Concept Maps: Making Learning Meaningful
Proc. of Fourth Int. Conference on Concept Mapping
Viña del Mar, Chile, 2010

ENHANCING COLLABORATIVE PROBLEM SOLVING IN DISTANCE EDUCATION COURSES USING WEB-BASED CONCEPT MAPPING

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Abstract. The purpose of this study is to investigate the use of web-based concept maps as a communications and problem-solving tool in an online graduate level course. The study used an exploratory-descriptive research design that applied a qualitative methods approach in order to explore how concept maps foster collaborative problem-solving activities in an online learning environment. Three of the five groups participating in the study effectively used concept mapping, which they combined with other communication strategies such as eliciting group suggestions, asking questions, and brainstorming ideas, to reach consensus and solve the CBR project required. These results indicate that concept maps are a practical and effective strategy to help distance learners communicate and collaborate in order to solve problems in online courses.

1 Introduction

Higher education is increasingly expanding its services through the implementation of online distance education. The distance learners of today are able to engage in collaborative problem solving, threaded discussions, and peer tutoring through asynchronous and synchronous distance learning environments. Gunawardena and McIsaac (2004) affirm that one of the recent trends in distance education research focuses on understanding pedagogical issues in the CMC (computer mediated communication) environment, and especially on collaborative learning in CMC. They emphasize the need for further research in this area because of the recent growing interest in facilitating collaborative learning in online environments.

From a constructivist and socio-constructivist viewpoint (see Bruner, 1966; Vygotsky, 1978; Leontiev, 1978), students should be provided with strategies and skills that foster collaborative learning, as well as with environments that allow them to share their cognition in a social context. Both the instructor and individual learners in the group can offer strategies that facilitate this social interaction and shared cognition (Resnick, 1991). Concept mapping is one of these strategies.

For the purpose of this study, we define a "concept" as a generalized idea of a thing or class of things, designated by a word or symbol that represents a unit of knowledge or meaning. A concept map is defined as a graphical representation that includes concepts, usually enclosed in circles or boxes; links, which are represented by lines or arcs ending in an arrow head and which show the directionality of the relationship between concepts; and words within each link which create a meaningful statement relating the two connected concepts. One or more concepts with a single link to other concepts, descriptions, or characteristics is referred to as a proposition if together these form a meaningful statement (Novak & Cañas, 2008). A concept that is not linked to anything else is referred to as an "independent concept."

In online distance education, interactive concept maps can become useful tools for students in groups to enhance the co-construction of knowledge, which leads to effective learning. Coffey & Cañas (2000) note that online courses that implement mapping techniques as a part of the course design may use them in activities such as brainstorming by individuals or groups, collective decision making, designing projects, organizing papers, and formulating research plans. Another possible application for concept mapping would be as a knowledge integration tool. Constructivist theory argues that new knowledge should be integrated into existing structures in order to be meaningful and be remembered (Jonassen & Wang, 1993).

The purpose of this study, therefore, is to understand the use of web-based concept maps as a communications and problem-solving tool in an online distance education graduate level course. This study will examine students' collaborative efforts to solve a case-based reasoning (CBR) problem during a semester-long period in order to explore how concept maps foster collaborative problem-solving activities in an online learning environment.

2 Collaborative Concept Maps as a Tool to Foster Students' Problem Solving

Following many years of research measuring the effectiveness of concept maps in a standard instructional setting, as cited in Novak & Cañas (2006), the literature now reflects a new research trend that focuses on exploring the use of web-based concept mapping techniques in the learning process and their effects in collaborative learning environments (Kremer, 1996; Plotnick, 1997; Stoyanova & Kommers, 2002; Keller, Tergan, & Coffey, 2006). Plotnick (1997) was one of the first to suggest that concept mapping might be an effective way to enhance the problem-solving phases involved in generating alternative solutions and options in a collaborative group effort. A concept map may, of course, be created by a single individual to organize and clarify his ideas. Alternatively, when a group collaborates to produce a concept map, the map represents the combined ideas of the group. In either case, concept mapping can be used as a communicative tool for people to discuss concepts and their relationships. In a group, this tool allows them to reach agreement on common terms and a common structure to use as a basis for further action (Plotnick, 1997). Such an agreement process developed within the group is referred to as the "collaborative construction of knowledge."

Researchers have examined a variety of aspects of concept mapping. Gaines and Shaw (1995), for example, have described the application of groupware concept mapping tools designed to support collaboration in dispersed learning communities. Their data shows that consensual maps are usually developed through negotiation. Gaines and Shaw have also observed that students working in collaborative groups usually divide responsibility by expertise or by preferences. They note that these groups end up producing a great deal of additional material in the form of networks of linked maps and associated resources.

Other research supports the idea that learning styles can play an important role in groups working on concept maps. This study on the effects of learning styles on group interaction (Papanikolaou, Gouli, & Grigoriadou, 2006) focused on the role that individual differences among group members played in collaborative concept mapping tasks. For example, a group would benefit if it included both visual and verbal learners, rather than just one or the other type of learner. The overall results of this study indicate a positive relationship between the inclusion of participants with a variety of learning styles in a group and the group's success with collaborative concept mapping tasks.

Fischer, Bruhn, and Mandl (2002) performed a study showing that one way of increasing the quality of discourse among members of collaborative learning groups is to provide visualization tools. The researchers found that concept maps as visualization tools supported the construction of knowledge by encouraging the learning partners to focus on and apply new concepts to task-relevant content.

Research by Keller, Tergan, and Coffey (2006) explored the use of a specific kind of awareness tool to improve the collaborative learning process. Groups used this KIA-Tool ("knowledge & information awareness" tool) to make their members aware of the knowledge and corresponding underlying information of the other collaborators, which increased the members' problem solving skills.

Stoyanova and Kommers (2002) investigated the effectiveness of concept mapping for computer-supported collaborative problem solving. The main assumptions underlying this research are that shared cognition is crucial to cognitive construction and reconstruction of knowledge, and that concept mapping is an effective tool for mediating computer-mediated collaboration.

3 Questions Addressed by This Study

This study addresses two research questions:

Research question 1: Is there a relationship between the propositions selected collaboratively by a group in constructing a concept map and the propositions stated in the solutions to the CBR problem as evident in the paper they completed?

The second research question expands on the first.

Research question 2: How did the generation of a collaborative concept map help to solve the CBR problem?

4 Methods

We will first discuss the design of the online course which was used for this research study, and then the research procedures for our study. An online graduate course on the Theory and Practice of Distance Learning offered by a Southwestern University in the United States was designed using the WisCom design model (Gunawardena, Ortega-no-Layne, Carabajal, Frechette, Lindemann, & Jennings; 2006), which is based on socio-constructivist theory. The WisCom design model emphasizes collaborative problem solving achieved through knowledge innovation, mentoring, and learner support, in a community-of-practice learning environment.

Five groups of students were each required to collaboratively solve an instructional problem in distance education using a CBR format. They were asked to apply the distance education principles learned in the online course to develop a distance education system that incorporated solutions to the problem they were given. Of the five groups, four groups contained three students and one group consisted of two students. These five groups are referred to as A, B, C, D, and E. Each group was required as a final course assignment to submit a concept map that reflected the group´s solutions to the problem and a paper describing their proposed solutions. The groups were evaluated and graded based upon these concept maps and papers.

Students were encouraged to use Cmap Tools software as a collaborative learning tool to generate their concept maps. Students were also asked to save all of their communications while generating the concept maps and the paper. These communications were saved in a discussion thread in WebCT intentionally set up for this purpose, and also in the Cmap software´s discussion thread and annotations. Each group generated one paper and one concept map which presented their graphical representation of the solutions to the problem.

4.1 Participants

The subjects for this study were fourteen graduate students: 10 females and four males. Of these students, 10 were Anglo-American, 3 Native American, and 1 Hispanic. The average age was 40. None of the students had generated a concept map before the study. Only a few had prior knowledge of concept maps as a strategy for organizing ideas.

4.1.1 Procedures

All of the students were trained in concept mapping techniques using Cmap Tools v.3 software (2003), focusing on specific collaboration features such as adding discussion threads to each concept as well as using annotation features to support the knowledge construction process. The training took place during the orientation session conducted face-to-face at the beginning of the semester. The software was selected because it is open-source and network-enabled, allowing the users to build and collaborate during the construction of concept maps with colleagues anywhere on the network. The participants were not only able to share and navigate through each others' concept maps, but the program also allowed them to integrate resources like documents, pdf files, and videos.

4.1.2. Data Collection

Data from this study came from five sources: 1) the concept map that each group generated to solve the problem; 2) the paper that each group wrote explaining their solutions; 3) the discussion threads in WebCT and Cmap where each group discussed the solutions of the problem; 4) the annotations in Cmap, which showed the groups' thinking processes; and 5) the survey on collaborative problem solving that was administered after the groups had created their concept maps.

The purpose of the survey was to determine which communication strategies students used during the problem solving task and to obtain information about their experiences while using collaborative web-based concept maps to solve the problem. Students were also asked to suggest the appropriateness of using these strategies for future online courses. The survey consisted of eight questions: two were Likert-scale and six were open-ended. The first Likert-scale question asked which strategies the group used to come to consensus on solving the problem. The second Likert-scale question asked each group to rank order the usefulness of the communication strategies they had employed in the problem solving activity. The open-ended questions asked them to describe: 1) their preferences among the communication strategies they used; 2) how the concept map facilitated interaction among members of the group; 3) how the online map generated by the group helped in the problem solving activity; 4) the advantages and disadvantages of using concept maps for promoting collaborative learning in distance education; 5) how the concept map helped the group to negotiate ideas to arrive at a consensus on what to include in the solutions to the problem; and 6) any additional suggestions or recommendations for using concept maps in future online courses. Two experts determined the construct validity of this survey.

4.1.3. Analysis

To address the first research question, all CBR papers and their respective concept maps were analyzed and compared in order to identify to what degree propositions stated in the maps helped students to write the CBR paper. First, using content analysis, researchers looked for concepts and propositions in the paper. Each of these was labeled with a number. All concepts and propositions were then summarized by the researchers at the end of each group paper. Second, a similar process was conducted with each concept map, by counting and summarizing the number of nodes or concepts, the number of propositions, the number of links, and the number of linked words. After all of the concepts and propositions had been identified and labeled, researchers made comparisons between the maps and the papers. For example, if the concept presented in the map matched any concept mentioned in the paper, that concept was counted as a single concept presented in both places. The same process was followed using propositions.

As shown in Table 1, several relationships were established between concepts stated in the map and in the paper. For instance, researchers compared the number of concepts that were stated in the map but not stated in the paper and vice versa. We expected that when a greater number of concepts and propositions appeared in both the map and the paper, this strong relationship would indicate a high probability that generating a concept map had effectively supported the collaborative problem solving process.

To answer the second research question, the researchers analyzed and compared several sources of data: a) computer transcripts generated by each group; b) each group's concept map; c) each group's CBR paper; and d) the online survey soliciting students' opinions on the use of concept maps as a collaborative communication tool to solve a common problem. ATLASti v.4.2 was used to analyze the computer transcripts obtained from discussion threads and annotations generated in the Cmap public server; the data from discussion threads generated in WebCT related to the CBR project; the CBR paper; and the open-ended questions from the survey. The Likert-scale questions were analyzed by examining computer frequencies and percentages, and the results were graphically represented using Microsoft Excel 2000. All the data obtained and analyzed was triangulated. A comparison of these results allowed the researchers to evaluate the degree to which each group attempted to use collaborative learning strategies for solving the problem and to what extent the generation of a collaborative concept map helped them to solve the CBR project.

5 Results and Discussion

The groups in the study had been given the freedom to start solving the CBR problem either through the generation of a concept map or by directly writing the paper. For those groups who decided to use the concept map as a starting point to solve the problem (3 out of 5 groups), there was a close relationship between the concepts and propositions generated in the concept map and those presented in the CBR paper. This implies that concept maps can serve as a foundation for solving problems in a distance education setting by assisting the students in identifying concepts, propositions, and the relationships among them. Table 1 breaks down the numbers of concepts and propositions used by each group.

Groups	Number of propositions in both map & paper	Number of concepts in paper but not in map	Number of concepts in map but not in paper	Total number of concepts/ propositions in paper	Total number of propositions in map
Group A	35	22	11	57	39
Group B	23	34	41	57	23
Group C	35	25	12	60	35
Group D	8	59	2	67	8
Group E	16	23	13	39	16
All Groups	117	163	79	280	121

Table 1. Number of concepts and propositions used by the groups on maps and CBR papers

As the table shows, Group A generated a total of 39 propositions of which 35 were found in both their paper and map, a high correlation. However, despite this strong correlation, 22 out of the 57 concepts in the paper were not present in the map. At the same time, there were 11 independent concepts stated in the map that were not referred to in the paper. We repeated this map-paper comparison process with the five groups. For those groups that had generated a collaborative concept map before writing their paper, we found a high correlation between the concepts presented in the map and the paper.

The correlations between maps and papers given in Table 1 will not address 1) how the collaborative concept map allowed the group to arrive at solutions for the CBR project; 2) which negotiation strategies were used by the group; and 3) how students arrived at a consensus in order to solve the problem. Therefore, research question number 2 examined those areas using a triangulation method. The results for both research questions for each group are summarized in the following descriptions of the groups' problem solving processes and their evaluations of the use of concept mapping.

Group A used the concept mapping technique as a brainstorming tool; they agreed that the tool was useful to begin solving the problem, but worked on the problem using a cooperative rather than collaborative strategy. They used the concept map to support their online discussion via e-mail, but divided their task once they made the decision about which components to include in their problem. About the value of a concept map, they state: " …it helped us to show gaps in our development and training needs." They also said that "concept maps posed a challenging way to think about problem solving." They agreed that the map helped them visualize the components to be included in the solutions presented in the paper and that it also helped with the creation of more concepts that were not present in the map.

Group B collaboratively generated a total of 23 propositions on the map, all of which were used to support their solutions in the paper. We also identified 34 independent concepts given in their paper which were not found in their map, as well as 41 concepts in the map that were not discussed in the paper (see Table 1). The high number of shared concepts makes us believe that the concept mapping process was useful to the group. They noted that their communication strategies were discussion threads, annotations, chat, and email; they felt these methods enabled them to make more efficient use of their time. One of the group members said that using the concept map allowed him/her to visualize good ideas and was useful for clarifying ideas. Another member said, "We could see quickly if someone had misunderstood what we were trying to say. It helped to keep us on track." The third member added, "Using maps was the main key for this assignment. If it is clear for all, then it will be easy to see the whole in a meaningful way." They all agreed that the generation of concept maps was a source for discussion, as well as a tool for providing a meaningful way of organizing concepts. One person said, "The generation of concept maps was only one strategy that helped to work collaboratively…the use of communicative tools such as discussion threads, annotations, and email was very important for the solution of our CBR project". This group used concept maps as a collaborative tool at the beginning, but once the main concept map was developed, they divided their tasks based on the components stated in the map, using e-mail communication and the CBR communication space located in the WebCT server to collaborate.

Group C generated three maps to represent the distance education system proposed to solve the CBR problem. A total of 35 propositions were found in both the map and the paper. Of the 60 concepts/propositions discussed in the paper, 25 were not represented on the concept map. Of the total of 85 concepts in the map, which includes those appearing in propositions, only 12 concepts were not discussed in the paper. This strong relationship between the maps generated and the solutions given in the paper supports the conclusion that creating the concept maps was very helpful to this group's completion of the project. The group reported that the communication strategies they used were those allowed by Cmap Tool and their discussion space in WebCT. Two of the group members agreed that concept maps helped them as tools for organizing and brainstorming. However, they reported that it was difficult as a group to agree on ideas to include in their paper or on solutions. One person regretted having to use concept maps, saying that maps did not help the group to solve the problem. This group noted that the level of complexity is higher when a concept map is generated incorporating others' ideas and levels of expertise, making the collaborative work effort a far more complex task.

Group D was comprised of three members, two of whom reported that they were experienced with computers. These same members expressed no confidence in using concept maps to generate solutions to the CBR project. However, since the creation of a concept map was part of the assignment requirement, they generated two maps. They used the first as a graphic representation of organizations within a distance education system, but this map did not contain any propositions. Each independent concept in the map is mentioned in their paper. The second concept map contained eight propositions, all of which were referred to in the CBR paper. Both maps contained a very low number of nodes, link words, and propositions. This group of students generated the greatest number of concepts in the paper, a total of 67 (see Table 1), but the correlation between maps and paper was quite weak. Group D was the only group whose members interacted solely through email communication and phone calls. The main reason they used email was because this system allowed them to speed up the communication process. Based on the analysis of their survey responses, this group did not work using collaborative learning strategies. They divided their responsibilities, and said "our primary strategy was to communicate through email, because for us that was an easy way to fill in sections of the paper related to areas of expertise. It worked well for us." Other members said they chose email "because it was easier to share versions of the paper and combine our contributions, ask each other questions, etc.". With regard to concept maps, they asserted that they all disliked the idea of using concept maps to solve their CBR problem. They argued that concept maps were not the best option for them because maps did not correspond to the way they think and solve problems; they preferred to communicate verbally, not visually. They argued that concept maps might be good for visualizing ideas and concepts but did not work for knowledge construction. Although this group did not use concept maps as a collaborative learning tool to solve problems, two members did mention some advantages. They said that concept maps are good for visual learners, allowing them to see the way in which others are thinking, and that this strategy would be helpful for expressing concepts across language and cultural barriers. We can conclude from this group's responses that students in future online courses need to be trained not only in the use of concept mapping and related software, but also in strategies to promote collaborative group learning.

Group E generated two concept maps. The first map contained a total of 21 concepts but had no link words, nor any evidence of connectors to form propositions. Of those 21 concepts, only 8 were present in the CBR paper. The second concept map contained 16 propositions, all which were present in the paper; however, this number is low by comparison to the number of shared propositions in Groups A, B, and C. In addition, the paper written by this group was weak; it presented the fewest number of solutions to the problem. This group used email as part of their communication strategy. When asked about concept maps as a strategy to facilitate group interaction, one of the three group members pointed out that the map served as a visual aid. The second member said, "I think it painted a clearer picture than just explaining verbally." However, the third member disagreed, saying the group had more interaction via email than by using the concept map. Although this group took longer than others to understand how to use the concept map as a collaborative tool, they agreed that the map helped them visualize CBR solutions. The group member who regretted using the Cmap Tool said, "Maps would work better if you are very clear on what you are building. Otherwise I think it would be very confusing." However, based on another member´s opinion, it seemed the group did learn how to use the map as a collaborative problem solving strategy by the end of the project. This member said, "I think it is helpful to use a concept map to structure all our thoughts together, but some group members did not think it was important, so there was little participation as a group effort in the concept map process until the end of the project." The same member affirmed in the survey that " I personally enjoyed making and using the concept map. I would like to suggest promoting the use of concept map as a strategy to learn and teach at the graduate level." The second member pointed out that it is important to have an entire session to train students in the use of concept maps in a collaborative learning environment before starting to learn about the course content.

From our analysis of the online survey, we found that four out of five groups had created concept maps to support their problem solving process and felt that this strategy had helped them to solve the CBR project. Only group D started the problem solving process by writing the paper first and then generating a map based on their paper. The rest of the groups used several strategies to reach consensus among the members, including concept mapping, asking for group suggestions, using questions, and brainstorming ideas.

The analyses of online discussions generated in WebCT and Cmap showed that the concept maps and the related discussions helped the groups solve the CBR project. There was enough evidence from groups A, B, and C to demonstrate high-to-moderate correlations between the propositions generated in their maps and later referred to in their CBR papers. Data triangulation showed that groups A, B, and C were using the concept maps to support or guide their problem solving process. In response to the survey, 50% of the students said that the most useful strategy for them during the CBR problem was creating a concept map, in combination with other communication strategies such as eliciting suggestions, asking questions, and brainstorming.

In the survey, groups A, B, C, and E mentioned that using a concept map for solving problems helped them with three main tasks: 1) to visualize all the important elements to be included in the problem; 2) to visualize gaps and suggest possible solutions; 3) to be able to see the entire problem at once. All three benefits allowed them to identify the appropriate strategies to generate more ideas within their own group and devise solutions for the problem.

Table 2 shows the advantages and disadvantages of using concept maps to solve a collaborative problem for distance education which students identified in the surveys that they completed at the end of the project.

Advantages	Disadvantages
Cmap Tool software can be used to: • Synthesize social construction of knowledge. • Preserve knowledge obtained from online environments. • Organize complex information. • Represent complex ideas. • Brainstorm ideas to be included in a problem-solving task. • Communicate ideas. • Negotiate ideas. • Reach consensus. • Visualize the whole. • Visualize different alternatives to solve a problem. • Visualize gaps or deficiencies in the problem context. • Facilitate collaborative learning and social construction of knowledge.	**Cmap Tool software requires that:** • Students have strong computer skills. • Computer hardware be able to support the software and interact with the server. • Students be trained in concept maps and collaborative use of the software. • Students be given sufficient time to learn-practice using concept maps. • Individual differences among group members be addressed. Otherwise, these could create obstacles in the learning process—e.g., visual students could react positively while verbal learners could refuse to use concept maps.

Table 2. Advantages and disadvantages of using Cmap in web-based instruction.

6 Summary

These research results suggest that web-based concept maps could be used collaboratively in online distance education graduate courses. When the collaborating groups generated concept maps to solve the problem prior to writing a paper giving their solutions, the propositions in the concept map correlated highly with those in the paper. This high correlation answers our first research question and leads us to believe that creating the concept map facilitated the problem solving process. The fact that three of the five groups in the study included even more concepts in their papers than in their concept maps seems to indicate that making these maps helped them write the paper, encouraging further discussion and concept generation in the process.

In answer to our second research question, the majority of the groups pointed out that generating a collaborative concept map was a time-consuming task. The students' main explanation for this was that it was difficult for them to build their own ideas upon someone else´s ideas in an online concept map. Doing this required many discussions to reach agreement, negatively impacting the time it took to complete the task.

According to our analysis of the survey, groups combined diverse communication strategies to reach consensus and solve the CBR project. These strategies included concept mapping, eliciting group suggestions, asking questions, and brainstorming. Groups also combined diverse communication channels during the problem solving process, such as concept maps, discussion threads, annotations, and email messages.

Our results suggest that concept maps are a practical and effective strategy to help distance learners communicate and collaborate in order to solve problems in online courses. However, in order to promote online collaborative learning using web-based concept mapping, groups need to be provided with specific training on how to use concept maps as a communication and collaboration tool.

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