Personalized Expert Skeleton Scaffolding in Concept Map Construction

Shang Wang[1], Erin Walker[1], Rishabh Chaudhry[1], and Ruth Wylie[2]

[1]Computing, Informatics, and Decision Systems Engineering, Arizona State University, USA
[2]Mary Lou Fulton Teachers College, Arizona State University, USA

{swang158, Erin.A.Walker, rchaudh2, Ruth.Wylie}@asu.edu

Abstract. Concept maps have been widely used in educational contexts to facilitate meaningful learning. Recent research has examined how concept mapping tools assist students in summarizing, relating, and organizing concepts. Our goal is to explore how personalized scaffolding can be applied to concept map construction. We provide personalized scaffolding in the form of an adaptive expert skeleton map based on student prior knowledge. We conducted a study comparing the adaptive map to a fixed map and to unscaffolded concept mapping. In an exploratory analysis, we examine the possible impacts of adaptive scaffolding on student learning processes.

Keywords: Concept maps, expert skeleton maps, adaptive scaffolding

1 Introduction

Adaptive scaffolding, the process of leveraging student characteristics and behaviors to provide students with personalized assistance, has been shown to lead to greater learning over fixed, non-personalized scaffolding [1]. Our goal is to examine how adaptive scaffolding can be applied to concept mapping activities. A concept map is a type of graphic organizer that uses labeled nodes to denote concepts and links to denote relationships among concepts. Learning takes place as students assimilate new concepts into existing propositional frameworks held by the learner [4]. Previous research has investigated how scaffolding tools can be used to reduce the time, effort, and cognitive load for constructing concept maps [2, 3]. In this previous research, an "expert skeleton map", which is a map previously prepared by an expert with some areas left blank for students to fill in, is often given to students as a guide.

Prior knowledge is a critical element in concept mapping, as knowledge construction occurs when students actively seek to integrate new knowledge with their prior knowledge [4]. Understanding learner's prior knowledge and providing relevant guidance could be a critical factor for scaffolding concept mapping [5]. Our work explores the potential effects of an adaptive expert skeleton scaffold that contains concepts and relationships for which the student has demonstrated prior knowledge. Filling in unknown or to-be-learned knowledge in the map is left as an exercise for the student. By presenting students with a map that already contains their prior knowledge, we hypothesize that students will both spend more time on unknown concepts and be better supported in connecting new knowledge to prior knowledge, thus improve learning.

2 Study Method

To investigate how different types of scaffolding affect learning, we had three conditions: adaptive scaffolding, fixed scaffolding and unscaffolded. In the adaptive scaffolding condition, the expert skeleton map was personalized to include concepts that students had already acquired. Students in the fixed scaffolding condition also received an expert skeleton map. However, instead of aligning the map to the student prior knowledge, students in this condition received one of the personalized maps from the adaptive scaffolding condition. In this way, the two conditions were yoked and we were able to control for content across conditions. Finally, in the unscaffolded condition, students constructed a map from scratch. In all three conditions, students were given a list of "suggested concepts", which included all the concepts in the original expert map, but not currently in the students' concept map. The system used for concept mapping was the Cmap tool, developed by Florida Institution of Human & Machine Cognition, which provides easy concept map construction and modification.

We conducted a study with 38 non-biology major students (22 undergraduate students and 16 graduate students). First, students were given a 10-minute online pretest to assess prior knowledge on plant reproduction. Next, students were given the chapter in an e-book format, and had 10 minutes to read. Students then received a 4-minute tutorial about what concept maps are and how to use the Cmap tool to construct one. Then, they were asked to construct a simple concept map from an example text. After the tutorial and practice, students were randomly assigned to conditions and received either an adaptive map, a fixed map, or a blank (no-scaffolding) map and were given 20 minutes to construct or complete the map based on the template. Finally, a posttest (counterbalanced with the pretest) was given.

To create the adaptive expert skeleton map, we first created an expert map to represent the concepts from the chapter. In order to determine which concepts to remove from the map, we mapped each question on the pretests to a portion of the expert map. This allowed us to modify the expert skeleton map based on students' pretests scores. For example, if a student incorrectly answers question 4 in Figure 1, the correct concept ("flower") is removed from the map and left for the student to complete.

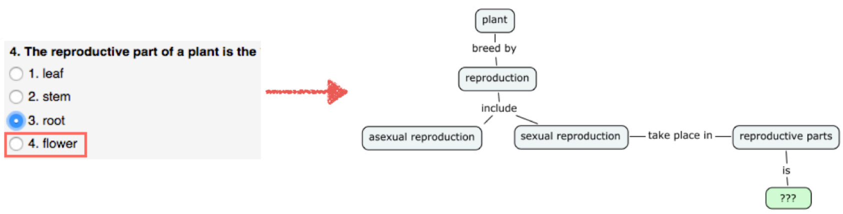

Fig. 1. Modifying the expert skeleton map based on a question testing the concept "flower".

3 Study Results

Our first step was to investigate the hypothesis that adaptive scaffolding is better than both fixed scaffolding and unscaffolded concept mapping. We conducted a two-way repeated-measures ANOVA with condition as a between-subjects variable and test-time as a within-subjects variable. Table 1a shows the mean and standard deviation of the overall scores on the 9 key ideas evaluated. Students got 1 point when they get a concept correct and 0 points when they got it wrong. All conditions had significant pre to post learning ($F[1,35]=39.60$, $p < 0.001$, $\eta^2 = 0.531$), but there were no significant differences between conditions ($F[2,35] = 1.16$, $p = 0.33$).

	Pretest		Posttest	
	M	SD	M	SD
Adaptive	3.21	1.31	4.64	2.13
Fixed	2.67	1.07	5.17	2.04
Unscaf-folded	3.00	1.60	5.50	2.02

	Gain per Student		# Concepts per Student	
	M	SD	M	SD
Exist close	0.59	1.18	1.59	0.51
Exist far	-0.15	1.08	2.04	0.92
Added	1.50	1.58	4.57	1.30
Not added	0.25	0.64	1.75	0.79

Table 1. (a) Test results between groups (b) Gains and number of concepts for each activity

As there was no significant difference between conditions, we were interested in exploring further how student interaction with the map influenced learning. We coded the 9 key ideas in the expert map as being: (1) added to the map by the student, (2) already existing in the expert skeleton maps, or (3) not added. For the already existing concepts in the expert map, we further categorized the concepts that were adjacent to the newly added concepts as "exist close" and the ones which were more than one hop away as "exist far". For each type of concept, we computed the learning gain for each user by subtracting pretest score from posttest score. As only students in the adaptive and fixed conditions experienced all types of concepts, we only analyzed results from this subset. Means and standard deviations of leaning gains and number of concepts in each interaction type are presented in Table 1b. It is not meaningful to make a statistical comparison between the types of interaction due to challenges with our data set (a small number of key ideas, each key idea maps to different numbers of concepts in the expert skeleton map, and it is likely that gain was influenced by level of prior knowledge for each type). However, looking at the means, it appears that adding concepts to the map was the most beneficial, followed by interacting with close existing concepts. "Exist far" concepts, which were not adjacent to concepts added, were not learned effectively. We see this exploratory analysis as a foundation for future work.

4 Discussion and Conclusions

We conducted a study where we compared adaptive scaffolding to fixed scaffolding and no scaffolding in concept map construction. While all students learned from the concept mapping activity, we found no significant differences between conditions. Exploratory results suggest that students may learn from concepts that are added to the map compared to ones that were not added, and, for the provided concepts in the template, students may benefit more from ones that are close to the interacted region.

There are several limitations in the data collection in this study that indicate caution in interpreting the results. The number of graduate students and undergraduates were not balanced throughout the conditions. Another potential problem was that the expert skeleton maps we gave to students might have been too large. While we 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.

However, the tentative learning difference in the existing concepts that are close or far from the area of the map where students interacted is worth investigating. While adding concepts to the template, students may benefit most from relating existing concepts directly with the new knowledge that is being added, as they did for the close concepts. Students did not interact with the far concepts directly, and thus may not have fully mastered those concepts at posttest. Expert skeleton maps should be designed in a way where the provided concepts and structures lead to more interactions with newly added concepts. In our future research, we plan to make improvements to the study design and carry out further experiments to test the effect of adaptive expert skeleton scaffolding.

Acknowledgments. This research was funded by NSF CISE-IIS-1451431 EAGER: Towards Knowledge Curation and Community Building within a Postdigital Textbook.

References

1. Aleven, Vincent AWMM, and Kenneth R. Koedinger. "An effective metacognitive strategy: Learning by doing and explaining with a computer-based Cognitive Tutor." Cognitive science 26.2 (2002): 147-179.
2. Luchini, Kathleen, et al. "Scaffolding in the small: designing educational supports for concept mapping on handheld computers." CHI'02 Extended Abstracts on Human Factors in Computing Systems. ACM, 2002.
3. Chang, Kuo-En, Yao-Ting Sung, and S. F. Chen. "Learning through computer-based concept mapping with scaffolding aid." Journal of Computer Assisted Learning 17.1 (2001): 21-33.
4. Novak, Joseph D., and Alberto J. Cañas. "The theory underlying concept maps and how to construct them." Florida Institute for Human and Machine Cognition 1 (2006).
5. Amadieu, Franck, et al. "Effects of prior knowledge and concept-map structure on disorientation, cognitive load, and learning." Learning and Instruction 19.5 (2009): 376-386.