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CONCEPT MAP AS AN EFFECTIVE INDICATOR OF CONCEPTUAL KNOWLEDGE IN AN ASTRONOMY COURSE

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Abstract: Concept mapping has the potential to be an effective learning tool that enhances conceptual understanding. It can be easy to approach science and math topics in a segmented manner and therefore lose sight of the interconnectedness and context of each topic. This paper describes a study that used concept mapping as a learning tool in an introductory astronomy course. The study investigated how concept mapping might affect student conceptual understanding, which was tested through weekly in-class quizzes. Although the study showed no significant gain in conceptual understanding with the use of concept mapping, the concept maps did prove an effective indicator of students' level of conceptual knowledge. Improvements to future iterations of the study are also discussed, which could yield different results.
Keywords: Astronomy course, conceptual understanding, experimental study, concept mapping

1 Introduction

Concept mapping is a tool that can be used to emphasize and establish conceptual links in and across topics. This skill is valuable in establishing an expert level of knowledge and is especially important to develop in situations where topics can appear segmented. Science and math courses can be easily approached in a segmented manner, which makes concept mapping a useful learning tool to try to enforce the interconnectedness of science and math fields. This paper presents a study conducted during the spring 2014 semester on an introductory astronomy course at a Midwestern university in the United States. The purpose of the study was to find out whether or not concept mapping would be a more useful learning tool than basic worksheets with questions. Students were given one of two review activities to participate in during class prior to taking an in-class quiz. Quiz scores were then analyzed for statistical variations between review activities.

2 Methodology

The following study used concept mapping as a learning tool for explicitly building an advanced conceptual framework in introductory astronomy. Concept maps were not used as an assessment tool that contributed to the students' course grade; rather they were used as a learning tool. Students participated in an activity where they created their own concept map from a given list of concepts. They were encouraged to look for connections between the listed concepts as well as build connections to concepts not listed. Student conceptual understanding was then tracked through in-class quizzes. Half of the class participated in a concept mapping activity for the first half of the semester while the other half of the class participated in a basic review sheet activity. Half way through the semester, the two groups switched review activities. All students took the same in-class quiz after participating in the review activity.

The introductory astronomy class had a total enrollment of 122 students. All enrolled students participated in the study activities, since they were built into the course design, but 79 students consented to have their in-class activities and quizzes used anonymously in the study. Only data from these 79 students were recorded for the study. In the end, only data from 72 students were analyzed due to lack of participation by the remaining seven students in the course. In order for a student's data to be analyzed, the student had to participate in at least two of each type of quiz review activity and the associated quizzes.

The entire class was split into two groups based on their last name. The students with last names that started with the letter A-L were in Group #1, and the students with last names that started with the letter M-Z were in Group #2. Out of the consenting and participating students, Group #1 contained 38 participants

and Group #2 contained 34 participants. Not all participants partook in the review activities and quizzes every single week of the semester. Recruitment for this study occurred through an announcement at the beginning of the semester. All English-speaking students enrolled in the course during the spring 2014 semester were eligible to take part in the study. Consent forms for the study were available in person during class sessions and also online via the course website. Only students who signed and returned a consent form had their review activity and quiz data recorded for the study.

This study involved both an experimental and a control group. Group #1 was considered the experimental group for the first half of the semester while Group #2 was considered the control group. The two group roles switched halfway through the semester. During 15 minutes of one class session per week, the experimental group participated in a guided concept mapping activity, and the control group worked on a review sheet on which straightforward questions were posed. As the students participated in the review activities, the instructor walked around the room and provided individual help when necessary. After participating in the review activities, all of the students took the same quiz.

Data collection occurred throughout the semester. Quiz scores from all students who consented to participate in the study were logged along with information about which activity they partook in that week. If they participated in the concept mapping activity, the quality of the concept map they produced was also assessed on a scale of High, Medium, or Low. Concept map quality was based on the number of concepts included, the hierarchy of the concept map, the presence of cross-links, and the use of concept linking prepositions. Along with the overall quiz score, student scores for each individual quiz question were also recorded. Each quiz question was categorized as conceptual or factual (definition).

Data analysis included quiz data analyzed quantitatively for statistically significant trends between review activity type and overall quiz score. Analysis also looked for statistically significant trends between review activity type and scores on different quiz question types. All quantitative data were aggregated and individual student trends are reported anonymously when appropriate.

3 Results

Analysis of the data shows no statistically significant differences between overall quiz score and quiz review activity. In addition, no statistically significant trend is seen between the quiz score on only conceptual questions and the quiz review activity. However, there is evidence for a correlation between the quality of the concept map and the quiz score. Students who produced higher quality concept maps received higher overall quiz scores consistently. Data from a total of 72 students were analyzed. Group #1 contained 38 consenting participants and Group #2 contained 34 consenting participants. Data from all ten quizzes were collected, but only nine quizzes were included in the analysis. The third quiz of the semester received very low participation. Only 50% of the consenting students completed both the quiz review activity with a reasonable effort and took Quiz #3. Therefore, this quiz was excluded from the data analysis. The overall quiz score average across all quizzes (#1-2, 4-10) for students who participated in the concept mapping review activity was 83%, and the overall quiz score average across all quizzes for students who participated in the review sheet activity was also 83%. Therefore, there was no correlation between overall quiz score and review activity type. The quiz score on just conceptual questions was also tracked on a quiz-by-quiz basis for each review activity group. The quiz score on just conceptual questions averaged over all quizzes (#1-2, 4-10) for the worksheet review activity was 79% and for the concept map review activity was 77%. Although there does appear to be a slight trend towards worksheet review activity scoring higher on conceptual questions, this trend does not appear to be statistically significant.

There were some changes throughout the semester that could bias some of the quiz results. Quizzes #1 and #2 may be biased when compared to Quizzes #4-10. After the low participation rate in Quiz #3, the instructor made the quiz review activities a part of the quiz grade. Students had to complete the quiz review activity to a reasonable effort to receive 1 out of the 10 points on their quiz, starting with Quiz #4. The quiz review activities were not graded for quality. If the students put a reasonable effort into the activity, they received the full 1 out of 10 points on their quiz grade. After Quiz #3, student participation rates and involvement in the quiz review activities increased. Another possible bias involves the switching of group

activities halfway through the semester. Quizzes #1-5 were the quizzes for which Group #1 participated in the concept mapping activity and Group #2 participated in the review sheet activity. For Quizzes #6-10, the two groups switched review activity roles. The overall quiz scores and the quiz scores on conceptual questions alone do not show statistically significant differences between each quiz review activity. This lack of a correlation between review activity type and quiz score is most likely due to limitations in the methodology.

A statistically significant trend that was observed was a correlation between the quality of the concept map produced and quiz score. Concept maps were rated in one of three categories: High, Medium, and Low. Concept maps were rated based on the number of concepts included in the map, the number and quality of cross-links, and the use of appropriate prepositions. The quality of the concept map did not directly affect the 1 out of 10 points received for participating in the review activity. However, there is a correlation evident between concept map quality and quiz score. The average score across all quizzes (#1-2, #4-10) for low quality maps was 76%, for medium quality maps was 82%, and for high quality maps was 89%. While medium quality maps could fluctuate between receiving high and low quiz scores, high quality maps consistently receive significantly higher quiz scores than low quality maps. This trend is consistent with previous work that has shown concept maps can be effective assessment tools (Austin & Shore, 1995; Turns, Atman, & Adams, 2000; Schau, Mattern, Zeilik, Teague, & Weber, 2001; Kinchin, Hay, & Adams, 2000).

4 Study Strengths and Limitations

There are aspects of the methodology used in the study that seemed quite strong and useful, but there were also several aspects that should be changed for future studies. Some strengths of the methodology included the set-up of the concept mapping activity as an individual, guided learning activity. However, if the study were to be conducted again, the review activity should be a graded component from the beginning. The introduction to concept mapping for each group of students should be improved by allowing for more time for students to complete the activity, and the study should implement a more conceptual-based assessment than a mostly multiple-choice quiz to test conceptual understanding.

The instructor found it necessary to give the students a guided approach to concept mapping. Concept mapping was brand new to many students in the class, and student feedback suggested that without some guidance it would have not been beneficial to them. The guidance provided by the instructor involved a list of concepts to include on their map each week. This gave students a starting point for how to begin their maps. Some students did state that they would have liked more of a skeleton map to begin with. However, this may have hindered their ability to build the conceptual connections on their own.

Requiring students to work individually on the review activities helped ensure that the results were true to each student's abilities. Without this requirement, it would have been difficult to correlate the quality of the concept map with the quiz score. However, group participation in these review activities could have been very beneficial to certain students. Building time into the review activity for individual work and then allowing for group collaboration towards the end of the review time could have been a way to accommodate more verbal learners.

While there were aspects of the study that worked quite well, there were other aspects that would need improvement if this study were performed with another group of students. One of the difficulties encountered was the size of the class. It is difficult to provide one-on-one instruction and to ensure full-class participation with a large class size. However, certain aspects of the study could have been structured to better suit the large class size. The quiz review activities were added as a graded component of student quiz grades only after Quiz #3. Making the quiz review activities graded is one way to encourage the majority of students to actively participate in the review activities, despite the large class size. This should be done from the beginning of the course in future studies. In addition, if the grading manpower is available, the review activities should be graded for quality as well as completeness.

Students could have benefited from more time to participate in the review activities. While no more class time could have been allotted, the review activities could have been made out-of-class, individual activities. Class time could have then been used to discuss the review activities in groups. As the review was structured, many students did not begin reviewing until the 15-minute review period right before the quiz. Requiring students to bring a completed review activity to class for discussion would have not only better prepared students for the assessment but also would have given students the proper amount of time to work on the activity outside of class.

Finally, the use of a mostly multiple-choice quiz for assessment was not ideal, since it can be difficult to assess conceptual knowledge from multiple-choice questions. Some quizzes did include short answer or diagramming/plotting questions. However, the large class size and the lack of grading manpower were the motivating factors in keeping the majority of the assessment as multiple-choice. If instead of conducting the study on a weekly basis, conceptual assessments were given just several times throughout the semester, then it would have been feasible to use a different, more appropriate, assessment technique.

5 Conclusions and Recommendations

Concept mapping should help build a conceptual framework and improve conceptual understanding, according to previous research on the topic (Romance & Vitale, 1999; Zeilik *et al.*, 1997; Zeilik, Schau, & Mattern, 1999). In this study, the assessment used to test conceptual understanding showed no significant difference in conceptual understanding between students who used concept mapping and those who did not.

Limitations in the methodology could have affected the study results. While the structure of the concept mapping was a strength, there were aspects of the study that should be improved upon in the future. The concept mapping and control review activity should be included as a required part of the course grade from the beginning of the course to ensure participation. Students could benefit from more time dedicated to the concept mapping, and a more appropriate assessment tool besides quizzes should be used to assess conceptual understanding.

The study did show a positive correlation between the quality of the concept map produced and student quiz scores. This trend is in agreement with previous studies that show concept maps can be effective indicators of conceptual understanding and therefore can be used as assessment tools. This trend could indicate that grading the concept maps for quality could result in more of an improvement in conceptual understanding. If more students are actively trying to improve their concept maps, this should then result in higher scores on other conceptual assessments. Future iterations of this study should include all of these improvements in methodology to give a better indication of the link between the use of concept mapping as a learning tool and student conceptual understanding.

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