Comparison of Hypermedia Learning and Traditional Instruction on Knowledge Acquisition and Retention

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ABSTRACT **A comparison was made of hypermedia learning environments and traditional instruction in terms of contribution to declarative, procedural, and conditional knowledge acquisition and retention in a specific subject area through a pretest-posttest control-group design. Thirty-nine 9th-grade biology students were assigned to experimental (hypermedia learning environment) and control (traditional instruction) groups through a matched-pair technique. Both groups were given pre-, post-, and retention tests. Posttest results indicated no significant difference between control and experimental groups in acquisition of declarative, conditional, and procedural knowledge. However, retention test results showed that the experimental group retained all three types of knowledge significantly better than did the control group.**

Key words: computer-based instruction, hypermedia, knowledge acquisition

Technology now offers significant capabilities for teaching and learning. Hypermedia is one of those capabilities that technology presents for use in various ways to promote learning. Hypermedia applications are viewed as the next generation of computer-based instructional programs that offer the learner more control over the learning experience.

The significance of hypermedia for learning comes from its knowledge structure as much as from its control and motivational effect. Organization of information in hypermedia programs is similar to that in human memory. According to Jonassen and Grabinger (1990), learning is the reorganization of knowledge structures, which refer to the organization of ideas in semantic memory. The structures are arranged in a network of interrelated concepts known as our semantic network. Structured networks, like hypermedia, are composed of nodes and ordered relationships (links) connecting them. The networks describe what a learner knows and provide the foundations for learning new ideas; this is the richest conceptual model of learning through hypermedia. Learning, then, results from the interactive processes of accretion, restructuring, and tuning.

There are many studies that support Jonassen and Grabinger's (1990) statements about learning and the effects of hypermedia on learning. Crane and Mylonas (1988) developed a hypermedia program at Harvard University on Greek civilization to support learners. As a result of the study, the authors stated that this kind of environment enhanced creative, individualized, and active learning. Harris and Cady (1988) developed a hypertext literature lesson at a high school in Maryland. The researchers found that students were motivated and even inspired to search at deeper levels of the program. Lohr, Ross, and Morrison (1995) designed a study to evaluate a hypertext model for teaching writing at the junior high and high school levels. They determined how three different age groups of students used and reacted to the program they developed. Their findings showed that older students benefited more from the program. Harding, Lay, Moule, and Quinney (1995) developed multimedia mathematics modules consisting of text, sound, still images, and animation. It was developed for freshman mathematics courses to provide students with self-study materials with or without little supervision. Even though they did not implement a formal evaluation of the program, the authors observed that the students, especially the 18-year-olds, showed positive attitudes toward the Renaissance Mathematics materials they studied at workshops.

Those studies suggest that learners appear to prefer learner-controlled instructional media and materials. Learner control is linked to a variety of positive affective outcomes, such as motivation, increased level of engagement, positive attitudes, and decreased anxiety. When instructional experience is effectively self-managed, it may add to an individual's sense of competence and self-efficacy, which, in turn, can enhance continuous motivation. Such systems not only help students use and transfer self-managed strategies, but

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they also ensure acquisition of cognitive outcomes and increase their desire to learn. In that sense, hypermedia appears to be an effective tool for learning.

Although many research studies have been carried out on hypermedia's effect on learning, its effect on learning different types of knowledge, namely, declarative, conditional,and procedural has less research to support it. Smith and Ragan (1993) and Schunk (1996) defined declarative knowledge as facts, beliefs, opinions, generalizations, theories, hypotheses, and attitudes; conditional knowledge (relational rules) as a network of condition–action sequences that describes the relationship between two or more concepts; and procedural knowledge as understanding how to perform cognitive activities. More detailed description of the three types of knowledge are presented in the following paragraphs.

Declarative Knowledge

According to Smith and Ragan (1993) and Schunk (1996), declarative knowledge involves knowing that something is the case. Anderson (1995) defined declarative knowledge as explicit knowledge that we can report and of which we are consciously aware. Although declarative knowledge often is processed automatically, there is no guarantee that it will be integrated with relevant information in long-term memory. Meaningfulness, organization, and elaboration enhance the potential for declarative information to be effectively processed and retrieved. Smith and Ragan (1993) stated that even though declarative knowledge acquisition is often mentioned as "lower level learning," it is the substance of much human thinking and is generally acquired within meaningful structures. Declarative knowledge is a critical part of what an individual learns throughout his or her life. To learn different knowledge types or rules, the learners should first possess declarative knowledge, an essential prerequisite for effective and higher level learning.

Gagné and Briggs (1979) identified three subtypes of declarative knowledge that are labels and names, facts and lists, and organized discourse (cited in Smith & Ragan, 1993). Learning facts and names requires making a mental connection between two elements. When the connection between two elements is meaningful, one can more easily learn. Facts and lists can be learned better when they are integrated into prior knowledge. Organized discourse learning occurs when reading a text; it should also be integrated into the existing knowledge structure. Smith and Ragan stated that declarative knowledge is comparable to recall and understanding levels of Bloom's taxonomy.

For declarative knowledge learning to occur, the learning process should include three activities: linking, organizing, and elaboration. To learn new declarative knowledge effectively, one should link it to the learners' existing knowledge or schemata; that type of linking requires a meaningful presentation of new declarative knowledge (Jonassen, 1991). Organizing newly acquired knowledge is another important cognitive activity when learning declarative knowledge (Smith & Ragan, 1993). Organization of knowledge, such as clumping sets together and subordinating, may simplify the cognitive load. Finally, elaboration is an important activity for the learner when individualizing new knowledge according to his or her experience. The elaboration process makes the new knowledge more meaningful for learners.

Conditional Knowledge

Conditional knowledge (relational rules) involves a network of condition-action sequences. Conditional knowledge consists of "if-then" or "condition-action" statements; these statements describe the relationship between two or more concepts. "If" statements indicate conditions; "then" statements indicate actions. Conditional knowledge can be propositions, principles, laws, axioms, theories, or postulates. Smith and Ragan (1993) stated that conditional knowledge enables learners to predict what will happen if one of the variables, either condition or action, is changed. To learn conditional knowledge, learners should first determine the variables or concepts involved in the situation and then decide on the rules applying to that situation. Once known and unknown variables are identified, the effect of known variables on unknown variables should be determined. At the end of the condition-action sequence, the learners should reach a conclusion about the situation. Conditional knowledge helps learners predict, explain, or control circumstances. Smith and Ragan suggested two strategies for relational rule learning: inquiry strategy and expository strategy. In inquiry strategy, a puzzling situation can be presented to the learners and they direct yes or no questions to the teacher or to the source. Then the learners reach a conclusion about the situation. In expository strategy, conditional knowledge is first presented to learners in a meaningful way, then learners apply the knowledge.

Procedural Knowledge

Procedural knowledge (procedural rules) is more sophisticated than declarative and conditional knowledge in terms of cognitive level; it involves both declarative and conditional knowledge. According to Schunk (1996), procedural knowledge consists of concepts, rules, and algorithms. It is the knowledge of how to perform cognitive activities and is often implicit. Procedural knowledge originates in problem-solving activity in which a goal is decomposed into subgoals for which the problem solver possesses operators (Anderson, 1995). Smith and Ragan (1993) stated that procedural rules are a "generalizable" series of steps initiated in response to a particular class of circumstances to reach a specified goal and tell learners what certain actions should be taken. Examples of those processes include solving mathematical problems and proving geometric theorems. When learning procedural knowledge, one should highlight the related conditional knowledge. Retrieval of procedural knowledge is similar to that of declarative knowledge. Gagné (cited in Smith & Ragan, 1993) distinguished procedural knowledge from declarative knowledge by stating that procedural knowledge reflects "knowing how," whereas declarative knowledge involves "knowing that." In Bloom's level of cognitive objectives, procedural knowledge includes application, analysis, and evaluation levels. To solve problems, learners may simultaneously select and apply conditional and procedural knowledge and apply related rules. In that process, learners should also recall declarative knowledge related to those rules. When learners employ both conditional and procedural knowledge to solve a problem or to reach a conclusion, the learning process in which they are involved is called higher order rule learning or problem solving (Smith & Ragan).

Schunk (1996) stated that the distinction among the three types of knowledge is important in terms of their implications for teaching and learning. Deficiencies of different types of knowledge not only hinder learning but also produce low self-efficacy among students. In addition, discovering what type of knowledge is deficient is a necessary first step to planning remedial instruction. From that perspective, how hypermedia contributes to different types of knowledge acquisition and retention in comparison with traditional instruction becomes a significant question. Therefore, the purpose of this study was to assess the effect of hypermedia in comparison with traditional classroom instruction on acquisition and retention of different types of knowledge; namely, declarative, conditional, and procedural.

Method

We used a pretest-posttest experimental design in this study. Control variables were prior achievement and pretest performance scores; the independent variable was the treatment (hypermedia learning environment or traditional instruction); the dependent variables were posttest performance and retention test performance. Detailed description about the hypermedia learning material, participants, data collection instrument, procedures, and limitations of the study are presented in the following paragraphs.

Hypermedia Learning Material

The hypermedia learning material developed for this study included circulatory and excretory systems of the human body for a ninth-grade biology course run under Web browsers such as Netscape Navigator or Internet Explorer. We developed the material using a hypertext mark-up language (HTML) editor, Microsoft FrontPage 2.0. An instructional system development process and a conceptual linking approach guided the development of the hypermedia, which involved the use of text, sound, still pictures, motion pictures, graphics and video.

The hypermedia learning material consisted of 166 screens; 4 screens were introductory, 2 were advance organizers, 2 were main menus, 62 were information, 32 were practice, and 64 were feedback. The hypermedia learning material provided participants with three types of navigation paths in addition to Internet Explorer's back-and-forward navigation tools. The users had a chance to navigate through the path structured by the programmer via the concept map according to his or her own interest or from the menu provided on each screen. The users were therefore provided flexibility in their navigation choices.

Designing the hypermedia learning material involved these three phases: preparation, development, and evaluation, which are discussed in the following paragraphs.

Phase 1: Preparation

Determining the users' characteristics. Learner characteristics is one of the most important factors effecting the design of hypermedia learning material. Specifically, it seems necessary to examine the level of prior knowledge that the learners have on the subject. If the learner has prior knowledge, it is easier to integrate the new knowledge into the existing knowledge structure and decide on meaningful learning steps in the instructional tool. In addition, the age and maturity of the users are other important aspects to be considered. First, the users who participated in this study had no previous knowledge on the two units selected for the study. The students took a biology course in the previous semester, but it did not include the selected units. Second, the researcher consulted four subject-matter experts (one university instructor and three biology teachers) about the participants' age and maturity level and concluded that the two units selected for the study would be appropriate for this group of students.

Identifying the objectives of the units. The objectives of the two units covered in the instructional material were determined on the basis of the Ministry of Education's Biology Curriculum Guideline.

Conducting content analysis. Content analysis was conducted and concepts, interrelated concepts, and procedures were determined on the basis of the objectives of the units determined. Systematic relationships between the concepts were organized. A subject-matter expert evaluated the semantic relationships of the concepts determined. In the light of this evaluation, the semantic relationships between the concepts were reorganized.

Determining the learning strategies. According to Schunk (1996), meaningful learning involves gaining ideas, concepts, and principles, and then relating new knowledge to existing knowledge. Considering the characteristics of the users and units, we adapted Ausubel's deductive learning strategy. We first provided general and simple knowledge, then detailed and specific knowledge. At the beginning of each unit, short video episodes that explained the units overall were used as advance organizers to help users relate new knowledge to the existing knowledge in their memory.

Identifying the knowledge organization approaches that best suit the learning strategies. At this stage, we managed the issues of knowledge organization and linking nodes to each other. We used hierarchical links in that material. First we presented basic concepts, then subordinate concepts related to the basic concepts. In addition to hierarchical links, we used the elaboration approach to explain the concepts from simple to complex, general to specific. Both approaches were consistent with the learning strategies used in this material.

Phase 2: Development

Concept mapping. To ascertain interrelations between concepts determined in content analysis, we constructed concept maps of the units. That stage was important to show each node and links between the nodes.

Story boarding. Story boarding was the last step before the programming stage. Story boarding involves showing each navigation window on a page. Each window to be designed in this study was shown on a separate page. Active keys, the names of linked windows, links, text, visuals, video, sound, and graphics were also shown on that page.

Programming. We used Microsoft FrontPage 2.0, an HTML editor, for programming.

Phase 3: Evaluation

After the material was developed, we gave it to an instructional technology specialist, a subject-area expert, and three subject-area teachers for evaluation. We revised and improved the material according to the feedback received from those experts.

Participants

The participants in this study were ninth-grade biology students at a public high school located in a middle socioeconomic neighborhood in Ankara, Turkey. The school was assigned for the study by the Educational Research and Development Directorate from among a group of high schools (N = 6) established as laboratory schools by the Ministry of Education. The schools were equipped with computer laboratories to experiment with computer-based instruction. High schools in Turkey include Grades 9–11 and follow an 8-year primary education. The high schools prepare students for further education in universities; they receive students through a nationwide competitive examination. High school science courses are particularly critical for preparing students for the examination. Within that context, students pay particular attention to biology, which is taught in Grades 9 and 10.

Among the 3 ninth-grade classrooms in the assigned school, one was chosen through simple random selection. The students in that class were assigned to an experimental group or a control group through a matched-pair technique, according to prior biology achievement scores they received in the previous semester. Randomly from each pair, 1 student was assigned to the experimental group, the other student was assigned to the control group. That technique established equal representation in terms of prior achievement in both control and experimental groups.

Thirty-nine students (19 pairs and a single) originally participated in the study. Because there were only 20 computers in the laboratory, the researchers planned to have no more than 20 students in each group. On the basis of that limitation, the experimental group included 19 students and the control group included 20 students. However, 3 students from the experimental group and 6 students from the control group later dropped out of the experiment due to reasons that were beyond the control of the researchers. In addition, 2 students from the control group and 1 student from the experimental group did not participate in posttests and retention tests. At that point, it was not possible to include new students in both groups because the intervention was already in progress. As a result, 12 students from the control group and 15 students from the experimental group who participated in all phases of the study served as the final participants in this study.

Data Collection Instrument

We used an achievement test to determine students' achievement on three different types of knowledge before the experiment, at the end of the experiment, and 1 month after the experiment. The biology test, developed in two sections by the researchers, covered multiple-choice questions on the human circulatory system and excretory systems units. Each section involved declarative, conditional, and procedural knowledge-type questions on the respective unit. The questions were written on the basis of the learning objectives outlined in the Ministry of Education's Biology Curriculum Guideline. To establish the content validity of the test, we used a table of specifications to represent the learning objectives in the questions.

Declarative knowledge questions focused on facts, names,and lists and involved what and which types of questions. Conditional knowledge questions focused on understanding a network of condition-action sequences and predicting what happens if one of the variables in the sequence changes within the context of if-then, condition-action, or relationship statements. Procedural knowledge questions emphasized higher level cognitive activities such as employing algorithms and rules, identifying concepts and solving problems, and applying, analyzing and evaluating learned knowledge. Also, reasoning, associating, and distinguishing skills were included in procedural knowledge questions.

After the questions were categorized as explained above, the tests were given to one subject-area expert (a university professor) and three subject-area teachers at the high school level. They assessed the questions in terms of the three knowledge levels as well as the validity and relevance to the subject matter. That assessment helped the researchers revise some of the questions and include a few additional ones.

The revised version of the test consisted of two sections and 90 items. It was piloted by a group of students who had been exposed to the experimental units in the 1996–1997 academic year; their role was to assess item difficulty and clarity of questions. The circulatory system section of the achievement test included 50 questions (25 declarative, 13 conditional, and 12 procedural) and was given to a group of 43 students. Item analysis showed that one item was too easy (.977) and four were too difficult (under .1); they were therefore eliminated. Some of the items in the test were revised to enrich clarity. As a result, 45 questions (24 declarative, 12 conditional, and 9 procedural) were included in the circulatory system section of the test. The alpha reliability of the items after the revision was .92. The excretory system section included 40 questions (13 declarative, 12 conditional, and 15 procedural) and was given in a separate session to 37 out of 43 students who had previously answered questions on the circulatory system section of the test. Item analysis showed that one item was too easy (.946) and that six were too difficult (under .1). Three of the difficult items were revised and the remaining three were eliminated with the easy item. As a result, 36 questions were included in the excretory system section of the test (12 declarative, 11 conditional, and 13 procedural). The alpha reliability of the items after the revision was .79. At the end of piloting, the test constituted 81 questions covering the two biology units used in this study. Of those items, 36 were declarative, 23 were conditional, and 22 were procedural knowledge questions. Finally, the alpha reliability of the whole test in the pretest application was .85.

Procedures

This study was conducted during the spring semester 1998. Table 1 reports the data collection and analysis procedures that we used. At the beginning of the study, both experimental and control groups were asked to respond to an achievement test to measure their prior achievement in the selected units. Before the intervention started, the experimental group was given a 1-hr introductory session on how to use the hypermedia learning material prepared for this study. Then the biology teacher gave a 1-hr lecture to introduce the units in general to both groups together. After the introduction, the control group continued learning the units through regular classroom instruction and biology laboratory. Regular classroom instruction included mainly lecture and recitation methods supported by reading assignments. The experimental group studied the units using the hypermedia learning environment in the computer laboratory. The treatment continued for 3 weeks, 5 hr per week.

At the end of the treatment, the achievement test that previously served as a pretest was given again to students in both groups as a posttest. One month after the experiment, the same achievement test was given to both groups to measure the level of retention in three types of knowledge in the selected units. During the intervention, the participants in the experimental group had no access to hypermedia learning environments and the control group did not have a chance to repeat the experimental units. The data collected through the posttest and retention test were analyzed through descriptive and inferential statistics such as means, *t* test, and analysis of covariance (ANCOVA). Although a matched-pair technique was used to assign participants to experimental and control groups according to their prior biology achievement scores, 9 participants dropped out of the study. Because equal representation in both groups in terms of prior achievement no longer existed, we performed ANCOVA in addition to the *t* test to eliminate the effect of prior achievement.

Limitations

Small sample size and short duration of the study appear to be the most important limitations of this study. The nature of the study and the conditions of the school did not allow the researchers to increase the sample size and to extend the intervention. Also, technical problems caused by limited computer capacity such as slow motion of video episodes and loss of sound were occasionally faced during the implementation of the hypermedia in the computer laboratory. The limitations call for caution in generalizing the results of this study to a larger population. Furthermore, replications with larger samples may be needed to test the results of this study. Despite the limitations, we provided essential perspective with regard to the relationship between hypermedia and learning.

Table1.—Data Collection and Analysis Procedures

Group	Pretest	Introduction	Treatment	Posttest (given at the end of treatment)	Retention test (given 1 month after treatment)	Data analysis
Control (12 students)	Achievement test	Introductory lesson (1 hr)	Traditional classroom instruction (15 hr)	Achievement test	Achievement test	Means, standard deviations, *t* test, and analysis of covariance
Experimental (15 students)	Achievement test	Introductory lesson (1 hr)	Hypermedia (15 hr)	Achievement test	Achievement test	

Results

Posttest

Posttest results showed that the experimental group that was subjected to the hypermedia learning process had a higher level of achievement in declarative knowledge acquisition than did the control group that was exposed to traditional classroom instruction (*M* = 19.60 and 18.42, respectively; see Table 2). However, we used a *t* test to prove that the difference in the mean scores was not statistically significant. ANCOVA applied to declarative knowledge acquisition revealed that the prior achievement score was a significant covariate ($p < .05$), whereas the pretest score was not a significant covariate ($p > .05$). Those findings indicated that the small mean difference in the declarative knowledge posttest performance in favor of the experimental group could be explained through prior achievement.

Conditional knowledge posttest mean score of the experimental group (*M* = 14.33) was higher than that of the control group (*M* = 12.17; see Table 2). However, the difference in the mean scores was not statistically significant according to a *t* test analysis. ANCOVA applied to conditional knowledge acquisition indicated that the prior achievement score was a significant covariate ($p < .05$), whereas the pretest score was not a significant covariate ($p > .05$). Those findings indicated that the small mean difference in the conditional knowledge posttest performance in favor of the experimental group could be explained through prior achievement.

Procedural knowledge posttest mean score of the experimental group (*M* = 8.80) was higher than that of the control group (*M* = 7.92; see Table 2). However, the difference in the mean scores was not statistically significant as tested through a *t* test. ANCOVA applied to procedural knowledge acquisition showed that prior achievement score was a significant covariate ($p < .05$), whereas the pretest score was not a significant covariate ($p > .05$). Those findings indicated that the small mean difference in the procedural knowledge posttest performance in favor of the experimental group could be explained through prior achievement.

All of our findings indicated that the difference in the mean scores on declarative, conditional, and procedural knowledge acquisition in favor of the experimental group were caused by prior achievement. We therefore determined that the hypermedia learning environment did not produce a significantly higher level of achievement as measured immediately after the intervention in declarative, conditional, and procedural knowledge acquisition in comparison with traditional classroom instruction.

Retention Test Results

Declarative knowledge retention test mean score of the experimental group (*M* = 21.60) was higher than that of the control group (*M* = 16.08; see Table 3) and the difference in the mean scores was statistically significant as tested through a *t* test. Those findings indicated that the experimental group performed better than did the control group to retain declarative knowledge acquired over 1 month. Also, a covariance test showed that neither prior achievement nor declarative knowledge pretest score were influential on the higher level of performance of the experimental group in the declarative knowledge retention test ($p > .05$).

Conditional knowledge retention test mean score of the experimental group (*M* = 14.33) was higher than that of the control group (*M* = 8.83) and the difference in the mean scores was statistically significant as tested through a *t* test (see Table 3). Those results showed that the experimental group retained conditional knowledge better than did the control group over 1 month. A covariance test showed that prior achievement and conditional knowledge pretest scores were not influential on the higher level performance of the experimental group in a conditional knowledge retention test ($p > .05$).

Procedural knowledge retention-test mean score of the experimental group (*M* = 9.20) was higher than that of the control group (*M* = 6.25) and the difference in the mean scores was statistically significant ($p < .05$) as tested through a *t* test. Those findings indicated that the experimental group performed better than did the control group to retain procedural knowledge acquired over 1 month. A covariance test

Table2.—Declarative, Conditional, and Procedural Knowledge Posttest Results

Group	Declarative knowledge ($k = 36$)	Conditional knowledge ($k = 23$)	Procedural knowledge ($k = 22$)
Control			
M	18.42	12.17	7.92
SD	5.99	3.81	2.937
Experimental			
M	19.60	14.33	8.80
SD	5.40	4.37	3.299
p	.594	.188	.475
t	0.54	1.35	0.73

Table3.—Declarative, Conditional,and Procedural Knowledge Retention-Test Results

Group	Declarative knowledge ($k = 36$)	Conditional knowledge ($k = 23$)	Procedural knowledge ($k = 22$)
Control			
M	16.08	8.83	6.25
SD	3.988	4.108	2.179
Experimental			
M	21.60	14.33	9.20
SD	4.339	2.968	4.455
p	.002	.000	.003
t	3.40	4.04	3.26

showed that prior achievement and procedural knowledge pretest scores were not influential on the retention-test performance of the experimental group ($p > .05$).

The retention test findings indicated that the differences in the mean scores of the control and experimental groups on declarative, conditional, and procedural knowledge retention were statistically significant ($p < .05$) in favor of the experimental group. All those differences appear to have been caused by the treatment the experimental group received, indicating that the hypermedia learning environment contributed to the retention of all three types of knowledge more effectively than did the traditional classroom instruction.

Conclusion

Posttest results indicated that the participants in both experimental and control groups acquired similar levels of declarative, conditional, and procedural knowledge in the process of learning human circulatory and excretory systems units in a ninth-grade biology course. Several explanations in relation to the literature might be offered for those findings. First, Recker, Ram, Shikona, Li, and Stasko (1995) found that students with more background knowledge in the knowledge domain were able to set learning goals, form information-seeking strategies, and take advantage of access methods more effectively than students with less prior knowledge. In the beginning of this study, the participants in the control and experimental groups received a 1-hr introductory session on the experimental units. However, the prior knowledge gained from that session might not have been sufficient for the participants in the experimental group to form better knowledge-seeking strategies and to take advantage of access methods in the hypermedia learning environment that they were using for the first time.

Second, the limited capacity of the computers may have decreased the effectiveness and efficiency of the hypermedia learning environment. For example, slow motion of video episodes, loss of sound, and delay in navigation were occasionally observed during the experiment. Those factors probably slowed the students' ability to learn the basic concepts in the units and to form an effective understanding of the content through the help of still images, motion video episodes and sound effects, and navigation through the conceptual map of the units.

Third, the short duration of the experiment might have led to relatively less productive use of hypermedia, and this may have influenced the students' performance. If the experiment had lasted longer, the experimental group might have made better use of the hypermedia learning environment, and this might have resulted in better performance in acquiring different knowledge types. For those reasons, further study with extended intervention period may be needed to replicate this study.

Finally, it would be difficult to be certain that the experimental group would have been more successful than the control group in acquiring different types of knowledge if the above limitations could have been eliminated. The traditional classroom instruction in the control group might also have been effective in improving students' acquisition of different types of knowledge. In that sense, the hypermedia learning environment performed equally well with traditional classroom instruction with a teacher; that result alone could be an indicator of the valuable contribution of the hypermedia learning environment to students' learning without the teacher's help.

The retention test results show that there is a statistically significant difference between learning through hypermedia and traditional instruction in terms of declarative, conditional, and procedural knowledge retention in favor of hypermedia. Those results are consistent with the related literature. As Jonassen (1991) stated, learning is building new structures by assimilating environmental information, constructing new nodes, and describing and interrelating new nodes with existing ones and with each other. Learning requires forming links between existing knowledge and new knowledge to comprehend information. The hypermedia used in this study was designed on the basis of those principles, and students were able to build their knowledge structures effectively by forming links between their existing knowledge and new knowledge and by establishing meaningful understanding of the concepts. Those characteristics of the hypermedia learning environment may help students form long-term and meaningful learning of knowledge. Retention test results in this study show that unlike participants in the control group, participants in the experimental group formed links between existing knowledge and the knowledge presented by hypermedia in their long-term memory. As a result, students in the experimental group retained all three types of knowledge in the experimental units significantly better than did the control group.

The results of the retention test reveal that more meaningful learning occurred through hypermedia than through traditional classroom instruction. That is consonant with the propositions offered in the literature on the importance of using multiple channels in learning. Paivio (1971, 1986) and Clark and Paivio (1991) stated that information is processed through two cognitive channels. One channel processes verbal information such as text or audio; the other channel processes nonverbal images such as visuals and sounds. Learning occurs better when information is referentially and interactively processed through two channels than when information is processed through only one channel independent of the other. Dual processing produces an additive effect because the learner creates more cognitive paths that can be followed to retrieve information (Bagui 1998). Najjar (1996) suggested that information should be coded through different media to help persons learn more effectively. Dual coding helps to reduce the cognitive load in one's memory so that one can interpret the information by creating meaningful schema. We developed hypermedia learning material for this study on the basis of the dual-coding principle. Representation of information through multiple channels in the hypermedia learning environment appears to be effective in contributing to the retention of all three types of knowledge.

The results of this study are in accordance with Dale's (1946) assumptions (cited in Tergan, 1997). Dale suggested that different kinds of sensory experiences like listening, viewing, reading, and doing contribute to overall learning and retention. In developing the hypermedia learning environment used in this study, we used different sensory modes such as text, graphics, animations, and video episodes. Those features of the hypermedia learning environment may have significantly affected the experimental group's ability to learn and to retain different types of knowledge in the experimental units.

In addition to the nature of hypermedia learning material, the design of the hypermedia learning environment may have a positive effect on retention of the three different types of knowledge. Tergan (1997) stated that in addition to a learner's competency, such as verbal or visual literacy, instructional support and scaffolding are relevant conditions for taking advantage of multiple-symbol systems for effective acquisition and transfer of knowledge. When we conducted the experiment, we provided instructional support and scaffolding conditions to the participants. In the beginning of the experiment, the participants (in the experimental and control groups) were given a 1-hr introductory course on the experimental units to help them focus on the learning task. In the hypermedia learning environment, a video episode in the beginning of each unit was included to serve as an advance organizer or, in other words, a conceptual framework for the incoming information. During the experiment, one of the researchers supported the participants by describing the given paths in the program to help them understand different navigation paths. Those factors might also have helped the participants in the experimental group retain declarative, conditional, and procedural knowledge more effectively than the participants in the control group.

A hypermedia learning environment may help students learn course-related knowledge more meaningfully and construct a better framework for new knowledge in the same area. That environment also may be used as an instructional aid in traditional instruction to help students reach course goals, enhance learning, and provide an interactive and rich learning environment. Therefore, further studies are needed to explore hypermedia's contribution to knowledge acquisition and retention in different grade levels and subject areas. In addition, the ways that different cognitive styles might affect acquisition and retention of declarative, conditional, and procedural knowledge in hypermedia learning environments should also be studied. In those potential studies, the duration of the experiment should be longer than that in this study to assure that students make better use of the hypermedia learning environment.

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