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Use of concept maps for problem-solving in engineering

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ABSTRACT: This article presents a study on the use of concept maps as a learning tool for solving problems in engineering. Solving problems of structural analysis needs clear understanding of the fundamental concepts of the method and their links. Concept maps were used in lectures to explain the application of the concepts in solving problems and students were engaged in construction of concept maps before the actual calculations. Anonymous feedback was collected from students on the usefulness of concept maps in their learning. The responses show that the majority of the students found concept maps helpful in understanding the key concepts and their associations in solving problems. It helped students choose the right method from different options in solving a problem. Though the number of students constructing their own concept maps outside the classroom was relatively low, they wanted to see continued use of concept maps since it provoked the thinking process, and helped deep and meaningful learning. Thus, the use of concept maps facilitated student engagement in the classroom, helped solving problems and improved learning in the unit.

Keywords: Concept maps, deep learning, problem-solving, structural engineering

INTRODUCTION

Concept maps are graphical presentations of the network of concepts showing the relationships among them [1]. It can be presented as a Web diagram or a flow chart where each node is an idea or a concept and these concepts are connected together to show their relationships to each other. A hierarchy can be introduced in the map as some ideas can be grouped together. The connecting lines between the nodes may contain words describing the connection. Addition of colour and graphical elements in the map can help the user retain or recognise the information easily.

Concept maps are used as approaches of meaningful learning as they demonstrate the understanding and reflection of the subject matter. They can be used for brainstorming and creative thinking. The results of group brainstorming can be represented by a concept map and the map can form the basis of solution of the problem. It can also be used to store, organise and process the information graphically. It has the major advantage of presenting the information visually. Visual thinking can eventually improve creativity and retention of knowledge.

Construction of a concept map usually begins with a focus question. It is a question that clearly specifies the issue or the problem to be solved. A good focus question leads to a better concept map [2]. A concept map may sometimes need several revisions. It is necessary to have a clear understanding of the relationships among the concepts to construct a useful concept map.

Concept maps have been used in many disciplines of education. It has been shown to help learners learn better, researchers to create new knowledge, writers to write and evaluators to assess learning [2]. Construction of concept maps uses higher order learning skills, such as evaluation and synthesis of knowledge as identified by Bloom [3].

Roth and Roychoudhury studied the micro process of learning that takes place in students during concept mapping [4]. Their study recommended continued instructions on establishing the hierarchies and cross links between concepts and, then, facilitating students to reflect on the relationship between the concepts.

Throchim showed that concept mapping is a useful procedure for group conceptualisation tasks that result in an easily understandable and graphical representation of the group’s thinking with input from all participants [5]. Thus, concept maps were used to support the design of instructional materials [6] and successful instructional activities [7-9].

Concept maps can be used as tools for the evaluation of student learning [10]. They are a flexible assessment tool though they may require extensive time depending on the subject matter [11]. McClure et al evaluated the validity and practicality of using concept maps as a tool for classroom assessment [12]. The data collected from undergraduate and postgraduate students suggested that it was possible to train students in a reasonable period using a direct instruction method. It was recommended that the actual mapping task be kept simple and to use some form of relational scoring method, preferably with a master map. Similar conclusions were drawn by Markham regarding the validity of using concept maps for classroom assessments [13].

Gouli et al developed an adaptive Web-based concept map tool to support learning through the assessment process in science education [14]. Their model focused on the diagnosis of the learner's knowledge and the generation of the adaptive feedback. Tsai et al reported a Web-based concept map testing system for science students [15]. It was found that students with more skills in critical thinking and metacognitive activities showed more willingness to use the on-line testing system based on concept maps. Moreover, students with high test anxiety showed a preference for the Web-based test. Concept maps have also been used by researchers to communicate information [16-17].

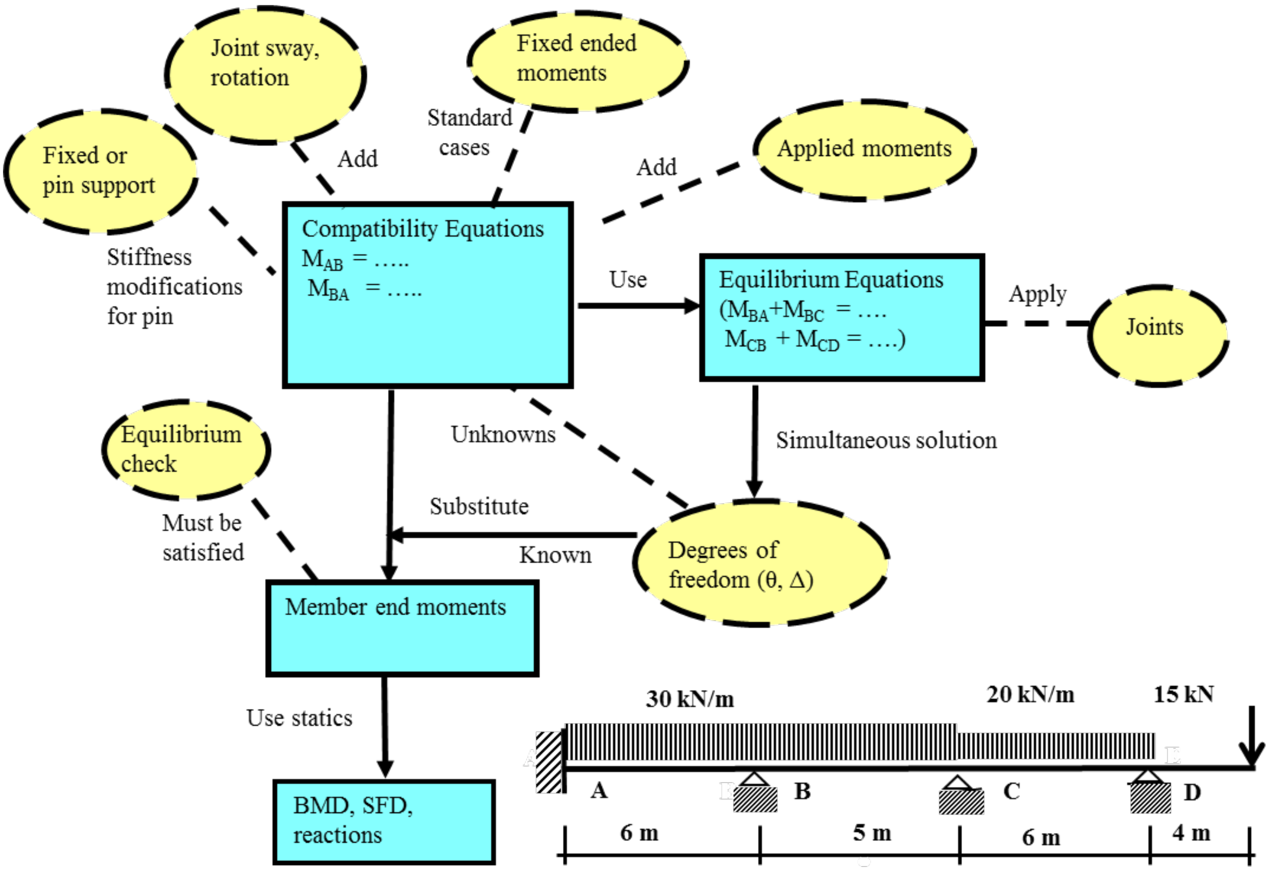

Figure 1: Example of a concept map for solving a statically indeterminate structure by the slope-deflection method.

In this study, the concept map was used as an instructional activity by the lecturer and a tool of engagement for students in the classroom to foster the thinking process. There were eight topics on analyses of different types of statically determinate and indeterminate structures in a structural analysis unit. It was found in class interactions and assessment tasks that students often mixed up the concepts of different methods and had difficulties with following the right steps of a method in solving problems. Therefore, it was necessary to find ways to reinforce the learning activities in order to make conceptual understanding of the subject matter clearer and deeper. In this challenge, a concept map was introduced in the class and the experience of students on its use in their learning process was analysed in order to understand how it helped in their learning process.

MATERIALS AND METHODS

The study was conducted on the second year students in a structural engineering unit in the Department of Civil Engineering. The content of the unit was analysis of different types of structures, such as statically determinate and indeterminate beams by using different methods. The solution procedure of structural analysis problems by a particular method is based on certain assumptions and key concepts. The concepts of each method have a relationship among themselves and they form a procedure for the solution for a problem. There are similarities and differences among the concepts involved in different methods. Also, only one particular method may need to be used or may be more suitable than the other methods for a given problem, while all the methods may be equally suitable for some other problems.

Thus, a clear understanding of the concepts and their applications in the step-by-step procedure of a method are important for choosing the right method for a problem. Concept maps were used in lectures to explain the fundamental concepts and their associations involved in each method of solution and this was followed by numerical examples. The maps were also used to explain the differences and similarities among different methods of solutions.

An example of a concept map used in the lectures is shown in Figure 1. The map shows the concepts and a general procedure involved in the slope deflection method of indeterminate beam analysis. The concepts are shown in the ovals and the steps of the solutions are shown in the rectangles. The associations of the concepts are shown by the lines with some words describing the relationship. Application of the concepts and their relationships in the solution procedure involved further theoretical derivations and numerical examples.

Similar concept maps were used for each method of solution. Students in the classroom were given tasks to get engaged in group work to construct a concept map before starting the actual calculations. They were engaged in group discussions to identify the concepts related to the given problem and drew the network of the concepts showing the steps of the solution procedure. Students, then, followed the map and conducted the step-by-step calculations to solve the problem. This was followed in the classroom and students were encouraged to draw a simple concept map before beginning the calculations, so that they started with a clear understanding of the step-by-step procedure of the solution.

A questionnaire was designed to collect anonymous student feedback to determine the usefulness of concept maps in the lectures. The major aspects included in the survey were how the concept maps helped learning of the unit materials, how students used the concept maps and if students constructed their own concept maps. The questionnaire was handed to students in a class at the end of the semester to collect their feedback.

The concept map survey consisted of eight statements for students to rate their agreement or disagreement on a scale of 1 - strongly disagree; 2 - disagree; 3 - agree; and 4 - strongly agree. These statements are given in Table 1. There was also one question (Question 1) asking if the use of concept map was new to the students. The usefulness of the concept maps was evaluated by analysing the student responses to the questionnaire and by the observation of their performance in class interactions and the assessment tasks.

Table 1: Students' responses on the use of concept maps.

No.	Statement	Number of responses				Mean score	Disagree/ strongly disagree %	Agree/ strongly agree %
		Scale 1	Scale 2	Scale 3	Scale 4			
2	Concept maps used in the lecture helped me to understand the key concepts.	5	19	39	3	2.61	36	64
3	Concept maps helped me understand the association of the concepts.	3	20	38	4	2.66	35	65
4	Concept maps helped me understand the steps involved in problem solution.	4	13	43	6	2.77	26	74
5	Concept maps helped to compare different methods of solutions.	3	29	29	6	2.57	48	52
6	I think about construction of my own concept maps.	6	27	28	3	2.44	52	48
7	Concept maps are easy tools for revision	15	37	14	1	2.01	78	22
8	I would like to see the use of concept maps in lectures in future.	2	15	43	4	2.77	27	73
9	Overall, the concept maps introduced the concepts and helped me retain the knowledge.	2	26	35	3	2.59	42	58

REULTS AND DISCUSSION

The unit had an enrolment of 106 students. About 20% were international students and the rest were domestic Australian students. The two-hour face-to-face lectures consisted of introduction of concepts, derivation of fundamental theories from the first principles and application of the theories for analysis of different types of structures. Applications of the concepts and theories were learned by working out solutions of numerical examples in the class. Students were, then, given a problem-solving task to work in small groups and they came up with a concept map of how to solve the problem. The maps drawn by different groups usually varied; however, it showed the concepts involved and a step-by-step solution procedure. The lecturer, then, discussed the maps drawn by different groups and the whole solution process.

The attendance of students in the lectures was generally above 80%. A total of 67 students provided feedback by responding to the questionnaire. The numbers of responses for each scale of agreements or disagreement are given in Table 1. The weighted mean scores of the responses, the percentage agreement (strongly agree and agree) and the percentage disagreement (strongly disagree or disagree) for each statement is also given in the table. The percentage agreements to the statements are also presented graphically in Figure 2.

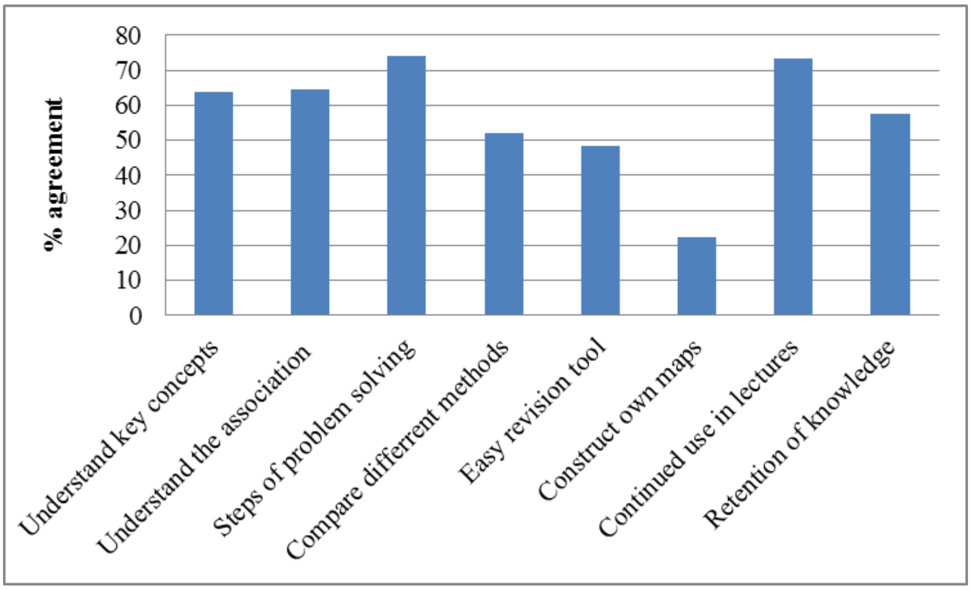

Figure 2: Percentage agreements of student response to differrent aspects of concept maps.

In response to Question 1, 86% of students responded that concept maps were new to them. Therefore, the use of concept maps in the classroom was new to most of the students. The mean scores of the responses to statements 2 and 3 were 2.61 and 2.66, respectively. The percentage agreement with these statements was 64% and 65%, respectively. Thus, about 65% of the respondents found the concept maps used in lectures to be helpful for them to understand the key concepts and the association of the concepts in solving problems. In response to statement 4, there was 74% agreement that the concept maps used in the lectures helped students understand the whole solution procedure of a problem. The mean agreement score to this statement was 2.77.

Relatively high rates of agreements to these statements support that concept maps were found useful by students to understand the methods of structural analysis and learn the problem-solving skills. This is further demonstrated by the 73% agreement to statement 8, which states that students would like to see the continued use of concept maps in the lectures.

Statements 5, 6 and 7 were used to find out how students used concept maps outside the classroom. There was 52% agreement that students found the concept maps helpful for comparing between different methods of solutions. The mean response score to this statement was 2.57. In response to statement 6, it can be seen that 48% of students thought about construction of their own concept maps outside the classroom. The mean response score to this statement was 2.44. In response to statement 7, only 22% agreed that concept maps were easy tools for revision of the unit materials before the end of semester examination. The relatively low agreement to this statement shows that they used the concept maps mainly at the initial stage of learning of a new method of analysis. When students became familiar with a method of solution after working out the practice problems in and outside the class, they were more confident to start the solution of a problem straight away without construction of a concept map.

Statements 8 and 9 were used to find out the overall perception of students about the use of concept maps. The mean response score to statement 8 was 2.77 with 73% agreement that students would like to see the continued use of concept maps in lectures. In response to statement 9, there was 58% agreement that the maps were helpful in introducing the concepts and retaining the knowledge. This means that the use of concept maps facilitated a deeper understanding of the concepts and their applications and, thus, they helped retain the acquired knowledge.

Generally, it can be seen from Figure 2 that the more helpful aspects of concept maps were in understanding the key concepts and their association, steps of problem-solving and retaining the acquired knowledge through a more clear and better learning outcome.

The use of concept maps in comparing different methods and as a revision tool was relatively less. Generally, students found the concept map to be a useful tool for engagement in the classroom and wanted to see more use of it in lectures. Improvements in the performance of students in the class interaction and assessments were also observed. This further supports the use of concept maps in lectures for improved learning outcomes of engineering units.

CONCLUSIONS

This article presents a study on using concept maps in lectures of a civil engineering unit on structural analysis. The student feedback shows that concept maps were generally seen as a useful learning tool in the classroom. Concept maps helped students learn the key concepts and their associations in the solution methods of structural analysis problems. Concept maps also helped students choose the right method to solve a problem. Enhanced student learning through a clearer conceptual understanding was observed in classroom interactions and in the formal assessment tasks. Therefore, students would like to see its continued use in lectures. However, the use of concept maps by students outside the classroom was found to be relatively less. This is because concept maps were more helpful in the initial stage of learning to grasp the concepts and develop confidence in the problem-solving skills. Once the skills are developed, students are able to attempt the calculations directly without drawing a concept map.

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BIOGRAPHY

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