

Designing metacognitive support for learning from hypertext: What factors come into play?

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Abstract: Traditional expository texts typically follow formats that have been well established and predictable. However, design of hypertext systems depend to a large extent on the epistemological, instructional and design perspectives that the design team espouses. Therefore, one of the important differences in learning from hypertext compared to learning from traditional text is that students need to understand the structure of the information space, i.e. they need to understand how the different semantic units are related to each other so that they can make better navigational decisions. In this paper we discuss results from a classroom study using CoMPASS, a hypertext system. Our results suggest that students who understood the structure of the system did better on measures of navigation and learning. Self-monitoring in a hypertext environment was seen to be contingent upon the learner's understanding of the structure well enough to be able to choose appropriate semantic units.

Introduction

Over the last few decades, there has been an extensive body of research on effective strategies in the comprehension of expository text. In their studies on reciprocal teaching Brown and Palincsar have shown the importance of comprehension fostering and comprehension monitoring strategies on students' understanding of text [1, 2]. Good readers have typically been found to look over the text before they read, noting such things as the structure of the text and text sections that might be most relevant to their reading goals. On the contrary, unskilled readers are quite limited in their metacognitive knowledge and tend to focus on reading as a decoding process than as a meaning-construction process [3].

With newer genres of text, most notably hypertext and hypermedia being used in education, it is not clear whether the metacognitive strategies that apply to traditional expository text apply to learning from hypertext documents. Does learning from non-linear text require specific skills? Learning from hypertext requires that learners not only understand the text itself but they also have to browse through the space selectively [4]. Learners need to make navigational choices and constantly have to decide which node or link they have to select next. The navigational decisions that readers need to make while reading from hypertext may present difficulties and impose a higher cognitive load, especially on readers with low prior knowledge [5, 6]. As a result they may get lost in the hyperspace, unable to identify where they are, what links to follow and in what order information will be accessed [7, 8]. Conklin (1987) described this dilemma as 'informational myopia'. In such rich and fluid environments there is a tradeoff between system flexibility and cognitive overload on the user. System flexibility does not guarantee better learning without the learner's active involvement and right decision making.

Hypertext users should be able to plan certain cognitive learning activities and to manage to monitor these activities such as setting a learning goal or using a strategy [9].

As described by Dillon & Vaughan [10], “understanding the information space meaningfully requires more than an ability to navigate it.” Traditional expository texts typically follow formats that have been well established and predictable. However, design of hypertext systems depend to a large extent on the epistemological, instructional and design perspectives that the design team espouses. Therefore, one of the important differences in learning from hypertext compared to learning from traditional text is that students need to understand the structure of the information space, i.e. they need to understand how the different semantic units are related to each other so that they can make better navigational decisions.

We conducted a series of studies in both classroom and controlled environments to tease out the factors that affect learning from a hypertext CoMPASS [11]. In this paper we discuss results from a classroom study. Our results suggest that experience with the conceptual representation in the system did not help student navigation and learning. On the other hand, students who understood the structure of the system did better on measures of navigation and learning. Self-monitoring in a hypertext environment was seen to be contingent upon the learner’s understanding of the structure well enough to be able to choose appropriate semantic units.

Design of CoMPASS

CoMPASS is a hypertext system that uses two representations – concept maps and text to help navigation and learning. Each page in CoMPASS represents a conceptual unit such as ‘force’ or ‘acceleration’ and the screen shows a conceptual map of that unit and other related units (left half of the screen) as well as a text description (right half of the screen). The conceptual representation in CoMPASS, in the form of concept maps, is based on an analysis of the domain into conceptual units. All units are stored in a database along with an index of the relationship strength between the units. So two units that are closely related have a strength index of 1 and units that are not related have an index of 0. The maps are dynamically constructed and displayed with the fisheye [12, 13], so that the concept that the student has chosen is in the center of the map with the most related concepts at the first level of magnification and the ones that are not as closely related to the focal concept at the outer level of the map (see Figures 1 and 2). The fisheye view is therefore organized in such a way that the concepts that are *most related* conceptually to the focus are displayed *close to each other spatially*. We have used the relationship strength to determine the spatial proximity of the concepts. Thus the stronger the relationship between the two concepts, the closer they are spatially in the concept map. The maps are redrawn every time a student selects a concept by retrieving the information from the database. Thus the maps not only support navigation but also *provide conceptual support* for helping student learn science. The two representations, maps and the text, are closely linked such that the text contains a description of the focal concept and the links in the text are the same as the ones in the maps. Students can therefore navigate through the text or the maps.

In CoMPASS there are also hyperlinks that allow students to change views and study the conceptual units in different contexts (right upper part of the screen). For example, in the unit of Simple Machines a students might choose to read about mechanical advantage in lever, pulley or inclined plane and study how this concept applies to each machine. Therefore, CoMPASS allows for exploration and support students to follow different investigation paths based on their learning goals at any particular time. Students can study the domain either in breadth or in depth.

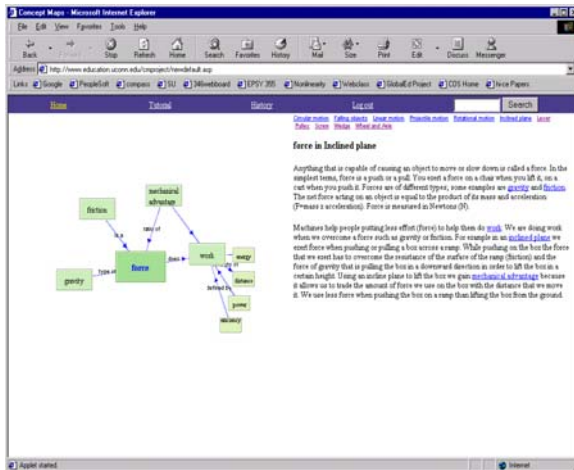


Figure 1: Fisheye with force as the focus

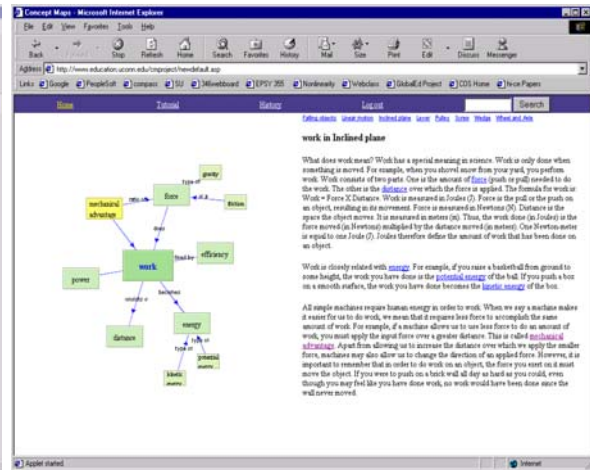


Figure 2: Fisheye with work as the focus

Method

We used CoPASS in sixth grade classes in a local middle school. CoPASS was used in association with the Simple Machines unit that we developed. This unit started with the can-lift challenge¹ in which students were asked to design a device using simple machines to help a person who had had a wrist injury lift an object. Students were required to design a scaled down version of the device to lift a 16-oz can of food. After initial brainstorming, students experimented with each of the six simple machines and went back to revise their designs after the first three machines. At the end of the unit they worked on their final designs applying what they had learned. For each machine, students came up with questions and researched on CoPASS so that they found the information relevant to their goals and applied it as they experimented with each machine and eventually to their can-lift designs. The unit lasted for 10 weeks and students used CoPASS for an average of 60 minutes per week.

Data sources

Data from multiple sources were collected. All participants took the pretest of science knowledge consisting of multiple choice and open-ended items, at the beginning of the unit. As students used CoPASS, a complete log of their activity was kept which included the time spent on each concept, the transitions that they made, the source of their navigation, i.e. whether they used the map or the text for navigation. We also used two concept mapping tests, one approximately half way through the unit and the other at the end of unit in which students were asked to draw a concept map of their understanding of the domain. Students took a post-test (same as the pretest) at the end of the unit. We also used an attitude survey at the end of the unit to understand how students used the maps in CoPASS. Four classes of students taught by a single teacher participated in the study. The total number of students was seventy-seven.

Analysis

The pre and post test consisted of multiple choice items as well as some open ended items. The open-ended items were scored by two raters based on a rubric and the inter-rater

¹ Adapted from the Learning by Design project, Georgia Tech.

reliability was between 90-95%. We also scored the concept map based on a rubric. For each map, we computed the number of concepts and the number of connections (NCON, NCONT). Each valid concept got a score of 1. Each connection was scored based on a rubric. Zero points were given if there was no descriptor on an arrow. One point was given for a correct but simplistic connection such as “type of,” “causes,” or “is a.” As connection that showed a higher level of understanding (such as mechanical advantage (MA) increases or decreases with an increase or decrease in distance) was given a score of two. We converted the scores for the maps into ratios to get the depth and accuracy of student understanding. The first ratio, R1, was the “richness ratio” and was obtained by dividing the number of connections with the number of concepts. A higher value indicated that the map was very rich and that the student had demonstrated knowledge of the interconnectedness of the concepts used in the map. The second ratio was the “depth ratio” and was a ratio of the points scored and the number of connections. This ratio was a measure of the depth of student understanding.

The log files were analyzed using the pathfinder algorithm [14]. Pathfinder, is a graph theoretic technique that allows for representing and comparing *dynamic* properties of navigational paths. Pathfinder yields a network representation that consists of nodes and links. Pathfinder analysis also yields the most frequently chosen path (see Figures 3-8). The most frequently chosen path is illustrated by darker and thicker lines. Each node in the figures consists of two numbers, thus, force 30,29 means that the concept force got visited 30 times and students went away from it 29 times.

Results

In this section, we will start by examining student scores on the CoMPASS attitude survey in which they had to response to Likert-type items on their use of the maps in CoMPASS. We will then discuss learning gains in the concept mapping test and finally discuss differences in navigation patterns.

Understanding of structure: We studied students’ responses on the CoMPASS survey, which was a Likert-type questionnaire in which students responded to items related to the usefulness of the maps. A one way analysis of variance was conducted and we found that there was a significant difference between the classes ($F=3.00$; $df=3,55$; $p=.038$). A post hoc analysis for pairwise comparisons using Tuckey’s HSD showed that class 4 had a significantly higher mean score on items that related to the use of the maps in CoMPASS, compared to class 1 (Table 1). Students in class 4 found the maps useful to find related concepts. Students found the concept maps and the connections thereof very helpful in understanding the relationships among concepts.

	N	Mean	Std. Deviation
1	10	2.8538	0.17
2	20	3.0462	0.23
3	14	2.9945	0.30
4	15	3.1846*	0.34

Table 1: Scores on the CoMPASS survey

Learning gains: We analyzed the pre and posttest scores as well as the concept mapping scores of the four classes. A one-way analysis of variance showed that there was no significant difference in the pre and post test knowledge scores on the test that contained multiple choice items and open-ended items. However, there was a significant difference in the final concept mapping scores. We found a significant difference in scores for the number of connections, NCONCT ($F=3.87$; $df=3,74$; $p=.012$), in the total scores on the map ($F=3.9$; $df=3,74$; $p=.012$), and in the richness ratio ($F=5.0$; $df=3,74$; $p=.003$) as well as the depth ratio ($F=23.7$; $df=3,74$; $p=.000$). A post-hoc analysis showed that students in class 4 did significantly better than students in class 1 (see Table 2). To further understand these results we looked into the navigation patterns of the two classes to understand whether there might have been differences in their navigation that may have contributed to these results.

	Class	N	Mean	Std. Deviation
NCONCT_F	1	15	21.4	11.83
	2	21	28.81	11.07
	3	23	21.91	10.71
	4	19	32.74*	14.94
NCONC_F	1	15	12.87	3.87
	2	21	12.81	2.78
	3	23	12.74	5.39
	4	19	14.32*	4.51
TSCORE_F	1	15	22.06	11.99
	2	21	29.61	11.21
	3	23	22.60	10.87
	4	19	33.63*	15.10
R1_F	1	15	1.57	0.63
	2	21	2.26	0.83
	3	23	1.67	0.60
	4	19	2.26*	0.76
R2_F	1	15	1.03	0.03
	2	21	1.03	0.03
	3	23	1.72	0.60
	4	19	1.03*	0.05

Table 2: Students' scores on concept mapping test

Students' navigation patterns: Figures 3-8 show the navigation patterns of two classes on three representative days in the unit. The graphs show around 25 minutes of navigation each and were created using the pathfinder algorithm as discussed earlier. As the figures show, the maps of class 1 were more cluttered compared to class 1, on all of the days, although they indicate student activity at three points during the unit. This shows that students may not have improved in their navigation as the unit progressed. We will now compare the two classes on each of the three days.

On the first day, students were exploring "levers". Figure 3 shows that students in class 1 were not very focused in their navigation. The most frequent transition was between the topic description of levers and the concept force. The next most frequent transition was between levers and force and levers and work. However, as the graphic indicates there were numerous other transitions which were not related to the goal for that day, which was to

Figures 7 and 8 show navigation on a day in the last week of the unit on which students were learning about the screw and the wedge. It is clear from figure 7 that students in class 1 stayed mainly at the topical level. They seemed to have visited the topic description for the screw and the wedge. They also seem to have floundered a lot and visited concepts in the topic of rotational motion. On the other hand, figure 8 shows that students in class 4 explored many concepts within each of the topics of screw and wedge.

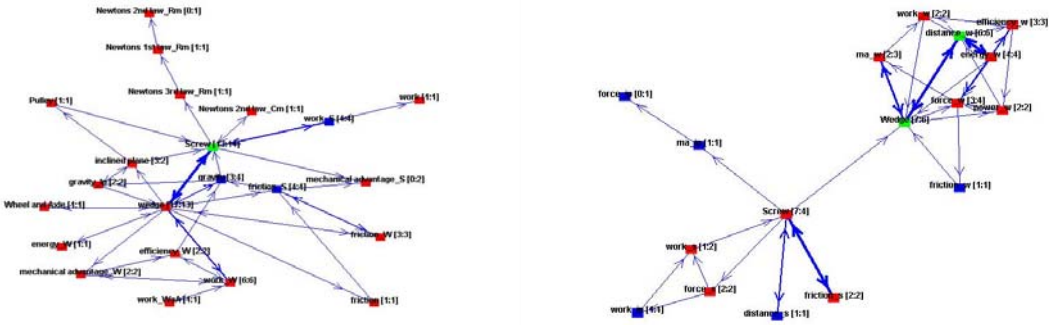


Figure 7: Navigation map class 1 – Wedge/Screw Figure 8: Navigation map class 4 – Wedge/Screw

Although pathfinder shows the navigation graphically, the graphs only depict the qualitative differences between the classes. We looked at the percentage of logical and goal related transitions to see whether the two classes differed in the number of transitions as well. Table 1 shows the results. Class 1 had fewer goal related transitions than class 4 on all of the three days. The table also shows that there was no systematic increase in the percentage of transitions and they actually went down for both the classes on the last day. This might be an indication that more experience with the conceptual representation did not help navigation.

	Class 1	Class 2
Lever	13%	43%
Pulley	64%	77%
Wedge/Screw	61%	74%

Table 3: Number of goal-related transitions on the three days

Discussion

Our results point toward two levels of metacognitive support: support to help students understand the structure of the system and support to help students relate navigation to their goals to enable a deeper understanding of the domain. The effect of understanding structure is known to play an important role in learning from traditional text [15]. Studies have also shown the effect of prior knowledge and the use of different types of representational structures on student learning. In a study by Potelle and Rouet [16], low prior knowledge and high prior knowledge students were found to benefit from different types of representational structures. Hierarchical maps were found

to be more helpful for low prior knowledge individuals. In our study, there were no differences in the prior knowledge of students in the two classes. However, we found that there was a difference in the way they understood the structure of the system. Students in class 4 understood the use of the maps better than students in class 1. We were interested in examining whether this difference could have led to a difference in the navigational patterns and found that students in class 4 were not only more focused in their navigation but they also had a greater percentage of goal-related transitions. We also found that there were no significant differences in the post-test scores of the two classes, but there was a significant difference in the concept mapping scores. We believe that this may have been because of the difference in students' understanding of the structure. Students in class 4 who understood the structure of the system better also showed more focused and goal related navigation. This may have been the reason that they scored better on the concept-mapping test which tested a deeper level of understanding than did the pre and post tests. Our results therefore suggest two types of metacognitive support in learning from hypertext systems – support to help students understand the structure and support to help them relate navigation to their goals, both of which are related to each other.

Conclusion

To ease the cognitive load in traversing through a nonlinear representation of content, designers of adaptive hypertext systems have used methods such as link hiding or disabling, adaptive presentation of content [17], or adaptive navigation support in the form of a customized next or continue link [18], and annotated links [19, 20]. We propose that rather than hiding choices or signaling “readiness” students need to be scaffolded in specific skills in learning from hypertext so that they can explore as well as learn. Students can be encouraged to explore up to a point, but as our results show, too much exploration can amount to floundering. Therefore, we need to scaffold students to understand the structure of the hypertext environment as well as to identify which units they are selecting are related to their goals.

Our study was conducted in a classroom context and although the same teacher taught all four classes and was consistent in her style, experiments in controlled settings are necessary to further investigate the effect of the factors.

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