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ABSTRACT

The Elaboration Theory of Instruction offers guidelines for several patterns of simple-to-complex sequencing that were developed primarily from cognitive theory, especially schema theory, although there has been relatively little empirical research on the theory. This study helps fill this void by conducting "formative research" to identify weaknesses in the theory and possible ways of overcoming those weaknesses. Four chapters in a text on electrical circuit analysis were revised according to the theory. The first phase of the study used interactive data collection for immediate, detailed reactions and suggestions on the sequence. Phase two used noninteractive data collection to assess the external validity of the results. Thirteen college sophomores participated in phases one and two. Qualitative data analysis provided insights into ways to improve the theory. None of the results indicated that elements should be deleted. Weaknesses were identified as methods that should be added to the theory and methods that should be modified or enhanced. Overall, the elaboration sequences were effective and appealing to the students. (Contains 3 figures and 4 tables.) (Author/SLD)

FORMATIVE RESEARCH ON SEQUENCING INSTRUCTION WITH THE ELABORATION THEORY

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Abstract

The Elaboration Theory of Instruction offers guidelines for several patterns of simple-to-complex sequencing which were developed primarily from cognitive theory, especially schema theory. However, there has been relatively little empirical research on the theory. This study helps fill this void by conducting "formative research" to identify weaknesses in the theory and possible ways of overcoming those weaknesses. Four chapters in a text on electrical circuit analysis were revised according to the theory. The first phase of the study used interactive data collection for immediate, detailed reactions and suggestions on the sequence. Phase two utilized non-interactive data collection to assess the external validity of the results. Qualitative data analysis provided insights into ways to improve the theory. None of the results indicated that elements should be deleted. Weaknesses were composed of methods that should be added to the theory and methods that should be modified and/or enhanced.

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Bruner (1966) proposed that the sequence of instruction will affect the students' ability to grasp, transform, and transfer what they are learning. "The sequence in which a learner encounters material with(in) a domain of knowledge (will) affect the difficulty he(/she) will have in achieving mastery" (p. 49).

Sequencing deals with the order in which elements of subject matter, including information, skills, and cognitive strategies, are taught during instruction. Reigeluth has striven to integrate the knowledge base about sequencing instruction into a comprehensive set of strategies and prescriptions called the Elaboration Theory of Instruction (Reigeluth, 1987, 1992; Reigeluth & Darwazeh, 1982; Reigeluth & Rodgers, 1980; Reigeluth & Stein, 1983). Reigeluth's work is a result of his concern that most of the widely used sequencing strategies were "highly fragmented," "demotivating," and "inconsistent" with much knowledge generated recently by cognitive psychologists about how new knowledge is best assimilated into schemata (Reigeluth, 1979, p. 8). Therefore, Reigeluth pursued the goal of producing guidance for developing more holistic sequences that would enhance understanding, foster motivation, and have the potential to facilitate learner control. M. D. Merrill provided much initial insight and inspiration for the development of the Elaboration Theory.

The Elaboration Theory of Instruction

The Elaboration Theory of Instruction (ETI) prescribes different patterns of sequencing for different kinds of learning. It currently only deals with the cognitive and psychomotor domains, and not the affective domain. First a distinction is made between task expertise and content expertise. Task expertise relates to the learner becoming an expert in a specific task, such as business management, creative writing, or solving algebraic equations. Content expertise relates to the learner becoming an expert in a body of knowledge not tied to any specific task, such as economics, biology, or history.

For building content expertise, the ETI (Elaboration Theory of Instruction) prescribes one pattern of sequencing if the content is primarily concepts and another if it is primarily principles. The **conceptual elaboration sequence** (Reigeluth & Darwazeh, 1982) was derived primarily from Ausubel's (1968) advance organizers and progressive differentiation but provides greater guidance as to how to design that kind of sequence. The **theoretical elaboration sequence** (Reigeluth, 1987) was derived primarily from Bruner's (1960) spiral curriculum but differs in several important ways and also provides greater guidance as to how to design it. Both types of elaboration sequences can be used simultaneously if there is considerable emphasis on both types of content in a course. This is referred to as multiple-strand sequencing (Beissner & Reigeluth, 1994).

For building task expertise, the ETI prescribes the Simplifying Conditions Method (SCM) for sequencing the instruction, but the SCM is a bit different depending on whether the task is primarily a procedural task (or algorithmic task—one for which experts use a set of steps to decide what to do when) or primarily a heuristic task (or transfer task or complex cognitive task—one for which experts use causal models—interrelated sets of principles—to decide what to do when). The **procedural SCM sequence** (Reigeluth & Rodgers, 1980) was derived primarily from the work by Scandura (1973) and P. Merrill (1978, 1980) on path analysis of a procedure. And the **causal SCM sequence** (Reigeluth, 1989; Reigeluth & Kim, 1991) was derived primarily from the procedural SCM sequence. Both types of SCM sequences can be used simultaneously if there is considerable emphasis on both types of tasks (procedural and heuristic), and both SCM and elaboration sequences can be used simultaneously as well. Again, this is referred to as multiple-strand sequencing (Beissner & Reigeluth, 1994).

The development of the ETI has been based primarily on theoretical work (see e.g., Reigeluth & Stein, 1983) and on some limited empirical research, mostly on relatively small amounts of instruction (Berg, Daal & Beukhof, 1983; Beukhof, 1985; Carson & Reigeluth, 1983; Chao, Ruiz & Reigeluth, 1983; Frey & Reigeluth, 1981; Reigeluth, 1981). However, sequencing is likely to influence learning most when large amounts of instruction are involved. Unfortunately, research with large amounts of instruction is lacking because of the time and expense of producing and researching such instruction.

The purpose of this study was to help fill this void by conducting research on the ETI. The goals of the course chosen entailed both theory and practice, so we selected a multiple-strand sequence using both the theoretical elaboration sequence and the procedural SCM sequence.

Theoretical Elaboration Sequence

According to Reigeluth (1987), the theoretical elaboration sequence

> . . . follows the psychological process of developing an understanding of natural processes (primarily causes and effects), which is usually similar to the order of the historical discovery of such knowledge. . . . [It is] a sequence that progresses from the most basic and observable principles to the most detailed, complex, and restricted principles. (p. 251)

The first lesson in the sequence is termed the "epitome lesson" and should "epitomize" the whole subject domain by teaching the one—or at most few—most fundamental, generalizable, and inclusive (broadly applicable) principles, such as the law of supply and demand in economics or ohm's law in electricity. The principle(s) should be taught at the concrete application level, where learners learn to apply the principle(s) to a range of real-world situations.

Reigeluth (1987) describes the process for designing a theoretical elaboration sequence as the following:

> After "brainstorming" to list all the principles (usually statements of causes or effects), ... [you should] "epitomize"; that is, look for the simplest principle or principles that are among the most basic, observable, and representative of the whole set of principles for the curriculum. Several useful heuristics for doing this include: (a) ask a subject-matter expert (SME) what principles he or she would teach if it was possible to teach only one; and (b) ask an SME to identify what principles were discovered earlier. (p. 260)

Procedural SCM Sequence

The procedural SCM sequence is based on the notion that complex cognitive tasks (procedural and causal) are performed very differently in different situations, some of which are much simpler than others. Therefore, there exists a wide variety of versions of the task, ranging from simple ones to complex ones. The ETI prescribes that the simplest one that is still fairly representative of the task in general should be taught first to novices, and that the instructional sequence should entail teaching progressively more complex versions of the task until the desired level of competence is reached (or time available for instruction has expired). Of great importance is that every "module" of the course teaches a complete, real-world version of the task. This is hypothesized to not only be more motivational for learners, but also to provide a better schema or mental model of the task, for it allows learners to perform as experts from the very beginning of the course, albeit for a very restricted domain of problems.

The SCM provides considerable guidance as to how to create this kind of sequence (Reigeluth & Kim, 1991). Briefly, one begins by identifying the simplest version of the task that is still fairly representative of the task in general, and identifying the conditions that distinguish when that version of the task should be performed instead of a more complex version. Then those "simplifying conditions" are rank-ordered based on the complexity, representativeness, importance, expense, and safety of the version of the task that each requires. The simpler, more representative, more important, less expensive, and safer versions are, of course, taught first. That rank-ordering then determines the instructional sequence. Frequently, eliminating a single simplifying condition requires a tremendous amount of learning to reach a mastery level for the corresponding version of the task. Whenever it requires more learning than can be done in a single module of the course, then "secondary" simplifying conditions should be identified that allow simpler "subversions" of the task to be taught before more complex subversions of that version. Although we currently have no good publications on the procedural SCM sequence, one is nearing completion.

Research Questions

Given that the ETI's sequencing prescriptions (a) have such strong theoretical support, (b) have some empirical support, and (c) are still in the early stages of development, the purpose of this study was to further develop and improve the sequencing prescriptions in terms of their influence on the effectiveness and appeal of instruction. The questions that had to be answered to achieve this goal were: "What ETI prescriptions work well?", "Which ones do not work well?", "For whom do they work or not work well?", and "What improvements can be made?" These types of questions cannot be answered by using only quantitative data.

Methodology

Since the focus of the study was to improve the ETI's sequencing prescriptions, the research methodology chosen for this study was formative research. The study relied on predominantly qualitative data with limited use of quantitative data.

Reigeluth (1989) has suggested the "formative research" methodology to improve instructional theories and models. In formative research some instruction is designed and developed based as purely as possible upon a theory (or model). The instruction is then an "instance" of that theory, just as treatments in an experimental study are developed as instances of the independent-variable concepts. A series of one-on-one formative evaluations is conducted with learners from the target population to identify the strengths and weaknesses of the instruction and ways of improving it. Since the instruction is an "instance" of the theory, the results may reflect the weaknesses and strengths of the theory and ways of improving it. Issues of reliability and validity play an important role in formative research, as in experimental studies. Naturally, replication with different types of content, learners, and training situations is necessary to assure generalizability of the findings.

There were two phases to the study. In the first phase, four chapters in a text (Boylestad, 1990) on electrical circuit analysis were revised according to the sequencing prescriptions of ETI. This phase used interactive data collection and was conducted to collect immediate, detailed reactions to and suggestions on the instructional sequence. Phase two utilized only non-interactive data collection to enhance the external validity of the results. Qualitative data analysis was performed and included a summary of the data on the effectiveness and appeal of the instruction. The outcome of the qualitative data analysis provided insights into ways to improve the theory. Phase 1 took 8 weeks and Phase 2 took 2 weeks to complete.

Subjects

The 13 students who participated in the two phases of this study were sophomore students from the Electronics and Computer Technology (ECT) program in the School of Technology at Indiana State University. They were enrolled in a circuit analysis course titled ECT 221. The student ages ranged from 18 to 50, and approximately 50 percent were non-traditional students.

Students were selected to be representative of the student population for the course. Information regarding the students' characteristics was gathered from a data sheet that the students filled out. Three primary factors were used in the selection process: grade point average (GPA), scores on the pre-test for content knowledge, and scores on the pre-test for prerequisite knowledge (described later). Ten students were asked to volunteer to participate in Phase 1, and three students were asked for Phase 2.

The GPA criterion was used because of the need to have a cross section of ability groups that was based on academic performance in their specific major. For Phase 1 four students were selected from the high ability group (above 3.3), three from the average group (2.8-3.3), and three from the lower group (below 2.8). For Phase 2 one student was selected from each of the three groups. The pre-tests assured that all participants had attained a minimum competency score on a prerequisite knowledge test and did not have prior circuit analysis knowledge.

Materials

The instruction was a revised version of three chapters of Robert L. Boylestad's text, *Introductory Circuit Analysis*, 6th edition, 1990. The first author revised the textbook instruction at the macro level according to multiple-strand sequencing utilizing the ETI's theoretical elaboration sequence and procedural SCM sequence. He also revised it at the micro level according to Merrill's Component Display Theory (Merrill, 1983), which is prescribed by the ETI. The revisions of the three chapters were developed as consistently as possible with the prescriptions of the theories. See Figures 1, 2, and 3 for a depiction of the sequence of the theoretical and procedural strands, along with the simplifying conditions for each, for the three chapters (topics).

Insert Figures 1, 2, and 3 about here

The instruction was presented on Macintosh computers using HyperCard and took over 11 megs of disk space. It was reviewed for accuracy by two subject-matter experts who had considerable expertise in this area.

Instruments

Six instruments were used to collect data. These included: two pre-tests, a post-test, a set of impromptu questions used during the interactive phase, a set of questions used during debriefing, and an attitude survey.

Of the two **pre-tests**, the first was to ensure that none of the students had any prior content knowledge in circuit analysis. Such prior knowledge would not allow us to collect data on ways to improve the elaboration sequence for learners with no prior knowledge. This test was essential because of students: 1) transferring into this program from other programs, and 2) retaking the course. Students had to score 30% or below to participate in the study.

The second pre-test was to ensure adequate prerequisite knowledge. A serious problem would have been encountered by students if they did not have the necessary prerequisite knowledge. The class dealt extensively with students solving problems through circuit analysis techniques that called for them to have competency with certain mathematical skills (algebraic manipulation). The lack of this prerequisite knowledge would have severely hampered a student's ability to benefit from the instruction and its sequence. Students had to score 70% or above to participate in the study.

The **post-test** was administered after each topic (e.g., series circuits, parallel circuits). Three post-tests were administered. Their purpose was to assess achievement and measure the effectiveness of the instruction. A secondary purpose of the test was to have the students reflect upon the instruction. It was hypothesized that a post-test would give students more insight into how effective the instruction was and, therefore, they would be more critical of the instruction and would help us to find more ways to improve the theory.

Of the two **qualitative instruments**, the first was a set of **impromptu questions** that were asked of each student during the interactive data collection stage. These questions were designed to identify particular aspects of the instruction that helped or hindered the student's comprehension and to identify instruction that was considered ambiguous. These impromptu questions were used only during Phase 1, and the nature of the questions depended upon comments by the student, student expressions, and progression through the instruction (the student taking an excessive amount of time working through a portion of instruction was questioned so that the problem area could be identified and a solution proposed).

The second qualitative instrument was a set of **debriefing questions** used during the debriefing sessions of Phases 1 and 2. Students were questioned to gain insight on things not directly observed (e.g., feelings, thoughts, and intentions). It is not always possible to observe how students perceive instruction and the meaning they attach to what is going on during instruction, so it is beneficial to question them about those things. The purpose of these questions was to enter into the student's perspective. The debriefing questions allowed students an opportunity to evaluate the elaboration sequence, to think about specific strengths or weaknesses not previously mentioned, and, for Phase-1 students, to make any suggestions that they had forgotten to make during the interactive data collection. The same set of debriefing questions was administered after each topic was covered. The reliability and consistency of data across students were assessed.

An **attitude survey** was used to assess 1) the appeal of the instruction and 2) the student's attitude toward the instruction. The students were asked to rate on a scale from 1 to 5 the degree to which they: liked the sequence of the instruction, felt the instruction was effective, felt the organization of the instruction was appropriate, felt the summaries were appropriate, and so forth. This instrument served as a way of cross-checking the qualitative statements that the student had previously made.

Procedure for Phase One: Interactive Data Collection

One-on-one formative evaluation as described by Dick and Carey (1985), provided the direction during this phase. The formative evaluation process was used to obtain data to increase the effectiveness and appeal of the instructional sequence. The emphasis in formative evaluation is on the collection of data to improve the instruction and to assure that the instruction is free of problems. The interactive data collection was conducted with the investigator sitting at the side of each student while he/she studied the material.

Ten students were involved in this phase. Each student was given specific instructions on the use of HyperCard and was allowed to practice before starting the instruction. This allowed the student to become familiar with the characteristics of the computer and software before starting the instruction. The purpose of this practice was to eliminate problems due to the lack of knowledge of the computer program or peripherals (e.g., being able to manipulate the mouse or being able to move from card to card).

It was explained to each student that a new instructional resource had been designed and that her reaction to it was desired. The student was informed that any mistakes that he might make would probably not be their fault, but due to deficiencies in the instruction. Each student was encouraged to be as critical of the instruction as possible so that the weaknesses could be identified and so the instruction could be made as trouble-free as possible. The student was encouraged to be relaxed and to freely comment about problems with the instruction and methods that worked for her.

During the interactive phase, there was constant communication with each student to determine what methods and tactics were either working or not working. The card number from the HyperCard program was recorded and used to identify the precise location in the instruction at which the student was having difficulties or where the student liked a specific aspect of the instruction. All comments were recorded. The student was audio taped during this phase as a way of guaranteeing the thoroughness of data collection.

As a student used the instruction, he found typographical errors, omissions of information, branching problems, improperly labeled schematics, and other kinds of mechanical difficulties that inevitably happen. This information was used to revise the instruction through the correction of small errors and gross problems

Once a student was finished with the instruction, she was asked if she had any questions. A post-test was given after all the lessons of a topic were presented. Upon completion of the post-test, the student was asked to fill out the attitude survey.

Once a student finished the attitude survey, he was debriefed. An outline of the sequence of the material was given to the student to help prompt his memory. The debriefing session was audio taped in an attempt to maximize the thoroughness of the data collection. The tape counter was set and the number was recorded so that pertinent comments could be referenced to a tape number. A debriefing log was kept with comments and the associated tape counter numbers. The debriefing concentrated on such questions as what the strengths and weaknesses of the instruction were, whether the student liked or disliked the instruction and why, and what suggestions she had for improving the instruction.

Procedure for Phase Two: Non-Interactive Data Collection

The non-interactive data collection was carried out in a more secluded environment and was used to enhance the external validity of the study. Each student worked through the instruction by herself while the researcher unobtrusively observed her and wrote notes about student comments and problems with the instruction. Completion time of each unit was logged. During this phase the investigator and the student did not communicate except during the debriefing session.

In Phase 1 the researcher continually interacted with each student in an attempt to detect methods or tactics that worked or did not work. This action caused students to constantly consider the utility of the instructional methods. We were concerned that the Phase-2 students would not be as cognizant of what tactics worked or did not work, since they were not continually reminded to consider them (e.g., students would find the instruction appealing, but not know "why" because they had not been prompted to think as much about the explicit reason the instruction worked). Therefore, in the debriefing session the Phase-2 students were asked about a method if they did not comment about it.

Identical instructions were given concerning the use of the software and practice exercises in both Phases 1 and 2. After each of the three topics was completed, students were asked if they had questions. They were given the post-test and then asked to fill out the attitude survey. After the attitude survey was completed, the students were debriefed again. The same questions were used in all three debriefings.

On the next scheduled class period after each debriefing, students were asked to verify a typed summary of their submitted comments. This practice was used to enhance construct validity according to the guidance of Yin (1984). The students either approved their comments or suggestions or modified them as necessary. The audio tapes were transcribed, and this information was used for data analysis purposes.

Results and Discussion

The research results clearly indicate the strengths of the theory, and methods/tactics that should be added and/or modified. None of the information collected reflects that certain elements should be deleted. Weaknesses are composed of two categories of tactics or methods: those that should be added (methods or tactics that should be included in the theory but are not) and those that should be modified and/or enhanced.

Qualitative Results

Student comments made while working through the instruction and during the debriefing session were categorized and placed on a matrix (e.g., Table 1). Each matrix represents either a category, continuation of a category, or student suggestions for an improvement in a category. A letter is assigned to each row (tactic/flaw/improvement) for easy reference. The matrix reflects the responses categorically within the phase (i.e., Phase 1 or Phase 2) and the ability group (i.e., low, average, and high). Each ability group was represented in Phases 1 and 2. Responses were combined and sub-totaled for each ability group. The combined total response from all three groups is presented in the final column.

Insert Table 1 about here

Qualitative Comments on the Elaboration Theory

Table 1 represents the overall tenor of qualitative comments that students made concerning the Elaboration Theory of Instruction. Many of the comments made were in support of sequencing, and are indicative of the strong influence that sequencing has on learning. There are many areas worth discussing in this category. Most students (near even distribution across ability groups for each category) liked the organization (10; row a), simple-to-complex presentation (13; row b), and the logical order (10; row c). Some comments made by students that were relative to these issues follow:

> The material is straight forward, well organized, and easy to follow.
>
> It was easy to follow.
>
> The sequence was very good.
>
> It was progressive, each topic built on the one before, progression was from easy to difficult and variance of problem set up allowed for a challenging lesson.

Each sequence was related to the one before.

I could more easily build on what I had learned.

It seemed I learned something new with every problem.

It seemed to flow together, one section led into another, it builds on itself.

The farther along you got, the more knowledge you had to use to solve problems.

The topics fell right into place. You learn one thing before adding to it.

Similarly, there were many positive comments made in support of the use of the epitome, and this is indicative of its influence on learning. In this category there are many areas worth discussing. The use of an epitome was very effective in terms of: ease of understanding (10; row d), being focused (10; row e), identifying critical areas (10; row f), relating previous knowledge (8; row g), cueing important relationships (6; row h), motivating the student (7; row i), and building confidence (8; row j). Noteworthy attributes, rows k through m, were high visualization, prominent use of arrows, and use of bold face. Responses were from nearly equal distribution of ability levels.

It is noteworthy that students commented that the simple circuits of the "Down to the basics" (epitome) allowed them the opportunity to learn procedural and theoretical information in a focused manner without extraneous detail (row e). These responses came predominantly from the high-ability-level group. Students felt that the categorizations of conditions that started with the "Down to the basics" gave them the ability to concentrate (focus) on a specific complexity of circuit analysis and become competent within that condition before progressing to more complex circuits.

Five of the thirteen students did not like the redundancy of procedural information (row n). These students did not like to read the "same steps" of the different levels of procedural information. However, two students liked it. (The remaining six students made no comments about it.) This issue will be elaborated in the improvement table. However, eight students felt that the reiteration process of instruction at the macro-level was important to them for learning to occur (row o). These students commented that going over problems with the same condition, but with divergence within a level of complexity of circuit analysis, helped learning occur (e.g., the voltage divider rule can be used for a simple series circuit and can also be used for series elements in a series/parallel circuit).

Eight students liked that the theoretical information was explained and, then, the prominence and utility of the theory was illuminated by the procedure (row p). These theories are used in every circuit analysis problem (e.g., these theories can be used for more than just problem solving -- they are also used in the verification of answers).

Eight students commented that categorization of conditions (e.g., a short in a series circuit with multiple voltage sources, a parallel circuit with an open, etc.), when presented in a simple-to-complex sequence, helped them develop a strategy to determine a solution (row q), particularly in more complex circuitry. The same eight students found the labeling of conditions appealing (row r). The labeling of the conditions was provided for each generality, example, and practice. The labeling of the condition was not deliberately intended, and was not a part of the elaboration theory, but occurred accidentally. The button for the menu for the generality, example, and practice was labeled with the condition. Students would depress the button and a menu would appear allowing them to pick the strategy component that they desired. However, students also used the button as a label for the condition. The label was on each card of every generality, example, and practice exercise with the name of the condition. Students commented that the labeling of the condition allowed them to relate the condition with the theoretical and procedural information. As the sequence continued and the circuitry became more complex, students could interpret the circuit according to the condition and apply the knowledge previously gathered. They commented that they could then categorize the condition of the circuit and apply the appropriate principles to analyze the circuit.

Nine students commented that the instruction helped them understand principles and the conditions for which these principles could be applied (row s). In certain instances it is not enough to know theoretical information, but it is requisite to understand for which conditions the theoretical information is appropriate. This positive finding is probably a strong influence of multiple-strand-sequencing (i.e., sequencing of procedural and theoretical knowledge). In row t, nine students commented that the sequence allowed them to categorize the problem according to underlying principles (i.e., need to understand Kirchhoff's voltage law to determine the unknown voltage, or that a portion of a circuit is series, therefore, the voltage divider rule can be used to find the voltage drop across R_3).

Seven students commented that the macro-level sequencing helped develop a better interpretation of the problem (row u). In "real world" circuit analysis, complex problems have extraneous information, and part of the task is to learn to differentiate what information and knowledge is needed and what is not needed to solve the particular problem. Simple examples and practice problems did not have extraneous information, while complex examples and practice problems had irrelevant information. The sequence allowed for levels of extraneous information to be presented. This process of slowly adding extraneous information and knowledge to the sequence allowed students to better handle this type of complexity. Therefore, the sequence helped students develop the ability to distinguish the information and knowledge needed to solve a problem from nonessential information and knowledge.

Furthermore, students felt that the simple-to-complex sequence provided insight into the relationship between the interpretation of the problem and the solutions of the problem (row u); it allowed students to interpret the problem at a simple level (the epitome) and then progress to more complexities.

There were certain aspects of the epitome that certain students did not like (rows v and w). As illustrated in row v, eight students, with nearly equal distribution of ability groups, did not like examples that used numbers that complicated the calculations (e.g., 20 volts/4 ohms = 5 amperes rather than 524 millivolts/614 kilo ohms = 853 nanoamps). Also, in row w, one lower-ability student commented that the epitome gave him the impression that he was knowledgeable in an area, but as he progressed through the instruction he discovered he needed to have a richer sense of knowledge (more detailed knowledge base). The epitome gave him a sense that he knew it all when he did not. One average-ability student (row x) commented that two of the epitomes were too simple. As the student progressed through more of the instruction, he commented that learner-control could be used to help facilitate the proper entry level for each student.

Improvements

Table 2 is the improvement table for the Elaboration Theory of Instruction. A plus (+) sign indicates that a student suggested that an improvement should be made in that tactic or strategy. Rows a and b address the dilemma of when a condition is relaxed and the procedure is modified. Some of the steps of the procedure changed to reflect changes in the condition, but other steps of the procedure remained the same from one condition to the next. This forced the student to repeatedly read the same steps for the different conditions. Some students felt that they wasted time determining the differences between the two procedures.

Insert Table 2 about here

The implications for changes in ETI are that procedural information should be organized so that students can use the method that works best for them, i.e.. the instruction should be structured so that the student can choose to either read or not read the identical steps for the different conditions. The instruction should compare and contrast the steps between the previous procedure and the current procedure. The instruction should identify the condition and tell what steps were the same and what steps were different, and why.

Seven students suggested that examples and problems in the epitome should use numbers that are easily computed (row c). This approach would allow students to concentrate on the underlying principles and procedures, rather than being burdened with the complexities of the math.

The data suggest that epitomes are quite effective in the learning process and should continue to be used within the ETI. Another implication (row c) is that the epitome should be focused on the principles and procedures that are being epitomized. The epitome should allow the student's cognitive processes to be focused on theoretical and procedural knowledge, rather than on the complexities of the computation.

One lower-ability student desired the instruction to induce a sense of uncertainty, but to give a clear indication of how to progress from the epitome with minimal effort (row d). Once the student realized that there was more to learn than the knowledge at the epitome level, he felt that the epitome allowed him the opportunity to build confidence. There seems to be a delicate balance between simplifying the content too much so that the student becomes overconfident, and not simplifying it enough so that the student lacks sufficient self-confidence.

The instruction informed students of the simple-to-complex sequence, but attention-focusing devices were not used to draw the students' attention to this fact. Nor were attention-focusing devices used to prompt the student to use learner-control, as needed, to omit easy material.

The implication for ETI is that the epitome needs students to be informed of the simplex-to-complex sequence (by using attention-focusing devices), and students need to be prompted to use learner-control to enter at the most appropriate level.

Quantitative Results

Quantitative data (i.e., post-test scores, ability, phase participation, sex, GPA, SAT, age) were numerically coded and entered into a system file for analysis using the Statistical Package for the Social Sciences (SPSS).

Each of the 13 students took three tests. Group means and standard deviations for the post-test are shown in Table 5. The high-ability group achieved a mean of 95.0, the average-ability group achieved a mean of 93.7, while the lower-ability group achieved a mean of 84.1. The overall mean was 91.8.

Insert Table 5 about here

These scores appeared to be higher than normal for this course, and as a matter of curiosity, we explored how these scores compared to the mean scores of previous students (scores on a similar criterion-referenced test on the same subject matter). The mean score was 77.3 % for 189 students who took 3 similar tests during the previous two years. Although these data do not represent a controlled comparison, it appears that these students did indeed perform better than previous students (91.8% compared to 77.3%). Nevertheless, the intent of this study was not to compare instruction designed according to ETI to instruction designed without ETI, but to gain insights into ways to improve the ETI.

The summary data from the attitude survey are presented in Table 6. The table is arranged so that ability groups are separated into phase participation. The number of students that participated in a group and from an ability level is indicated above each column.

Insert Table 6 about here

In general, the information on this table supports the qualitative statements made by the students in that they liked the instructional unit (1.62), liked the sequencing (1.46), liked the epitome (1.46), liked the synthesizers (1.62), liked the summary (1.46), felt that it was not too difficult (4.31), felt that it was well-organized (1.46), felt good about the instructional unit (1.62), liked the analogies (1.69), and felt it was appropriately related (1.31).

Conclusions and Recommendations

Sequencing

A significant strength of the theory was in sequencing. It appears to be a very powerful tool in helping students to understand difficult theories and procedures, and it constitutes a most appealing element of the instruction. Additionally, it appears to be a strong motivating factor. The use of sequencing from simple-to-complex benefits all ability groups.

The following are conclusions and recommendations for improving the theory.

1. If the instruction is for procedural information, compare and contrast the steps between the previous procedure and the current procedure. The instruction should distinguish what steps are the same and what steps are different, and should inform students of why the steps are different. Allow students the choice to either read or not read the identical steps of procedural information for the different conditions.

2. Provide a label for each condition. This allows students to relate the condition with the theoretical or procedural information and gives them the ability to categorize the problem according to appropriate underlying principles. Providing a label for each condition allows students to effectively use learner-control. For example, when a student is working through instruction and needs to refer to an example from a previous condition, the student needs a label to locate that condition.

3. If the instruction involves problem solving, then students need to be able to differentiate information or knowledge that is needed from what is not needed to solve particular problems. Slowly adding extraneous information and knowledge to the sequence allows students to better acquire this capability.

4. The reiteration process at the macro level is important. Going over problems with the same condition, but with divergence within a level of complexity, helps learning to occur.

Epitome

The epitome is quite effective in the learning process. It allows students to learn highly representative procedural and theoretical material in a focused manner without extraneous detail. Epitomizing involves teaching a small number of ideas at the "application level." The following are conclusions and recommendations for improving this aspect of the theory.

1. Present an epitome to highlight important relationships and relate previous knowledge. Epitomes should be focused and easy to understand, so all of the student's cognitive processes may be focused on it. Eliminate complexities that do not enhance the student's concentration on the fundamental theoretical or procedural skills. Strip away extraneous factors so that students can focus or concentrate on the underlying principles or procedures, rather than burdening them with extraneous complexities (e.g., mathematical computations and segregating essential information from nonessential information).

2. Inform students that the epitome is entry-level, fundamental information and that complexities will be added in layers. Inform students that knowledge at the epitome level is not sufficient to solve problems at the more complex levels. Label the instructional material as the epitome (or some suitable synonym).

3. The epitome should not be so simple as to make students overconfident. Direct students to use learner-control if the material is too simplistic. This tactic is most beneficial to the low-ability students.

In conclusion, the elaboration sequences were clearly both effective and appealing to the students involved in this study, and the ETI therefore appears to be both effective and appealing in its current state of development. But more importantly some ways were found to improve the sequences that were used in this study, and they may well reflect ways to improve the sequencing prescriptions of the ETI.

We encourage other researchers and especially instructional developers to engage in a similar process of formative research (formative evaluation of instruction that is developed using the ETI) to identify whether the improvements found in this study are also useful for other content, learners, and instructional contexts, and to identify other ways of improving the ETI. Furthermore, we would be happy to share our HyperCard course with those who would like to do further research with it, and we hope that you will share with us the results of any research you do.

References

Ausubel, D. (1968).
Beissner, K., & Reigeluth, C.M. (1994).
Berg, Daal & Beukhof, (1983).
Beukhof, (1985).
Boylestad, (1990).
Bruner, J. (1960).
Bruner, J. (1966).
Carson & Reigeluth, C.M. (1983).
Chao, Ruiz & Reigeluth, C.M. (1983).
Dick, W., & Carey, L. (1985).
Frey & Reigeluth, C.M. (1981).
Merrill, M.D. (1983). Component display theory. In C.M. Reigeluth (Ed.),
Merrill, P.F. (1978).
Merrill, P.F. (1980).
Reigeluth, C.M. (1979).
Reigeluth, C.M. (1981).
Reigeluth, C.M. (1987).
Reigeluth, C.M. (1989).
Reigeluth, C.M., & Darwazeh, A. (1982).
Reigeluth, C.M., & Kim. Y. (1991).
Reigeluth, C.M., & Rodgers, C. (1980).
Reigeluth, C.M., & Stein, F.S. (1983).
Scandura, J.M. (1973).
Yin, (1984).

Series Circuits

Lesson	Level of Elaboration	Lesson Elaboratedon	Simplifying Conditions
1	Epitome	-	- No more than one voltage source in series - No shorts - No opens - No ground references - No single subscript notation - No double subscript notation - No elements have two points in common - No parallel voltage sources
2	1	1	Remove this: - No more than one voltage source in series
3	2	2	Remove this: - No shorts - No opens
4	1	1	Remove this: - No ground references
5	1	1	Remove this: - No single subscript notation - No double subscript notation

Figure 1. A Sequence Blueprint for Series Circuits

Parallel Circuits

Lesson	Level of Elaboration	Lesson Elaborated on	Simplifying Conditions
1	Epitome	-	Remove this: - No elements have two points in common.
2	1	1	Remove this: - No more than one voltage source in series Remove this: - No more than one parallel voltage source * Add these: - No shorts in a parallel network - No opens in a parallel network - No series/parallel combinations - No ladder networks - No multiple branch currents
3	2	2	Remove this: - No shorts in a parallel network - No opens in a parallel network

Figure 2. A Sequence Blueprint for Parallel Circuits

Series-Parallel Circuits

Lesson	Level of Elaboration	Lesson Elaborated On	Simplifying Conditions
1	Epitome	-	Remove this:- No series/parallel combinations.
2	1	1	Remove this: - No more than one voltage source in series or parallel.
3	2	2	Remove this: - No shorts in a series/ parallel network. - No opens in a series/ parallel network.
4	1	1	Remove this: - No ladder networks

Figure 3. A Sequence Blueprint for Series-Parallel Circuits

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TABLE 1

QUALITATIVE DATA INVENTORY: Elaboration Theory of Instruction

Tactics/Strategies Comments:	Ability Group N	Low Phase 1: 1	Low Phase 1: 2	Low Phase 1: 3	Low Phase 2: 1	Low Sub Total	Average Phase 1: 1	Average Phase 1: 2	Average Phase 1: 3	Average Phase 2: 1	Avg. Sub Total	High Phase 1: 1	High Phase 1: 2	High Phase 1: 3	High Phase 1: 4	High Phase 2: 1	High Sub Total	Comb. Total
(a) Organization			+	+	+	+3	+		+	(+)	+3	+		+	+	+	+4	+10
(b) Simple-to-complex		+	+	+	+	+4	+	+	+	(+)	+4	+	+	+	+	+	+5	+13
(c) Logical order		+	+		+	+3		+	+	+	+3	+	+		+	(+)	+4	+10
(d) Easy to understand		+	+	+	+	+4	+	+		(+)	+3	+		+		+	+3	+10
(e) Well focused				+	(+)	+2		+	+	+	+3	+	+	+	+	(+)	+5	+10
(f) Identified critical areas		+		+	(+)	+3		+	+	+	+3	+	+		+	(+)	+4	+10
(g) Related previous knowledge				+	+	+2	+	+	+	+	+4			+		+	+2	+8
(h) Cued important relationships			+		(+)	+2	+		+	+	+3					(+)	+1	+6
(i) Motivating Kept interest		+		+	(+)	+3			+	+	+2			+		(+)	+2	+7

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ◯ were solicited. (Continued)

TABLE 1 - CONTINUED
QUALITATIVE DATA INVENTORY: Elaboration Theory of Instruction

Tactics/Strategies Comments:	Ability: Low					Average					High							
Group	Phase 1			Phase 2	Low Sub Total	Phase 1			Phase 2	Avg. Sub Total	Phase 1				Phase 2	High Sub Total	Comb. Total
N	1	2	3	1		1	2	3	1		1	2	3	4	1		
(j) Built ‹ ›nfidence	+	+		⊕	+3	+	+		⊕	+3	+				⊕	+2	+8
(k) Highly visual	+	+		+	+3		+		⊕	+2	+				⊕	+2	+7
(l) Used arrows	+	+		⊕	+3		+	+	⊕	+3	+			+	⊕	+3	+9
(m) Bold face/underlined	+		+	⊕	+3	+	+		⊕	+3	+				⊕	+2	+8
(n) Redundancy of Procedural information	-			+	-1,+1		-		0	-1	+	-	-		⊖	-3,+1	-5,+2
(o) Repetition with divergence	+		+	⊕	+3		+		+	+2	+			+	+	+3	+8

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ◯ were solicited.

TABLE 1 - CONTINUED

QUALITATIVE DATA INVENTORY: Elaboration Theory of Instruction

Tactics/Strategies Comments:	Ability	Low					Average					High						
	Group	Phase 1			Phase 2	Low Sub Total	Phase 1			Phase 2	Avg. Sub Total	Phase 1				Phase 2	High Sub Total	Comb. Total
	N	1	2	3	1		1	2	3	1		1	2	3	4	1		
(p) Explained theoretical information and then pulled together in procedural information			+		(+)	+2	+		+	(+)	+3		+	+		(+)	+3	+8
(q) Categorized conditions		+		+	(+)	+3		+		(+)	+2		+		+	(+)	+3	+8
(r) Labeled condition		+		+	(+)	+3		+		(+)	+2		+		+	(+)	+3	+8
(s) Pertinent conditions		+		+	(+)	+3		+	+	(+)	+3		+	+		+	+3	+9
(t) Categorize by underlying principles			+	+	(+)	+3	+			(+)	+2	+	+	+		(+)	+4	+9

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ◯ were solicited.

TABLE 1 - CONTINUED

QUALITATIVE DATA INVENTORY: Elaboration Theory of Instruction

Tactics/Strategies Comments:	Ability	Low					Average					High							
	Group	Phase 1			Phase 2	Low Sub Total	Phase 1			Phase 2	Avg. Sub Total	Phase 1				Phase 2	High Sub Total	Comb. Total
	N	1	2	3	1		1	2	3	1		1	2	3	4	1		
(u) Interpretation of problem and solution of problem			+		(+)	+2	+		+	+	+3			+		(+)	+2	+7
(v) Easy to calculate numbers			-	-	-	-3		-	-	(−)	-3	-				(−)	-2	-8
(w) Gave impression that you know it all		-			(+)	-1,+1				(+)	+1					(+)	+1	-1,+3
(x) Too simple										-	-1							-1

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ◯ were solicited.

TABLE 2
QUALITATIVE DATA INVENTORY:
IMPROVING THE ELABORATION THEORY OF INSTRUCTION

Tactics/Strategies Comments:	Ability Group	Low					Average					High						High Sub Total	Comb. Total
		Phase 1			Phase 2	Low Sub Total	Phase 1			Phase 2	Avg. Sub Total	Phase 1				Phase 2			
	N	1	2	3	1		1	2	3	1		1	2	3	4	1			
Sequencing:																			
(a) Steps of the procedure that change from previous procedure are underlined. Inform students that underlined steps are different from previous steps of procedure. Inform students that non-underlined steps are the same as previous procedure.		+			(+)	+2		+		(+)	+2				+	(+)		+2	+6
(b) Describe why the steps are different from one process to the next.		+			(+)	+2				(+)	+1				+	+		+2	+5

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ◯ were solicited.

TABLE 2 - CONTINUED
QUALITATIVE DATA INVENTORY:
IMPROVING THE ELABORATION THEORY OF INSRUCTION

Tactics/Strategies Comments:	Ability	Low					Average					High						
	Group	Phase 1			Phase 2	Low Sub Total	Phase 1			Phase 2	Avg. Sub Total	Phase 1				Phase 2	High Sub Total	Comb. Total
	N	1	2	3	1		1	2	3	1		1	2	3	4	1		
(c) Easy to calculate numbers			+	+	+	+3		+	+	○	+3					(+)	+1	+7
(d) Induce uncertainty		+			(−)	+1,-1				(−)	-1					(−)	-1	+1,-3

where: + = liked, - = disliked, and 0 = neutral to a solicited response. Responses enclosed by a ○ were solicited.

Table 3

GROUP MEANS AND STANDARD DEVIATIONS

ABILITY	MEAN	SD
High	95.0	5.843
Average	93.7	5.867
Low	84.1	10.037

Table 4
ATTITUDE SURVEY GROUP MEANS SUMMARY

Attitude Survey Items	Ability	Low		Average		High		TOTAL
	Group Number of students	Phase 1 N = 3	Phase 2 N = 1	Phase 1 N = 3	Phase 2 N = 1	Phase 1 N = 4	Phase 2 N = 1	N = 13
1. Liked the instruction		1.67	2.0	1.67	1.0	1.75	1.0	1.62
2. Liked the sequencing		1.67	1.0	1.33	1.0	1.75	1.0	1.46
3. Liked the epitome		1.33	1.0	1.33	1.0	1.75	2.0	1.46
4. Liked the synthesizers.		2.00	2.0	1.33	1.0	1.50	2.0	1.62
5. Liked the summary		1.67	1.0	1.33	1.0	1.75	2.0	1.46
6. Too difficult.		4.00	4.0	4.33	4.0	4.50	5.0	4.31
7. Well organized		1.67	1.0	1.67	1.0	1.50	1.0	1.46
8. Felt good about the instruction.		2.00	1.0	1.67	1.0	1.75	1.0	1.62
9. Liked the analogies		2.00	1.0	1.67	1.0	1.75	2.0	1.69
10. Appropriately related		1.33	1.0	1.67	1.0	1.25	1.0	1.31

Scale used was: 1 = Strongly Agree, 2 = Agree, 3 = Undecided, 4 = Disagree, 5 = Strongly Disagree

Table 5

GROUP MEANS AND STANDARD DEVIATIONS

ABILITY	MEAN	SD
High	95.0	5.843
Average	93.7	5.867
Low	84.1	10.037

Table 6
ATTITUDE SURVEY GROUP MEANS SUMMARY

Attitude Survey Items	Ability: Group (Number of students)	Low Phase 1 N = 3	Low Phase 2 N = 1	Average Phase 1 N = 3	Average Phase 2 N = 1	High Phase 1 N = 4	High Phase 2 N = 1	TOTAL N = 13
1. Liked the instruction		1.67	2.0	1.67	1.0	1.75	1.0	1.62
2. Liked the sequencing		1.67	1.0	1.33	1.0	1.75	1.0	1.46
3. Liked the epitome		1.33	1.0	1.33	1.0	1.75	2.0	1.46
4. Liked the synthesizers.....		2.00	2.0	1.33	1.0	1.50	2.0	1.62
5. Liked the summary		1.67	1.0	1.33	1.0	1.75	2.0	1.46
6. Too difficult.............		4.00	4.0	4.33	4.0	4.50	5.0	4.31
7. Well organized		1.67	1.0	1.67	1.0	1.50	1.0	1.46
8. Felt good about the instruction...............		2.00	1.0	1.67	1.0	1.75	1.0	1.62
9. Liked the analogies		2.00	1.0	1.67	1.0	1.75	2.0	1.69
10. Appropriately related		1.33	1.0	1.67	1.0	1.25	1.0	1.31

Scale used was: 1 = Strongly Agree, 2 = Agree, 3 = Undecided, 4 = Disagree, 5 = Strongly Disagree