured;
3) the purpose of the synthesizer was not presented to the learners in the instruction; and
4) the concept labels were often concept attributes.

Therefore, because of these problems, the need for replication for external validity, and the need for further research in this area, this study is an extension of the Frey and Reigeluth study. Efforts will be made to correct for the methodological problems identified above. It is hypothesized that:

1) the presence of a synthesizer will facilitate the learning of concepts, and
2) the most effective position of the synthesizer is dependent upon the sequence of the instruction, i.e., the synthesizer is most effective in a general-to-detailed sequence when placed at the end of the instruction and is most effective in a detailed-to-general sequence when placed at the beginning of the instruction.

METHOD

Subjects

One hundred twenty-eight of one hundred forty-four eighth grade pupils in the Painted Post Middle School of the Corning-Painted Post School District were the subjects for this study which was conducted during the weeks of December 14-18, 1981, and January 4-8, 1982. The remaining sixteen pupils were not included due to absenteeism or because their schedules were such that they could not participate. The subjects, primarily from lower-middle to middle income families, lived in a rural area. The mean score for these pupils on the Stanford Achievement Test, which was administered nine months prior to the time of this study, was the eighth month of the eighth grade. The subjects were randomly assigned to the treatment groups.

Design

Since the teachers indicated that the content area was new to the pupils, a posttest-only experimental design was employed. The statistical design was a 2x3 factorial design, and a two-way analysis of variance was used. The factors were sequence (general-to-detailed and detailed-to-general) and synthesizer (absent, present at the beginning of the instruction, and present at the end of the instruction). The statistical design is shown in Figure 1.

Insert Figure 1 about here

Instructional Task and Materials

The subjects viewed a slide-tape dealing with the parts of a microcomputer. Identical slides were used in each slide-tape series. The content of the slides included original photographs of the parts of a microcomputer system, copies of pictures of the parts of a microcomputer system, printed words, and simple diagrams with printed words.

The function of each of the twenty parts of a microcomputer system was presented by first describing the general function of the part, then providing at least one example of the function, and finally, providing at least one practice item on remembering the function. The nature of the task is further described in Figures 2-4 below.

The Painted Post Middle school had recently acquired a microcomputer, so the students were aware of what one look

FIGURE 1

SEQUENCE	SYNTHESIZER		
	No Synthesizer	Synthesizer First	Synthesizer Last
Detailed-to-General	D→G, none	D→G, first	D→G, last
General-to-Detailed	G→D, none	G→D, first	D→G, last

like and were very interested in knowing more about microcomputers. Although some pupils had had experience using a microcomputer, they had received no instruction regarding its parts or their functions prior to the instruction used in this study.

Treatments

There were six treatments (see Figure 1 above). Three versions used a general-to-detailed sequence and three used a detailed-to-general sequence (see Figures 2 and 3, respectively, for these sequences). Each set of three consisted of one without a synthesizer, one with the synthesizer at the beginning of the instruction, and one with the synthesizer at the end of the instruction.

The synthesizer was a tree-chart diagram of a parts-conceptual structure (see Figure 4). It was introduced and explained as follows:

> This diagram shows you the parts of the microcomputer system. For example, a microcomputer system (the box on the top) is made up of the parts: microcomputer, video display, program, and floppy disc subsystem. And, a floppy disc subsystem (on the right hand side of the slide) is made up of the drive, diskette, and interface. I'll give you a while to look it over and see what parts belong to other parts. Look it over well; it will help you understand the information you (will be seeing) (saw) on the rest of the slides.

Insert Figures 2, 3 and 4 about here

Based on the parts-conceptual structure shown in Figure 4, the general-to-detailed sequence began with the concept at the top of the diagram and proceeded down one level at a time, whereas the detailed-to-general sequence started at the bottom and proceeded up one level at a time (see Figure 5).

Insert Figure 5 about here

Figure 6 shows the number of slides and the length of the narration for each treatment. Each treatment containing the synthesizer had one additional slide and two additional minutes of sound on the audio tape. The general-to-detailed sequence treatments each contained four more slides than the comparable detailed-to-general treatment. The four additional slides in the general-to-detailed sequences were duplicates of other slides included in the programs and were included to maintain

DETAILED-TO-GENERAL SEQUENCE

NARRATION	VISUAL
A diskette can store information sort of like an audio tape stores sounds.	DISKETTE
A diskette looks like this.	Picture of a diskette
This is a drive	Picture of a drive
It either records or plays back the information on a diskette when the diskette is placed in it.	DRIVE
The drive can either send information to the microcomputer or receive information from the microcomputer.	PUT INFORMATION IN OR GET INFORMATION FROM
Guess what goes between the drive and the microcomputer?	Black slide
Excellent if you said interface. If you didn't say interface, remember, an interface must be used to connect any piece of equipment with the microcomputer for it to be able to communicate with the microcomputer.	INTERFACE
Together, the diskette, drive, and an interface form what is called the floppy disc subsystem.	FLOPPY DISC SUBSYSTEM
What part of the floppy disc subsystem records or plays back the information?	Black slide
The drive	DRIVE
What is the information recorded on or played back from?	Black slide
Right, a diskette.	DISKETTE
Is the floppy disc subsystem used to put information into the microcomputer or to get information from the microcomputer?	Black slide
It is used to do either. It can put information into the microcomputer or it can get information from the microcomputer.	PUT INFORMATION IN OR GET INFORMATION FROM
What are the three parts to a floppy disc subsystem?	Black slide
Right, diskette, drive and interface.	FLOPPY DISC SUBSYSTEM DISKETTE DRIVE INTERFACE

GENERAL-TO-DETAILED SEQUENCE

NARRATION	VISUAL
Another part of the microcomputer system is the floppy disc subsystem which is made up of the drive, diskette and interface.	FLOPPY DISC SUBSYSTEM DRIVE DISKETTE INTERFACE
The main part is the drive.	DRIVE
It looks like this.	Picture of drive
It can either send information to the microcomputer or receive information from the microcomputer.	PUT INFORMATION IN OR GET INFORMATION FROM
A diskette	DISKETTE
which looks like this is put into the drive. The kiskette can store information sort of like an audio tape stores sounds. The drive records or plays back information from the diskette.	Picture of diskette
What part of the floppy disc subsystem records or plays back the information?	Black slide
The drive	DRIVE
What is the information recorded on or played back from?	Black slide
Right, a diskette.	DISKETTE
Is the floppy disc subsystem used to put information into the microcomputer or to get information from the microcomputer?	Black slide
It is used to do either. It can put information in to the microcomputer or it can get information from the microcomputer.	PUT INFORMATION IN OR GET INFORMATION FROM
Guess what goes between the drive an the microcmputer?	Black slide
Excellent if you said interface. If you didn't say interface, remember, an interface must be used to connect any piece of equipment with the microcmputer for it to be able to communicate with the microcomputer.	INTERFACE
What are the 3 parts of the floppy disc subsystem?	Black slide
Diskette, Drive and interface.	FLOPPY DISC SUBSYSTEM DRIVE DISKETTE INTERFACE

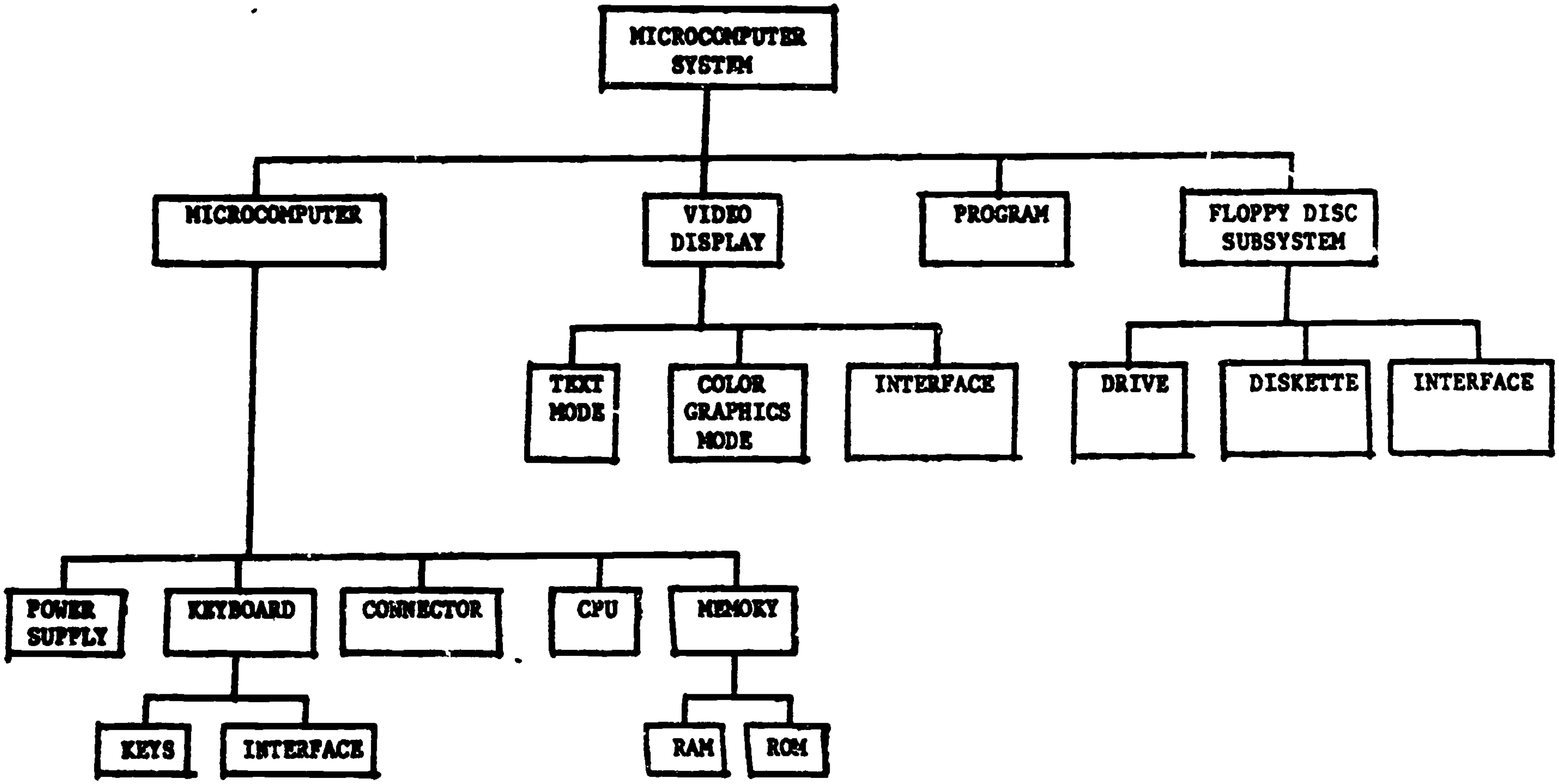
MICROCOMPUTER SYSTEM
MICROCOMPUTER
VIDEO DISPLAY
PROGRAM
FLOPPY DISC SUBSYSTEM
TEXT MODE
COLOR GRAPHICS MODE
INTERFACE
DRIVE
DISKETTE
INTERFACE
POWER SUPPLY
KEYBOARD
CONNECTOR
CPU
MEMORY
KEYS
INTERFACE
RAM
ROM

FIGURE 5

ORDER OF PRESENTATION

DETAILED-TO-GENERAL	GENERAL-TO-DETAILED
1. Power Supply	1. Microcomputer System
2. Keys	2. Microcomputer
3. Interface	3. Video Display
4. Keyboard	4. Program
5. Connector	5. Floppy Disc Subsystem
6. CPU	6. Power Supply
7. RAM	7. Keyboard
8. ROM	8. Keys
9. Memory	9. Interface
10. Microcomputer	10. Connector
11. Text Mode	11. CPU
12. Color Graphics Mode	12. Memory
13. Interface	13. RAM
14. Video Display	14. ROM
15. Diskette	15. Text Mode
16. Drive	16. Color Graphics Mode
17. Interface	17. Interface
18. Floppy Disc Subsystem	18. Drive
19. Program	19. Diskette
20. Microcomputer System	20. Interface

continuity with the audio portion of the programs. They accounted for no additional information regarding the subject-matter content.

Insert Figure 6 about here

Tests and Measures

The test was a 26-item, paper-and-pencil test. The test items were classified as either relationship or attribute items.

Figure 7 shows the six relationship items used on the test. They elicited responses about relationships among concepts. Each of these items was at the remember-a-generality level, as described by the Component Display Theory (Merrill, in press). A total of 19 responses was possible on these six items.

Insert Figure 7 about here

Figure 8 provides five representative items from the attribute portion of the test. The attribute portion of the test included eighteen items eliciting twenty-six responses. Each item required the pupil either to name one or more parts, given its (their) function, or to describe the function, given the name of the part. This portion was also at the remember-a-generality level (Merrill, in press).

Insert Figure 8 about here

Two other items on the test measured neither relationships nor attributes and were not included in the analysis.

Procedure

The pupils were scheduled by the librarian to report to the Library/Media Center. They viewed the instructional materials individually or in a small group, based on the number available per treatment and the Librarian's schedule. Before viewing the slide-tape, each pupil was told:

> You are going to be learning some new material about the parts of a microcomputer system. This is part of an experiment to find out the best method for learning this type of information. There are six slide-tape programs and each one teaches the same

FIGURE 6

SEQUENCE	SYNTHESIZER		
	No Synthesizer	Synthesizer First	Synthesizer Last
Detailed-to-General	81 slides 15'50"	82 slides 17'50"	82 slides 17'50"
General-to-Detailed	86 slides 15'55"	87 slides 17'55"	87 slides 17'55"

FIGURE 7

RELATIONSHIP ITEMS

2. What are the two parts of the keyboard called?

8. What are the two parts of the memory called?

14. What are the three parts of the video display called?

15. What are the three parts of the floppy disc subsystem called?

22. Name the four main parts of a microcomputer system.

26. Name the five parts of the microcomputer.

FIGURE 8

Examples of ATTRIBUTE ITEMS

1. What is the part called that provides the electricity for the microcomputer to be able to run?

5. What is the purpose of an interface?

9. When you put information into the microcomputer, it is temporarily stored in what part of the memory?

17. What kind of information do you see in the text mode?

24. Name two parts of the microcomputer system that you can use to put information into the system with.

information in a different way. You will look at one of them and take the same test as everyone else in the eighth grade. You will not be graded as part of your math grade but if you would like to know how you did you can find out from me (the Librarian). Pay close attention and do your very best.

Following these instructions by the Librarian, each pupil viewed the slide/tape to which he/she had been randomly assigned. At the end of each slide/tape the subjects were instructed to get a copy of the test from the Librarian and complete the exam. Most pupils finished the exam within the remaining time of the scheduled period (about 20 minutes). However, if more time was needed, the pupil was allowed more time to complete the test.

Results

The mean numbers of correct responses on the relationship items and on the attribute items are presented in Table 1 in the form of percentage correct out of 19 and 26, respectively. Significant main effects for both sequence and synthesizer were found on the relationship test, $F(1,122) = 4.00$, $p=.048$ for sequence and $F(2,122) = 4.35$, $p=.015$ for synthesizer (see Table 2). On the attribute test a two-way analysis of variance yielded no significant main effects nor interaction (see Table 2). No significant interaction was found on the relationship test either.

Insert Tables 1 and 2 about here

With respect to sequence, these results indicated that a general-to-detailed sequence is superior to a detailed-to-general sequence. With respect to synthesis, Duncan's Multiple Range Test was performed to identify the source of significance. The results showed that having the synthesizer at the end of the instruction is significantly better ($p=.01$) than having it at the beginning and having no synthesizer is significantly better ($p=.05$) than having it at the beginning of the instruction.

No formal affective measures were taken regarding this study. However, the Librarian who administered the study in the school indicated that most students showed a great deal of interest and effort in doing the work. Several pupils could not be scheduled during school hours so they volunteered to do the work after school. About 40% of the pupils asked for the results of their exam.

TABLE 1

MEAN SCORE (in percent) OF CORRECT RESPONSES
RELATIONSHIP ITEMS

SEQUENCE	No Synthesizer	Synthesizer First	Synthesizer Last	
Detailed-to-General	43.09 (22.59) n=22	27.55 (23.70) n=22	40.85 (26.36) n=20	37.[illegible] (24.8[illegible] n=6[illegible]
General-to-Detailed	43.09 (21.88) n=23	38.57 (23.60) n=21	54.95 (22.97) n=20	45.3 (23.4[illegible] n=64
	43.02 (21.98) n=45	32.93 (24.03) n=43	47.90 (25.43) n=40	

MEAN SCORE (in percent) OF CORRECT RESPONSES
ATTRIBUTE ITEMS

SEQUENCE	No Synthesizer	Synthesizer First	Synthesizer Last	
Detailed-to-General	49.82 (23.61) n=22	35.82 (22.71) n=22	42.05 (26.91) n=20	42.[illegible] (24.[illegible] n=6[illegible]
General-to-Detailed	48.35 (22.91) n=23	45.14 (20.20) n=21	52.40 (21.87) n=20	48.[illegible] (21.[illegible] n=64
	49.07 (23.00) n=45	40.37 (21.78) n=43	47.23 (24.76) n=40	

(Numbers in parentheses represent standard deviations)

TABLE 2

TWO-WAY ANALYSIS OF VARIANCE

RELATIONSHIP TEST

SOURCE	SUMS OF SQUARES	df	F	pr > F
Sequence (A)	2211.13	1	4.00	.0477
Synthesizer Position (B)	4803.17	2	4.35	.0150
A X B	1165.70	2	1.05	.3515

ATTRIBUTE ITEMS

SOURCE	SUMS OF SQUARES	df	F	pr > F
Sequence (A)	1146.01	1	2.15	.1453
Synthesizer Position (B)	1770.49	2	1.66	.1945
A X B	934.78	2	0.88	.4190

Discussion

The results of this study do not support the first hypothesis, since under no condition was the presence of a synthesizer superior to having no synthesizer. Neither did the results support the second hypothesis in that there was no significant interaction (i.e., the presence of a synthesizer following the instruction was superior in both the general-to-detailed and the detailed-to-general sequences). This result is inconsistent with the Elaboration Theory, which advocates the use of a synthesizer at the beginning of the instruction. It could be that a parts-conceptual structure functions well in reinforcing the information that has been taught, but that it is not necessary at the beginning and may even cause confusion.

Likewise, it appears that it is better to use a general-to-detailed sequence than a detailed-to-general sequence, which is in support of the Elaboration Theory. The synthesizer was introduced by reading from the top of the taxonomy down in a general-to-detailed sequence for both the general-to-detailed and detailed-to-general treatments receiving synthesizers as part of the instruction. This may have introduced a confounding variable, in that the detailed-to-general treatment groups receiving synthesizers probably should have been presented a taxonomy with the subordinate concepts at the top of the slide and read down to superordinate concepts to maintain continuity with the instructional sequence.

The number of concepts included in the instruction may have been too large for a single lesson. The use of a synthesizer containing nineteen subordinate concepts may have been too much for pupils at this age level to grasp in such a short period of time.

In addition, although the purpose of the synthesizer was explained and a brief description of how to use it was given, a more detailed explanation, leading the subjects through the structure so they might see the relationships more clearly might have provided the pupils with a better understanding of the synthesizer. No attempts were made to test for prerequisite skills in interpreting such structures and no instruction in reading tree-chart diagrams was provided prior to the subjects' participation in this study. It is possible that the tree-chart diagrams might have been too difficult for the age level of the subjects.

Further research about the effects of sequence and the use of synthesizers in teaching concepts is certainly needed. Additional research should consider the following:

1. consistency of the sequence of the synthesizer with the sequence of the instruction,
2. the number of concepts that should be included in a synthesizer,

3. the age level at which synthesizers can be understood by pupils, and
4. the degree of abstraction of a synthesizer that can be used at various age levels.

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