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Using a concept map knowledge management system to enhance the learning of biology

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A B S T R A C T

This study was undertaken with the goal of developing a Concept Map Knowledge Management System (CMKMS) for use as a tool in observing change in a student's understanding of biology concepts over time. The CMKMS should be useful in assessing the extent of a student's knowledge and in revealing their unique thought processes. The study was concerned not only with a student's self-evaluation of learning but also with their level of satisfaction after using the CMKMS. The CMKMS combines the diagnosis of concept mapping with the style of thought processing, and promotes teaching activities step-by-step, in order to promote effective student learning. In analyzing the factors that influence the effect of teaching, the teacher can determine a student's knowledge structure and highlight misconceptions by inspecting the concept maps and logs. The results of this study show that knowledge management involved in computer-aided instruction in the teaching of biology had a positive influence on learning effectiveness. The CMKMS also was useful in promoting the student's thought processing, creativity, and ability to judge.

1. Introduction

Although modern biology problems are complex, teachers want students to learn to explain patterns and processes in the natural world and to be able to make predictions about system behaviors. Concept mapping as a means for students to learn new information has been widely recommended and accepted in science, mathematics, and educational psychology (Brown, Nagel, Zlatanova & Kolbe, 2013; Chiou, Lee & Liu, 2012; Empson, Greenstein, Maldonado & Roschelle, 2013; Wijeysundera et al., 2013). Concept mapping allows students to apply nodes, labels, and links in order to graphically represent the relationships among multiple concepts (Tseng, Chang, Lou, Tan & Chiu, 2012). Students can draw concept maps to explore the incompleteness of a concept or a defect in understanding. Therefore, concept mapping can help students to improve their conceptual understanding and improve their attitude toward a new course (Novak, 1990).

A concept map is also an effective and efficient tool that can be used to evaluate student learning, because concept maps reflect a student's internal semantic networks with regard to the knowledge they perceive, accumulate, and comprehend (Hung, Hwang, Su & I-Hua, 2012; Wu, Hwang, Milrad, Ke & Huang, 2012). There, the teacher can estimate a student's learning by evaluating the content and structure of a concept map they have constructed. The traditional method of concept map scoring was based on the components and structure of the concept map, whereby points are assigned for valid lists of concepts, cross-links, propositions, and examples derived from expert-prepared maps: 1 point for each proposition, 1 point for each branch, 1 point for each example, 5 points for each level of hierarchy, and 10 points for each valid cross-link (Novak & Gowin, 1984). Some researchers have sought to confirm and extend a computer-based technique for automatically scoring concept maps (Cline, Brewster & Fell, 2010; Lee, Lee & Leu, 2009). Ruiz-Primo and Shavelson (1996) have described methods that can be used to compare a student's map to that of an expert. Expert maps may be constructed by a teacher, a domain expert or a group of teachers or domain experts. Some researchers have experimented with a combination of methods based on traditional component-based scoring and methods based on comparisons to expert maps in order to weigh the propositions put forth in student maps (Jeong & Lee, 2012; Soleimani & Nabizadeh, 2012).

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However, as far as could be ascertained, the previous citations in the literature have surprisingly neglected the process that students use to develop their concept maps, since these methods focused on examining the finished concept map. The lack of information about how students categorize, reorganize, and link their perceived concepts, would result in teachers not understanding the learning patterns of students with different personalities, cultures, and backgrounds. This would lead to an inability by teachers to objectively evaluate learning performance and to provide constructive suggestions. However, with regard to cooperative learning, the final concept map does not demonstrate the learning performance and cooperative behavior of each team member, which leads teacher difficulty in observing the knowledge accumulation and organization processes for each of the individuals within a team. Therefore, the teacher cannot deliberately guide the discussion of a team during the development of the concept map, and neither can he/she assist the members who do not follow up on the concepts constructed by the team. Therefore, the need of a new framework to both observe the developing procedure and to evaluate the results of the concept map is inescapable.

Biology courses are often taught in the traditional teacher-centered style. Classes are usually dominated by direct instruction. Students are generally expected to take responsibility for their own learning without questioning the teacher. The teacher-centered approach assumes that all students have similar levels of background knowledge in the subject being taught and that they absorb new material at a similar pace (Lord, 1999). In contrast, the constructivist learning approach allows students to work together in small groups and answer a posed question (Yager, 1991). These students can be at different levels of knowledge and abilities to learn since students assist each other in the process. For the constructivist, knowledge is created rather than discovered. The use of concept mapping is often linked to the 'constructivist' view of learning, because a concept map makes a good starting point for constructivist teaching.

When teachers step into the classroom, they must find effective teaching strategies to assist the students. Although there are many different ways to teach students, direct instruction and constructivist theories of learning are two of the most common methods. Each of these methods has advantages and disadvantages for the teacher and the students. No matter what method the teacher selects, it is important that the teacher take any means necessary to improve student motivation and engagement in the learning process. Biology teachers must clearly modify the way they teach in order to develop students who are enthused about the subject and who really understand the material.

The aim of the present study was to compare two sections of a biology course - one that was dominated by lecture and one that used the constructivist model. After surveying the literature on problem-solving in e-learning and biology, proposal was made as to how biology education researchers could apply research-supported pedagogical techniques from concept mapping to enhance biology problem-solving by students. The need for the development of a knowledge management system using concept maps for biology was apparent. The first step was to characterize the problems that biology students are typically asked to solve. In the present study, a framework was developed for the analysis of individual learning performance and cooperative behavior on knowledge accumulation and organization using concept maps. The Concept Map Knowledge Management System (CMKMS) was then developed to empirically evaluate and confirm the effectiveness of the proposed framework. The CMKMS maintains current and historical versions of concept maps, and it also records the discussion/cooperation history of the concept map developing process. Finally, in the present study, proposals were made as to how biology teachers can apply the best practices in biology education research. Recording the evolution process of a concept map allows a teacher to observe the concept map as it is being created/modified, by whom, at what time, and with which modifications. This enables a teacher (1) to guide students in the appropriate developing direction of the concept map in a timely manner, and (2) to help students improve their learning performance and to adjust to the cooperative learning process. Moreover, from the perspective of students, the CMKMS can be applied in practice to measure their learning quality and to enable them to evaluate alternative concept linking and the construction of viewpoints through the maps drawn either by teachers or by other students. This could provide another valuable format for the evaluation of different teaching styles for similar biology curricula.

2. Literature review

2.1. *E-learning in biology teaching*

Technology advances have allowed educators to create lessons that will interest and engage students during the learning process. E-learning is defined as the use of any of the new technologies or applications in the service of learning or learner support (Sangrà, Vlachopoulos & Cabrera, 2011). When a new technology is introduced, earlier studies focus on demonstrations of efficacy, followed by studies comparing the new technology against the old. These comparisons are important because e-learning can make a significant difference: to how students learn; how quickly students master a skill; how easy it is to study; and, equally important, how much the students enjoy learning.

Recent research provides reassurance that e-learning is better than nothing and similar to traditional instruction. E-learning has been used very effectively in biology classes to enhance the traditional forms of teaching and administration (Efferth, 2013; Rajkumar & Imad, 2012; Wang, 2010). Owusu, Monney, Appiah and Wilmot (2010) investigated the comparative efficiency of computer-assisted instruction (CAI) and conventional teaching methods in biology for senior high school students. The results indicated that even though the CAI group did not perform better than the conventional approach group, the students in the CAI group perceived CAI to be interesting when they were interviewed. Quinnell, May and Peat (2012) used hierarchical cluster analysis to survey freshman students' conceptions of biology. By comparing cluster membership at the start and end of the semester, they were able to assess whether students (1) maintained their incoming approach to study and conception of the discipline of biology, and (2) whether certain Learner Profiles were more persistent than others.

Teaching through traditional passive lectures makes learning difficult, conceptual materials more difficult, and should be replaced with more interactive lectures coupled with more practical inquiry-based and small group-learning sessions to increase student engagement and interest in the subject. Flowers, White and Raynor (2012) have suggested that a reduction in the transactional distances for online learning may positively influence retention rates and student learning outcomes of biology courses. Interactive computers could be used to give students an alternative to writing as a form of active participation in knowledge-building. E-learning enables students to communicate through networks of communities practicing a cybernetic approach that embraces change and innovation as an inherent property of the system. At the same time, we need a way to create a common infrastructure of agreed standards of interoperability that will enable, rather