The Influence of Configurational Knowledge on Children's Problem-Solving Performance in a Hypermedia Environment

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Abstract

We believe hypermedia environments need to be defined by their capacity to interact effectively with the limitations and constraints of students' cognitive information processing system. In this study, we contrasted four navigational platforms to test the hypothesis that the development of configurational knowledge increases learners' abilities to (a) find information in a hypermedia environment and (b) use that information to solve a scientific problem. We had learners search a hypermedia environment on the temperate rainforest with the goal of learning as much as they could about the problem in order to offer solutions to the current conflict over use of the old-growth forests of the Pacific Northwest. Learners navigated through the site using (a) a traditional outline, (b) a labeled diagram of the cyberspace environment, (c) a visual metaphor showing categories of information as puzzle pieces, and (d) a geographic map of the Pacific Northwest. Results revealed noteworthy findings regarding metacognitive abilities and hypermedia learning.

Background and Purpose

Computer use in education will continue to increase at an astounding rate over the next 10 years. Students are using hypermedia systems in exponentially-increasing numbers to understand and solve problems, find

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information, and communicate with new friends. Indeed, we believe hypermedia systems found on the Internet will be the principle source of information for American students, surpassing books, traditional teacher practices, and television over the next 15 years. In short, the Internet will be a sine qua non source of knowledge acquisition and development for American adults and youth.

Yet, the Internet is only a medium for disseminating and interacting with new information. The nature of that information, in terms of the way the information is organized, configured and presented, will determine the success of the Internet as a source of new knowledge, and a tool with which to teach. Teachers *and* students will have to be able to successfully use the Internet.

However, Jonassen (1989) outlined three problems commonly associated with use of hypermedia environments. Students may (a) get disoriented in informational networks due to unsuitable links or navigation methods, (b) have difficulty finding information or making correct choices in paths, and (c) not be able to construct a conceptual overview of all the parts of the system. These problems make it difficult to learn from hypermedia environments because learners must allocate cognitive resources to construct concepts of location and space—resources that take away from higher order thinking. Indeed, learners must (a) remember where information is located relative to its semantic and spatial relatedness, (b) keep track of metacognitive skills such as goal setting and comprehension monitoring, and (c) form concepts from the content contained within the hypermedia environment.

We believe hypermedia environments need to be defined by their capacity to interact effectively with the limitations and constraints of students' cognitive information processing systems. Thus, we designed an investigation to determine if different hypermedia environments are more or less effective in facilitating learner's abilities to (a) find information within a hypermedia environment, and (b) derive a content-conceptual overview in order to solve a problem defined by the information within that environment.

Theoretical Framework

The National Science Education Standards (1996) establish that American students must become scientifically literate. "Learners need to be able to identify scientific issues underlying national and local decisions, and express positions about those issues that are scientifically and technologically informed" (p. 23). Indeed, the Standards underscore that learning about science should be accomplished by way of student-generated inquiry and that inquiry into authentic questions, generated from student experience, is the central strategy for teaching science.

A group of educators at NASA's Classroom of the Future (COTF) believe that Internet-based hypermedia systems can be environments in which scientific inquiry can be taught (Myers, Botti & Pompea, 1997). They have designed Internet-based modules that enable teachers to teach students about scientific issues in a problem-based format. Students read about a situation that defines a scientific problem. They navigate through a hypermedia environment containing pictures, documents, and satellite images providing information about the problem. Finally, the students are asked to come up with solution strategies to solve the problem and to advise a group of experts accordingly. The COTF team has produced a number of problem-based modules on contemporary scientific issues: competing uses of the temperate rainforests, El Nino and consequent meteorological changes, ozone depletion and global warming, African gorillas and human sociopolitical infringement, and other modules in various stages of completion or development. We used the problem-based module on the temperate rainforests because it lent itself well to a controlled examination of the relative effectiveness of different navigational platforms on information finding and problem solving.

Navigational platforms can be designed around a myriad of different structures. However, Shapiro & Diehl (1994) suggest that hypermedia environments designed in accordance with a theory of how the information is processed cognitively by learners will lead to greater educational benefits, that is, more ecologically-valid outcomes. Indeed, Diehl and Ranney (1996) provide evidence that it is the spatially-based platforms, the diagrammatic ones, that yield higher user preference ratings and more integrated cognitive representations of the information in hypermedia systems, even though students' spatial aptitude appears to mediate the relationship to some degree.

Yet, most navigational platforms across the Internet still conform to traditional outlines of text rather than diagrammatic representations of meaningful semantic categories. Thus, one of the questions that concerned us was whether there was an operational and theoretically-relevant definition of meaningfulness that could serve as a guide to the design of navigational platforms. If diagrammatic platforms are more spatial, and spatial environments yield better user preferences and results, then the spatial dimensions of a navigational platform would be the most meaningful to research. We looked to two sources for guidance, research on spatial cognition and research on the instructional use of maps.

<u>Spatial cognition.</u> The research on spatial cognition has focused on the development of route finding and mental representations such as cognitive maps. According to Siegel and White (1975), spatial knowledge is acquired developmentally in three stages: knowledge of landmarks, knowledge of routes, and knowledge of configurations. Knowledge of landmarks refers to learners' familiarity with a location with neither the knowledge of that landmark's position relative to other locations, nor how to get from one location to the next. Route knowledge is the knowledge of how to go from one specific location to another without definitive knowledge of the relative positions of those locations in space. Finally, configurational knowledge is what is commonly referred to as the "cognitive map," the knowledge of relative locations, including the distances and directions between those locations, in some environmental space. McDonald and Pellegrino (1993) explain that "configurational knowledge is seen as the goal of spatial learning, since it provides the most complete information about the environment, incorporating both route and landmark information" (p. 52).

<u>Instructional utility of maps.</u> On the other hand, there is a body of research on the instructional utility of cartographic maps which claims that learner's comprehension of textual material increases in excess of 30% when the text is accompanied by a map (c.f. Schwartz, 1997). The effect is highly reliable and is consistent across various map types and content areas of textual material (Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Schwartz, 1997; Schwartz & Kulhavy, 1981, 1988). Maps provide highly efficient cognitive templates for associating, storing, and

retrieving propositions derived from text. Researchers (c.f. Kulhavy, Lee, & Caterino, 1985; Kulhavy & Stock, 1996) explain that the maps are coded as images by learners, images that are uniquely effective in facilitating passage retention because they (a) are encoded and stored as intact units that take up little room in working memory, (b) can be searched with great efficiency during the retrieval process because they can be visually scanned, and (c) serve as organizing frameworks from which text-derived verbal codes are activated during retrieval. The question is whether maps function as effectively with navigation and problem solving in hypermedia environments as they do with text.

Conklin (1987) contends that difficult-to-use navigational platforms degrade learner's ability to successfully allocate cognitive resources. Learners must learn how to get from one location to the next; they must learn and remember the navigational tools they used; and, they must read, comprehend, and be able to use the information they apprehend in order to solve a problem. Thus, we believe that providing cues for the development of configurational knowledge of a hypermedia environment will yield better performance on higher cognitive tasks—especially if those tasks require knowledge acquisition and reasoning in order to solve a problem. Kim and Hirtle (1995) explain that good navigational tools are those that indicate to a learner an appropriate mental representation for understanding the structural configuration of a hypermedia space. If this is true, a better cognitive representation should provide more working-memory space (cf. Ericsson & Kintch, 1995) for summoning the metacognitive strategies necessary for locating pertinent information with which to solve problems. It should also allocate more working-memory space for concept formation and problem-solving strategies.

In the present study, we contrasted four navigational platforms to test the hypothesis that the development of configurational knowledge increases learners' ability to (a) find information in a hypermedia environment and (b) use that information to solve a scientific problem. We had learners search a hypermedia environment on the temperate rainforest with the goal of learning as much as they could about the problem in order to offer solutions to the current conflict over use of the old-growth forests of the Pacific Northwest. Learners navigated through the site using either (a) a traditional outline, (b) a labeled diagram of the cyberspace environment, (c) a visual metaphor showing categories of information as puzzle pieces, and (d) a geographic map of the Pacific Northwest. The outline was used because it provided information about categories of information, and only locational knowledge. The metaphor was used because it provided the same semantic and locational cues as the outline, but added higher-order semantic relationships by analogy without configurational cues. The cyberspace map was used because it provided location, as well as potential configurational information in an environment different from the real-world geographic environment in which the rainforest problem takes place. The geographic map provided the same potential configurational information as the cyberspace map, but the configurational information between the cyberspace and real geographic environment was the same.

Method

Design and Subjects

Fifteen students (10—17 years old) were randomly selected and assigned to one of the four between-subjects treatment groups (Total N = 58). Subjects were elementary and secondary students recruited from a group of students who had enrolled in a summer camp called Challenger Space Camp in a small town in West Virginia. As part of the experiment, subjects were told that they would be participating in a day-long camp sponsored by the NASA Classroom of the Future. Thus, all subjects participated in the investigation in the context of helping NASA understand the way children learn. The students were a heterogeneous group of learners who showed no apparent sensory or learning disabilities that would compromise their ability to navigate the Internet site.

Material and Procedure

Students were asked to complete a demographic data sheet, two metacognitive strategy-use questionnaires, e.g., the "Junior Metacognitive Awareness Inventory” form 2, version 2 (Dennison, Howard, & Hill, 1998) and “How I Solve Problems” (Fortunato, Hecht, Tittle & Alvarez, 1991), and three measures of spatial ability taken from the Kit of Factor Referenced Tests (Ekstrom, French & Harman, 1976). Then, students in all groups (N = 60) learned about the rainforest problem by searching the

Temperate Rainforest Site on the Internet for 150 minutes. Following their search, they were asked to (a) recall everything they could remember from the site, (b) write down their understanding of the problem, their position on the problem and justification for it, and their strategy for solving the problem, and (c) draw a sketch map of the Internet site. The entire procedural sequence took 210 minutes.

Results and Discussion

Results of the investigation revealed that there was no significant difference overall between the four navigational platforms on either the number of idea units recalled or the problem solving data. That is, learners showed no difference in either their problem identifications, problem justifications, or problem solutions as a function of the navigational platforms they used.

Still, several findings emerged when a reanalysis of the data was performed contrasting two of the platforms—the puzzle and the outline. These platforms were contrasted for two reasons. One, after the experiment was finished, learners were shown all of the platforms and asked which one they believed was easiest to use. They overwhelming chose the outline platform, advising us that the outline was the easiest to use because it showed the relationship between content aspects of the rainforest topic. We contrasted this with the puzzle platform, because the puzzle was the platform chosen by the program designers to use to present the rainforest content.

Reanalyses: Puzzle versus Outline

We asked several specific questions of the data. The first was whether metacognition, prior computer experience, and age would affect learning in the puzzle and outline environments. If so, we were interested which one would be the better predictor.

Our hypotheses in this first overall question were that metacognition would be significantly correlated to both the number of target pages found in the Internet site following navigation through it and the number of idea units recalled. We also expected prior experience with computer use to be significantly correlated to both targets and idea units recalled.

Finally, we expected that age of our learners would be significantly correlated to both targets and idea units.

Results of the correlations revealed that age was not related to the number of targets found; and experience with the Internet was not related to the number of idea units recalled. However, metacognition was highly related to (a) the number of targets found ($r = .43$, $p = .024$), (b) the number of idea units recalled ($r = .53$, $p = .004$), and (c) prior computer use ($r = .55$, $p = .002$). Moreover, least squares stepwise multiple regression revealed significance for targets, $F(1, 26) = 5.83$, $MSerr = 5.03$, $p = .02$, and for the number of idea units recalled, $F(1, 26)$ 9.94, $MSerr = 32.73$, $p = .004$, when metacognition, hours of computer use, and experience with the Internet were entered as predictors. However, only metacognition emerged as a significant predictor on the number of targets found, ($T = 2.41$, $p = .02$), and the number of idea units recalled ($T = 3.15$, $p = .004$). Age, ($T = .217$, $p = .83$), hours of computer use per day ($T = 1.47$, $p = .16$), and experience with the Internet ($T = 1.07$, $p = .29$), failed to emerge as significant predictors for targets or for idea units (Age—$T = 1.82$, $p = .08$; hours of computer use per day—$T = 1.66$, $p = .11$); experience with the Internet—$T = .51$, $p = .61$).

Because of these findings, we wondered whether metacognition was a significant predictor of targets and idea units regardless of the platform used. We hypothesized that if learners found a platform "easy," they would be less inclined to summon the metacogntive skills necessary for navigating and processing information from it. We conducted the same multiple regression analyses above. But this time, we ran them independently for the puzzle and outline groups.

Results from the regression analyses in the outline group revealed significance only for (a) hours of daily computer use on learners' ability to find targets ($T = 2.57$, $p = .03$), and (b) age on the number of idea units recalled ($T = 2.72$, $p = .02$). We concluded that the semantic relationships available in the outline platform was all that was needed for students to use the Internet site. Since students are eminently familiar with outlines of information, having been taught to use outlines to organize information in school, no higher order cognitive skills would be necessary to successfully navigate the Internet site. Page finding is simply and straightforwardly predicted by the number of hours students spend on the computer each day. The amount students remember from searching Internet pages is straightforwardly predicted by age.

However, one of the reasons learners advised us that the puzzle platform was harder may have been because the puzzle platform was void of the kind of semantic organizational markers the students are used to attending to in school—the kind of markers provided by the outline platform. If this was true, we reasoned that metacognition would be a salient predictor of page finding as measured by location targets and the amoung of information retained as measured by the number of idea units recalled.

The multiple regression analyses on idea units {F (1,12) = 7.93, MSerr= 10.73, p = .02}, but not targets {F (1,12) = 3.64, MS err = 6.10, p = .08}, revealed significance for the puzzle group, with metacognition being the only significant predictor of idea units in the puzzle group (T = 2.81, p = .02). That is, metacognitive skills were apparently "turned on" under a navigational platform in which semantic relationships were not readily revealed. It is interesting to note that metacognitive skills did not predict page finding (T = 1.91, p = .08). Thus, knowing where something is in an Internet site is not apparently the same thing as remembering information learned from navigating in that site—at least as it is predicted by metacognition. Metacognition appears to be essential for learners to activate in order to remember information in an Internet site that does not organize information for them semantically. Metacognition is not differentially related to location of that information.

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