EFFECT OF VARIED ELABORATED HYPERTEXT STRATEGIES IN FACILITATING STUDENTS’ ACHIEVEMENT OF DIFFERENT LEARNING OBJECTIVES

WEI-FAN CHEN & FRANCIS DWYER
The Pennsylvania State University

ABSTRACT
This study investigated the interaction between the hypertext instructional treatment and students’ prior knowledge. The research design of the study was a randomized posttest with a control group design. Two independent variables were studied: (1) Elaboration-Theory hypertext and (2) prior knowledge. Dependent variables were the four criterion tests that were given immediately after students finished reading a unit of online instructional materials. One hundred and twenty-five students participated in the study. A Multivariate Analysis of Variance (MANOVA) was performed to analyze the data. The main effects and the potential interaction of the two independent variables were examined. Where significant F-values were found, pair-wise multiple comparison tests were performed using Tukey HDS.

INTRODUCTION
Hypertext learning materials have been employed as major components for designing and implementing educational and training learning environments (Dillon & Gabbard, 1998). This fact can be validated by the increasing number of online courseware offerings in school settings and corporate environments as well as by the number of articles and journals in hypertext research literature. While creating hypertext learning materials is becoming part of the mainstream in the implementation of educational media in most of educational settings, the design and development of hypertext materials are still heavily based on technical issues or simply designed by intuition (Chen & Dwyer, 2003). Clark (1983) has indicated that media research studies tend to ignore the importance of theories and thus do not relate their research to theories. The deficiency of media research has not changed significantly in the last twenty years. Targan (1997) pointed out that hypermedia research was not sufficiently rooted in cognitive science of human learning with the aid of media and instructional design theories. Therefore, hypermedia research needs to be more bound to instructional theory-based methodologies.
To overcome these deficiencies in hypermedia research, one of the most cited and applied instructional theories, Charles Reigeluth’s Elaboration Theory (ET), is the target of investigation in this study. According to Reigeluth (1999), Elaboration Theory prescribes a macro level of instruction by sequencing information in a simple-to-complex approach. More specifically, the theory prescribes that instruction start with an epitome that teaches a few simple, general ideas in order to link to the learner’s prior knowledge (or experience). The remainder of the instruction presents progressively more complex ideas in order to elaborate on the ones previously presented. The purpose of this study is to investigate whether Elaboration Theory strategies are still able to serve as effective guidelines for designing hypermedia materials with the latest emerging technologies.

This study was designed primarily to compare two different Elaboration-Theory-based hypertexsts with a control-group design that did not employ any instructional theories and principles. The first instructional treatment designed a unit of hypertext materials by using two major Elaboration-Theory strategies proposed by Reigeluth (1987): (1) sequencing the instructional materials using a simple-to-complex format; and (2) considering learners’ prior knowledge. The second treatment employed the same structure used in the first treatment with the addition of three more Elaboration-Theory strategies. The three additional strategies involved the use of summarizers, synthesizers, and cognitive strategies (mnemonics).

In addition, this study also investigated the potential interaction between the hypertext instructional treatment and students’ prior knowledge, since prior knowledge has long been considered an important learning variable for acquiring new information (Dochy, 1994; Dochy & Alexander, 1995; Dochy, Segers & Buehl, 1999).

Specifically, the purpose of this study was to: (1) determine whether Elaboration-Theory-based hypertext, designed by using instructional strategies proposed by Reigeluth (1987), was effective in facilitating student achievement of different educational objectives; (2) determine whether different Elaboration-Theory-based hypertexsts (the one with the two Elaboration-Theory strategies versus the one with the five Elaboration-Theory strategies) were equally effective in facilitating students’ achievement of different educational objectives; (3) determine whether students with different prior knowledge levels (high and low) achieve differently on different educational objectives in the same hypertext environment; and (4) determine whether a significant interaction exists between Elaboration-Theory-based hypertext and learners’ level of prior knowledge.

The challenge facing educators is to produce appropriate instructional materials that make good use of current technologies. It is expected that educators would benefit from the results of this research in order to guide their development efforts by using appropriate instructional theories. Furthermore, the results of this study may guide instructional designers to design and develop more effective hypertext materials for learners with different prior knowledge by using appropriate instructional theories. More specifically, it would be beneficial for instructional practitioners to learn which Elaboration-Theory-based hypertext works best on the achievement of different educational objectives for the students identified as having high-prior knowledge or low-prior knowledge.
METHODOLOGY

Subjects

Participants in the study were recruited from a target population of undergraduate students (N = 125) who enrolled in a computer networking course in a state university in the United States. The volunteers who participated in the study were mainly freshmen majoring in Information Sciences and Technology. They received extra credit points from their instructors by completing this research study.

Instructional Materials

The instructional content used for designing the instructional treatments was the visualized version of 2000-word heart content module developed by Dwyer and Lamberski (1977). The visualized version of heart content includes 20 visuals of the human heart. The content was chosen because (1) it covers a variety of educational objectives (facts, concepts and comprehensions); (2) learners are intrinsically motivated to learn the course content since everyone has a heart; (3) the content is unrelated to the participant’s course, thus avoiding potential threats to internal validity of the study; and (4) the assessment measures of the study are reliable. Average reliability coefficients reported are: 0.83 for the drawing test; 0.83 for the terminology test, 0.81 for the identification test, 0.77 for the comprehension test and 0.92 for the overall criterion test (Dwyer, 1978, p. 47).

Independent Variables

Two independent variables were examined in this study: (1) students’ prior knowledge of general human physiology and (2) Elaboration-Theory-based hypertext. There were two levels (high and low) identified for the variable of prior knowledge of general human physiology. And three levels (one single Web page with no hyperlinks, Elaboration-Theory-based hypertext with two strategies, and Elaboration-Theory-based hypertext with five strategies) were identified for the variable of Elaboration-Theory-based hypertext.

Dependent Variables

Four criterion posttests were used to assess learners’ achievement of different educational objectives. The four posttests included a drawing test, an identification test, a terminology test and a comprehension test. Each test consisted of 20 test items. A description of each test follows (Dwyer, 1978, pp. 45-47).

(1) Drawing test (20 items): The drawing test evaluates a subject’s ability to construct and/or reproduce items in their appropriate context. Learners are required to draw a reasonable facsimile of the human heart and indicate the location of 20 specific areas discussed in the presentation from a list of specific terms. The quality of the drawing does not affect the test score. This test evaluates student learning of the locations of specific parts of the heart.
(2) Identification test (20 items): The identification test evaluates a subject’s ability to identify a part of the heart or its location on a black and white detailed drawing. The test measures a subject’s ability to use visual cues to discriminate one structure of the heart from another and to associate specific parts of the heart with their proper names.

(3) Terminology test (20 items): The terminology test measures knowledge of specific verbal symbols such as facts, ten-ns, and definitions by asking learners to answer multiple choice questions that describe parts of the heart. The objectives measured by this type of test are appropriate to all content areas that require an understanding of factual material that is prerequisite to the learning of concepts, rules, and principles.

(4) Comprehension test (20 items): Subjects are required to demonstrate their understanding of how specific parts of the heart function in relation to other parts. Given the location of certain parts of the heart at a particular functional moment, the learner determines the position of other parts of the heart at the same time. The comprehension test requires that subjects thoroughly understand the heart, its parts, its internal functioning, and the simultaneous processes that occur during the systolic and diastolic phases. The test measures a higher-level cognitive task where the learner understands what is being communicated and can use it to explain some other phenomenon.

## Instructional Treatments

Three instructional treatments were designed and developed for this study. They utilized identical instructional content. A description of each instructional treatment follows.

- Treatment 1 (Control Group): One single Web page without employing any Elaboration-Theory strategies
- Treatment 2: Developing the unit of heart content using two Elaboration-Theory strategies: (1) epitome and (2) sequencing methods.
- Treatment 3: Elaboration-Theory-based hypertext using five strategies: (1) sequencing the instructional materials by using a simple-to-complex format; (2) using an epitome to link the learner’s prior knowledge; (3) using summarizers; (4) using synthesizers; and (5) using cognitive strategies (mnemonics).

## Experimental Procedures

In the study, participants were first given a 36-item multiple choice physiology pretest to assess their prior knowledge of general human physiology. Based on the results of the pretest, they were divided into two groups of high- and low-prior knowledge. For each prior knowledge group, three instructional treatments were randomly assigned by using a stratified sampling method. The purpose of conducting the stratified randomized sampling was to ensure that each treatment had equal number of students from subject pools so as to avoid potential sampling bias.
Research Design

The research design in the study was a randomized posttest with a control group design. The two independent variables were Elaboration-Theory hypertext and prior knowledge. The dependent variables were the four criterion tests that were given immediately after the students finished reading the online instructional treatments.

A Multivariate Analysis of Variance (MANOVA) was performed to analyze the data. The main effects and the potential interaction of the two independent variables were examined. Where significant F-values were found, pair-wise multiple comparison tests were performed using the Tukey HDS method.

RESULTS

The multivariate analysis of variance resulted in a Wilks’ Lambda value that would determine whether independent variables and the interaction between the independent variables had any effect on any of the dependent variables (Cronk, 1999). According to Table 1, a significant effect of prior knowledge was found (Lambda (7.113) = .84, p < .05). A second significant effect of hypertext treatment was also found (Lambda (14,226) = .80, p < .05). However, the effect of interaction between hypertext treatment and prior knowledge was not significant (Lambda (14,226) = .881, p > .05).

<table>
<thead>
<tr>
<th>Effect</th>
<th>Wilk’s Lambda</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Knowledge</td>
<td>.840</td>
<td>3.085</td>
<td>.005</td>
</tr>
<tr>
<td>Treatment</td>
<td>.800</td>
<td>1.911</td>
<td>.026</td>
</tr>
<tr>
<td>Prior Knowledge * Treatment</td>
<td>.881</td>
<td>1.055</td>
<td>.401</td>
</tr>
</tbody>
</table>

The univariate analysis of variance resulted in an F-ratio that was used to determine whether variations in the performance on the criterion tests were affected by the various treatments and levels of prior knowledge of general human physiology. Two major findings follow.

Finding 1: Main effect of treatment

According to Table 2, analysis of the dependent variables showed significant main effects of the independent variables in all the criterion tests except for the treatment effect on the comprehension test. As the multivariate analysis concluded, the univariate analysis found no interactions between the independent variables. When the results of the analysis of variance showed significant differences among the criterion tests, the ad hoc follow-up pair-wise comparison procedure, Tukey HDS, was used to identify the sources of the differences.

The results of the Tukey HDS indicated that regardless of different levels of prior knowledge, instructional Treatment 3 (five-strategy group) is superior to
Treatment 1 (control group) on the drawing test, the identification test and the terminology test, but not for the comprehension test. In addition, Treatment 2 (two-strategy group) was significantly better than Treatment 1 on the drawing test.

Finding 2: Main effect of prior knowledge

Regarding the main effect of prior knowledge, it was detected in all the criterion posttests. high-prior knowledge students performed significantly better than the low-prior knowledge students for all the criterion tests. See Table 2.

| TABLE 2: RESULTS OF TESTS OF BETWEEN-SUBJECTS EFFECTS |
|---------------------------------|-----|-----|-----|
| Source                          | Df  | SS  | F   | p   |
| Drawing Test                    |     |     |     |     |
| Prior Knowledge                 | 1   | 246.106 | 11.766 | .001* |
| Treatment                       | 2   | 295.641 | 7.067 | .001* |
| Prior Knowledge *Trt            | 2   | 56.124 | 1.342 | .265 |
| Error                           | 119 | 2489.042 |       |     |
| Identification Test             |     |     |     |     |
| Prior Knowledge                 | 1   | 293.854 | 18.143 | .000* |
| Treatment                       | 2   | 147.878 | 4.565 | .012* |
| Prior Knowledge *Trt            | 2   | 18.864 | .582 | .560 |
| Error                           | 119 | 1927.404 |       |     |
| Terminology Test                |     |     |     |     |
| Prior Knowledge                 | 1   | 255.079 | 13.850 | .000* |
| Treatment                       | 2   | 181.814 | 4.936 | .009* |
| Prior Knowledge *Trt            | 2   | 4.649 | .126 | .882 |
| Error                           | 119 | 2191.705 |       |     |
| Comprehension Test              |     |     |     |     |
| Prior Knowledge                 | 1   | 125.922 | 8.017 | .005* |
| Treatment                       | 2   | 63.095 | 2.009 | .139 |
| Prior Knowledge *Trt            | 2   | 23.336 | .743 | .478 |
| Error                           | 119 | 1869.039 |       |     |

Significant at .05 level

DISCUSSIONS

Finding 1

From the above results of finding 1, it may be concluded, if not considering extraneous variables, that the two Elaboration-Theory strategies—(1) sequencing materials in a simple-to-complex format and (2) providing epitome at the beginning of the materials—might improve students’ achievement of learning
factual knowledge such as recall or identification of facts. Cognitive strategies (mnemonics) do improve students’ achievement of learning difficult-to-recall factual knowledge such as medical terminologies. In addition, summarizers may improve students’ achievement of learning conceptual knowledge.

The results also indicated that simply presenting a synthesis table at the end of learned materials as an instructional strategy did not involve activities of deeper information processing enough to significantly improve students’ achievement of learning comprehension knowledge.

Some extraneous variables on treatments may influence the results of the study. For example, in the Treatment I (control group), the interface between learners and computers is a scrolling bar in the navigation browser. Learners can freely review the contents by dragging the computer mouse. Based on this fact, they might review contents more than one time, which may enhance their depth of information processing. Another potential variable is the time spent on each learning task. Both extraneous variables should be investigated in the future study.

Finding 2

Based on the results of finding 2, prior knowledge, regarded as a learning variable in the study, was shown to be a significant predictor of students’ learning achievement. Specifically, high-prior knowledge students always showed higher achievement scores in all the four criterion posttests than low-prior knowledge students, regardless of instructional treatments.

This result supports Ausubel’s (1968) assertion on prior knowledge that the most important single factor influencing learning is what the learner already knows, and the learner should be taught accordingly. Furthermore, numerous investigations have shown that prior knowledge is an important variable affecting study results, and that it plays a major role in educational performance (De Corte, 1990; Dochy, 1992; Tobias, 1994). The overall results appear to be stable, regardless of the method of analysis.

The effects of prior knowledge on the learning process are classified into three categories by Dochy (1995): (1) an overall facilitating effect of learning, leading to better study results; (2) inherent qualities of prior knowledge influencing the facilitating effect; and (3) the effects of interaction between these two types of effect (p. 384). The results of this study reinforce the first category of the impact of prior knowledge. Moreover, Peterson and Swing’s (1982) study finds that students who possess both the capability to relate information to prior knowledge and to check information with others acquire higher scores on skill-specific achievement tests. The results of this current study support their finding that students from high-prior knowledge group with more relevant domain-specific knowledge have advantages over those with low-prior knowledge.

In addition, prior knowledge enhances human information processing. For example, restructuring theory and accessibility theory state that information is structured in a different way in long-term memory, and that prior knowledge increases the accessibility of knowledge and reduces the load on working memory, so that more information can be processed (Dochy, 1995).
According to Dochy (1995), prior knowledge is believed to influence the following phases: the direction of attention, the encoding of information, its processing in working memory, its storage in the long-term memory, and the retrieval of information from long-term memory. As the results of this study indicate, since each theory focuses on different positive components of prior knowledge, educators should take those stages into account and employ them, either in educational settings or as an instructional support. Thus, different entry levels of students may be provided with individual learning materials so that appropriate learning methods may be employed.

On the other hand, a review of research on the interest-prior knowledge relationship (Tobias, 1994) suggested that the common variance between these constructs might be approximately 20%. Some part of the variance in resulted indicates that interest facilitating learning must be ascribed to prior knowledge. Tobias (1995) suggested that it is important to assess prior knowledge in studies of interest and to account for it by blocking that variable or by making covariance adjustments for differences in prior knowledge.

**CONCLUSIONS**

This study is one of a few hypertext studies focusing on the investigation of instructional methods rather than media effects. It also takes Aptitude-Treatment Interaction (ATI) into consideration, as suggested by Tagan (1997), to explore the potential interaction between external instructional treatments and internal learners’ aptitudes. A number of conclusions derived from the results of the study are stated as follows.

The research results of the study support Tagan’s (1997) finding from an evaluation of meta-analytic studies on computer-based learning environments. He found that the most important variables for influencing learning achievement are “the characteristics of the learners, the task induced, and the instructional methods applied for supporting cognitive processing (p. 13).” In this study, it was found that students’ prior knowledge levels play a crucial role in influencing their learning achievement. The educational implication of this finding would assist instructional designers in developing appropriate hypertext learning materials by incorporating students’ prior knowledge as a recurrent feature in curricula.

It was also found that Elaboration-Theory-based hypertexts employing instructional strategies are superior to the linear hypertext in enhancing students’ achievement of factual and conceptual knowledge. This research result supports Clark and Craik’s finding (1992) that multiple media are not the factors that influence learning. The measured learning gains in studies of instructional uses of multiple media are most likely due to instructional methods that can be used with a variety of single and multiple media.

However, the results of the study do not provide evidence that Elaboration-Theory-based hypertexts employing synthesizer strategies would significantly improve students’ comprehension capabilities. This result confirms Jonassen’s (1993) finding that merely presenting knowledge structures does not automati-
cally improve the acquisition of structural knowledge. It is the constructive processing of the learner that results in effective learning from hypertext. This finding is in accordance with Cunningham et al.’s (1993) comment on the results of numerous studies with hypermedia that were designed to support critical thinking and constructive learning. They stress that the technology”...will not bring about the sort of educational revolution we are seeking (p. 45).”

Although there is no significant interaction between instructional treatment and prior knowledge, an interesting tendency that was found is that low-prior knowledge students benefit more from working with Elaboration-Theory-based hypertexts than high-prior knowledge students. This is similar to Balcytiene’s finding (1999). However, the question -- which Elaboration-Theory-based hypertext works best for the students identified as having high-prior knowledge or low-prior knowledge -- was not discussed in the study. It needs further investigation in the future study.

Direct Reprint Requests to:
Dr. Wei-Fan Chen
Information Sciences and Technology Department
The Pennsylvania State University
Wilkes-Barre Campus
Lehman, PA 18627
Email: weifan@psu.edu
REFERENCES


