Designing Interactive and Personalized Concept Mapping Learning Environments

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ABSTRACT
Concept mapping is a tool to represent interrelationships among concepts. Relevant research has consistently shown the positive impacts of concept mapping on students' meaningful learning. However, concerns have been raised that concept mapping can be time consuming and may impose a high cognitive load on students. To alleviate these concerns, research has explored facilitating concept map construction by presenting students with incomplete templates and concept map based navigational assistance on the learning material. However, it's not clear how these incomplete templates should be designed to address individual student needs and how concept map-based navigation can support students in creating concept maps and developing personalized navigation patterns. In this paper, I discuss my previous research in providing personalized scaffolding in concept mapping activities and describe plans of my research in exploring how personalized concept map scaffolding supported by navigational assistance could enhance student learning.

Keywords
Data mining, concept mapping, navigation, personalization, adaptive scaffolding, expert skeleton concept map.

1. Research Topic
Concept maps are graphical representations of knowledge structures, where labeled nodes denote concepts and links represent relationships among concepts. Concept mapping has been widely employed in educational settings to support student learning. Research has examined how concept mapping tools assist students in summarizing, relating, and organizing concepts [1][4]. However, there are limitations in using concept mapping. The main disadvantage of concept mapping is that the map construction is time-consuming and it requires some expertise to learn [3]. In addition, the complexity of the task often imposes high cognitive load and reduces student motivation [10].

Cañas and colleagues developed CmapTools, a computer-based concept mapping system, to support concept mapping by making it easier to construct and manage large representations for complex knowledge structures [6]. Although CmapTools provides a convenient platform for concept map construction, the system is independent from the learning content and students may encounter difficulties relating maps with resources and comparing linked concepts. To enhance concept maps with relevant resources, McClellan and colleagues designed a system that attaches resources like demos, homework and tutorials to the concept maps via keyword matching [11]. However, it might cause extraneous effort for students to process this additional information.

Apart from providing computer systems for concept map construction, other research canvassed the effect of providing students with incomplete templates called expert skeleton maps, within which some nodes and links were set as blanks, as a scaffolding aid [5]. Although studies show that the scaffolding had more positive effects on student learning than those who created concept maps from scratch [3], it's not clear how expert skeleton maps should be designed to provide better learning results. Questions like what concept nodes should be presented and what concept nodes should be left blank, how big should the expert skeleton map be, and should all students be given the same expert skeleton map, still remain unsolved. To address these challenges and the opportunities from the two directions discussed above, I propose a design of a personalized and interactive concept mapping learning environment that integrates a textbook with a concept mapping tool. This system will enable students to create maps directly from the textbook. Students will relate the created maps to the textbook content and the system will offer personalized scaffolding to facilitate concept map construction and meaningful learning. I also describe my plan of conducting an Amazon Mechanical Turk Study and an in-classroom study to test the system.

2. Proposed Contribution
2.1 Previous Work
Towards designing a personalized and interactive concept mapping learning environment, my prior work has examined how personalized expert skeleton maps affect student learning. More specifically, I studied the potential effects of an adaptive expert skeleton scaffold that contains concepts and relationships for which the student has demonstrated prior knowledge [7]. To create the adaptive expert skeleton maps, an expert concept map representing the knowledge structure from the chapter was first created as a foundation. I then mapped each question on the pretest to a certain part of the expert map to modify the expert skeleton map based on students' pretests scores. For example, if a student incorrectly answered question 4 as shown in Figure 1, the correct concept ("flower") was replaced with '???" and left open for the student to fill in. By presenting students with a map that contained their prior knowledge, I hypothesized that students would spend more effort on unknown concepts and be better supported in integrating new knowledge into prior existing knowledge structure, thus improving learning.

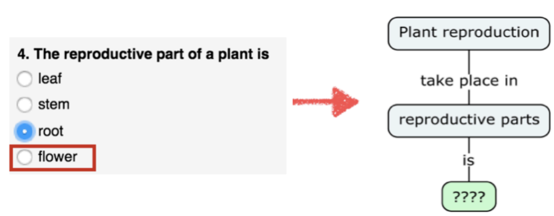

Figure 1. Modifying the expert map based on pre test answers.

To test my hypothesis, I conducted a study with 38 non-biology major students who were randomly assigned into three conditions: (1) adaptive scaffolding, (2) fixed scaffolding and (3) non-scaffolding. Students in the adaptive scaffolding condition received an expert skeleton map that contained nodes and links which they got correct in the pretest. Students in the fixed scaffolding condition also received a skeleton map. However, instead of tailoring the map to the student's prior knowledge, I presented them with maps from the adaptive scaffolding condition through yoked control. In this way, I was able to control for content across conditions. Finally, in the non-scaffolding condition, students constructed a map from scratch. Although I did not discover significant differences in learning gains between conditions, I found that different types of nodes in the template did lead to different learning gains on related concepts. To further investigate, I coded the key ideas in the expert map as being: added to the map by the student, already in the template, or not added. For the already existing concepts in the expert map, I further categorized the concepts that were adjacent to the newly added concepts as "close" and the ones which were more than one link away as "far". Results indicate that students benefit most from adding concept nodes to the map and benefiting more from the in template "close" nodes than the "far" and not added ones.

However, there were several limitations in the data collection that might have influenced the results. First, the number of graduate students and undergraduates was not balanced across conditions, and the learning differences in these two populations may have added extraneous noise to the learning gains. Another potential problem was that the expert skeleton maps students received might have been too large. While I assessed students on 9 key ideas, these ideas spanned more than 70 nodes in our expert map. The complexity of the given template might have imposed high cognitive load on students, reducing the benefits of the expert skeleton maps. What's more, the concept mapping system used in the study, the CmapTools, required students to type the words to create nodes. The system was also limited in terms of searching and comparing resources related to the concept maps.

2.2 System Design

Incorporating my finding discussed above, I present an iPad-based interactive concept mapping tool that is integrated with a digital textbook. When held in landscape mode, the screen splits into two, with the left side displaying the textbook and the right side showing the concept mapping panel. The built-in concept mapping view is directly associated with the learning material, so that students can construct concept maps directly from the words in the textbook, shown in Figure 2. An example of this process would be a student reads the textbook and find the concept "seed" that should be contained in the concept map, he can long click on the word and tap on the add concept button to add a node named "seed" to the concept mapping panel on the right. He can click on other concepts to add and delete links. This feature eliminates the tedious process of manually adding nodes and typing all the text while encouraging the cognitively beneficial processes of finding the important concepts and identifying the relations among them. Apart from that, a hyperlink between the node in the concept map and the words in textbook is created through the "click and add" action, allowing students to navigate through the textbook by clicking on the concept nodes. During their navigation, related concepts in the concept map and the text in the textbook are both highlighted, providing a visual comparison of key information. Since the concept maps are created by students themselves, the system enables students to form their own navigation patterns to assist them in locating key information in the textbook resource. The system is able to provide pre and post tests, which can be used to dynamically modify the expert skeleton map based on the student's prior knowledge. Furthermore, leveraging the hyperlinking navigation feature, the system enables students to click on the nodes in the expert skeleton to navigate directly to related pages.

I hypothesize that the system can alleviate the challenges discussed in the introduction and benefit students in different ways. It first allows students to easily construct concept maps via the "click and add" feature, which reduces the work of tediously typing words into the nodes while preserving the beneficial work of searching and identifying concepts to be added. The hyperlinking navigation provides more flexibility in comparing and finding connections between concepts that are located in different pages. Hyperlinking the expert skeleton map with the textbook enables students to click on the nodes provided in the expert skeleton map to see where these concepts are mentioned in the textbook. This would reduce the cognitive load of the template, which is a potential cause of reducing the effect of adaptive scaffolding in my previous work. What's more, providing students with expert skeleton maps that contain their prior knowledge would facilitate meaningful learning while they add new concept nodes to templates that represent their own knowledge structures. Since the concept nodes are already mastered by students, this approach also avoids potential shallow learning, which is a problem faced by many forms of computer-based instruction [8].

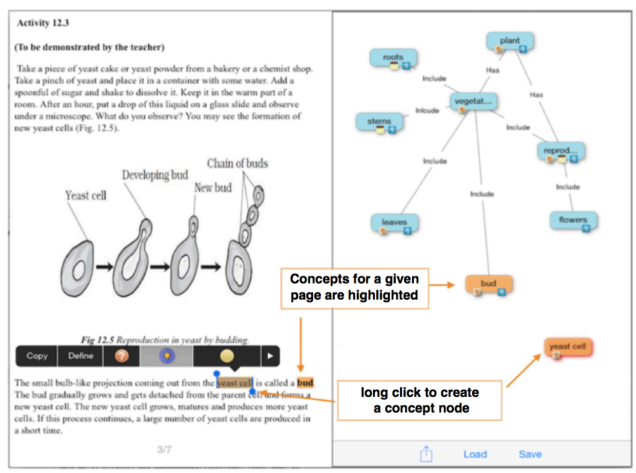

Figure 2. Interactive concept mapping system interface.

3. Results So Far

My previous study showed that types of interactions with the concept map have an effect on student learning gains [8]. However, limitations of the CmapTools and the complexity of the expert skeleton map reduced the effect of adaptive scaffolding. To solve these problems, I have implemented the proposed iPad-based concept mapping system and I'm currently running two studies to explore how different designs of expert skeleton maps and hyperlinking navigation effect learning out comes.

To test the effect of different types of scaffolding, I'm running an online study using Amazon Mechanical Turk, a human intelligent task market in which anyone can post tasks to be completed and specify prices paid for completing them. The literature indicates that Amazon Mechanical Turk could be a promising approach to get inexpensive, yet high quality data for research in psychology and social sciences [9]. However, few research has examined the quality of Mechanical Turk data in educational studies. Thus, I plan to explore how Mechanical Turk can be used as a cost effective way to get high quality data for educational studies. In this study, participants use an online iPad simulator running the concept mapping application to construct a concept map while they learn a chapter of a high school science textbook. First, students are given a 2-minute pretest to assess prior knowledge on water pollution. Next, students are given a 3-minute training about what concept maps are and how to use the application to construct one. After the tutorial and practice, students are given a randomly modified expert skeleton map and are given 20 minutes to construct or complete the map based on the template. Finally, a posttest is given. Instead of tailoring the scaffolding specifically to student prior knowledge, I'm randomly selecting the size and concept nodes that appear in the template, in order to generate more variations of the expert skeleton map. Learning outcomes based on these different designs of expert skeleton maps could help us understand how the expert skeleton map should be designed to better facilitate learning.

Furthermore, I plan to examine how concept map-based navigation facilitates concept map construction and how it helps students to form personalized navigation patterns. I am currently working with a high school teacher to conduct a study in one of her classes, which has been using concept maps as a class activity. The study will last 20 minutes per day for 5 days and it will be a substitute for a paper-and-pencil based concept mapping activity. Students will construct the concept maps while they learn about the current textbook chapter. Students will be randomly assigned into two conditions: The hyperlinking condition, where nodes in the concept maps are hyperlinked with the textbook, and the non-hyperlinking condition. Pre and post tests will be given before and after the study. To investigate the effect of hyperlinking, I will compare the learning gains between condition. Furthermore, I plan to use data mining techniques to extract patterns within student navigation activities. For example, if a student is navigating by clicking back and forwards on two linked concept nodes, it might indicate that the student is using the textbook content to compare the concepts. If a student is navigating by clicking on a series of connected nodes, it might indicate that the student is comparing multiple concepts to understand some knowledge structure in a higher level.

4. Advice Sought

For this doctoral consortium, advice is sought regarding two major concerns. First, how should I validate the Amazon Mechanical Turk study results? I'm currently using Amazon Mechanical Turk platform for the expert skeleton map study. As I'm randomly varying the size and the concept nodes which appear in the template, I need a large number of participants to form overlaps between the student prior knowledge and the given expert skeleton map. Amazon Mechanical Turk would be a cost-efficient approach to get large amount data. However, due to the large variations in the participant population, the results from the study might not truly reveal the effect of expert skeleton map scaffolding on high school students. How could I make use of the Mechanical Turk study data to design concept mapping scaffolding to better facilitate learning?

Second, what data mining techniques can be used to analyze the hyperlinking study data? I'm interested in discovering what student behavior patterns correlate to learning outcomes and what interactions are tedious and counterproductive, and can be potentially be supported or replaced by computer technologies.

Problems discussed above are major challenges I encounter to analyze the data from the studies. Advice on these two problems will be very helpful to my work of designing personalized expert skeleton maps to facilitate concept map construction and providing hyperlinking navigation to reinforce student learning.

Acknowledgments

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