A Framework of Active Learning by Concept Mapping[*]

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This study presents a student-centered teaching model based on concept mapping and problem-solving. The concept map is used as a tool to develop curriculum and evaluate teaching performance. Case-based teaching was implemented on the course of building energy conservation. The results of this study, which include teaching plans, evaluation tools, and auxiliary software, were shown in this paper.

Keywords: concept map, active learning, case-based teaching, problem-based learning, energy education

Introduction

The application of e-learning to improve traditional teaching and construct an effective learning environment has become an inevitable trend recently. With the rapid development of information technology, the scope of e-learning can be divided as: Web-based learning, computer-based learning, virtual classroom, and digital. They are delivered via the Internet, Intranets, audio, and videotape, satellite broadcast, interactive TV and CD-ROM, as defined by ASTD (American Society of Training Development) (2012).

Although the CAI (computer-assisted instruction) can improve the insufficiency in traditional instruction, not all teachers can make the most of it in the classroom. Most of the teachers use the computer to assist their activity in the classroom. This method is only to use the computer to convey knowledge. It is a teaching with the characteristics of one-way, teacher-centered learning from computer. So, it can be called in the stage of "use computer to learn". In this condition, the students are in a passive learning state rather than being the leader of learning.

Many courses labeled as CAI are actually "learning from computer" in essence. Some so-called e-learning Websites for CAI purpose just store digital teaching materials like lecture notes, solutions, tutorial videos, and other learning resources that are available for download. These information-only Websites, which lack interactive and diagnostic function, provide a one-way delivery of knowledge. Resorting to these simplified CAI resources may bring limited improvement to teaching efficiency. From the viewpoint of constructivists, it is necessary to develop a student-centered pedagogy to engage students in meaningful learning. A well-designed CAI should establish an interactive learning environment where the students can "use computer to learn" to construct their own knowledge.

Huang (2002) developed an online virtual physics laboratory (Demolab), where various experiments of

physics or physical phenomena were demonstrated by computer animation, which allows users to modify physical parameters to simulate different cases. However, similar efforts often fall into the area of natural science, such as the biology, physics, and chemistry, but few into applied science or engineering. Therefore, an attempt is made to establish an e-learning environment based on the theory of constructivism to improve traditional teaching methods and CAI. An engineering course of building energy conservation is also chosen as a case for the study.

The traditional teaching methods focus on memorizing mathematical equations instead of providing basic concepts of natural science. The goal of this study is to improve traditional pedagogy by proposing a new Web course. The computer can be used as a tool for students to search for knowledge, build analytical models, and solve problems. This study presents an e-learning environment based on the theory of constructivism. The works to achieve such a system need to design: (1) an auxiliary system to guide students to construct knowledge in applied science; (2) a course of "building energy conservation" that will be taught by case-based teaching method; (3) an auxiliary system to lead students to active participating in discussion; and (4) a Web-based system to engage students in interactive learning.

Literature Review

Chou (1999) pointed out that any new learning environment, instructional media, and applications tools should based on learning theory in order to achieve learning outcomes. Thus, how to use information technology to create an e-learning environment with modern teaching theory is more important, even e-learning has many advantages. Chang (1999) considered that constructivism emphasized the view of student-centered learning which leads in the present development of learning technology. Chang, Sung, and Chen (2002) have divided the information education into three stages, such as CAI, implementation of computer course, and teaching with information technology.

Sung and Ou (2002) applied the technique of virtual reality and constructivism theory to establish a Web-based learning environment by CAD (computer-aided design) named WebDeGrator to simulate the interactive learning system of computer graphics. Savelsbergh, de Jong, and Ferguson-Hessler (2000) used CAS (computer algebra system) and mathematics as tools to construct an interactive learning system of physics which emphasizes that student should construct their knowledge through the actual process of problem-solving.

Concept mapping is a technique to visualize the relationship of each concept by mapping, which includes the knowledge representation theories, constructive learning, and the meaningful learning (Chang, Sung, & Chen, 2001). It presents a clear understanding of the relationship between each concept. Chang, Sung, and Chen (2001) have applied the concept mapping theory to design two systems of biology in senior high school for concept building: The first one is construct-by-self, and the second one is construct-on-scaffold.

There has been much research effort devoted to the performance of concept mapping (Coffey & Cañas, 2003; Derbentseva, Safayeni, & Cañas, 2004; Leake et al., 2004; Novak & Cañas, 2007; Derbentseva et al., 2006). Most of the researches are focused on the applicability of concept mapping from a theoretical aspect. Only a few attentions were paid to the technology to implement concept mapping. For example, Cañas, Carvalho, Arguedas, Leake, Maguitman, and Reichherzer (2004) developed a program called C-map tools for knowledge modeling in a sharing environment. They also proposed a way to construct Web-based concept map using data mining technique (as cited in Cañas & Novak, 2008). Coffey et al. (2003) also investigated the learning environment organizer system, LEO, to support computer-mediated instruction.

Design Procedure

Step 1: Problem Identification

The first stage is to use a problem-solving model to activate student learning by raising questions. In the stage, students are requested to conduct observation and reflection. It is not necessary for teacher to be involved in the thinking process of students. Providing a free environment for the student, the teacher does nothing but gives students the case currently studied.

Step 2: Concept Mapping

In this stage, students are expected to use concept mapping technique to construct knowledge as well as to find possible paths to solve the problem. The concept map is a hierarchical structure. Establishing a concept map is the first step to develop curriculum. In this study, learners will be asked to make their own concept maps, which is the first step of learning as well as the basis for follow-up study.

Step 3: Study Advisor

The teacher plays a role of study advisor in students' learning process. The computer system can take the role of a teacher, so it will propose some problems to help the students to reflect on the issue currently studied after they finish concept maps. These problems can be used to make sure whether the knowledge constructed based on their own studies can lead to solution or not. It is like a diagnosis providing a self-constructed process to examine completeness of knowledge content.

Step 4: Interactive Learning

The stage is to establish an interactive learning system to guide students to actively participate in learning process. There are two stages in this system. The first is a demonstration of example, and there is a prompting interface to guide the students to solve the problem. The interface provides analysis procedures, governing equations, and correct answers. The computer system will also give a suggested answer for the students. If students fail to use the prompt to solve problems, then the system will lead them back to the previous system to review what need to be reinforced.

Step 5: Case-Based Teaching

The case-based teaching is the stage that teachers guide students in the teaching case and integrate related concepts. The curriculum used in case-based teaching is provided by the curriculum developer. The teacher has to offer necessary assistance to students according to a teaching plan.

Step 6: Final Evaluation

The final stage of this teaching model is to use concept map to establish an evaluation tool for teaching. A complete concept map of case-based teaching can be used to design an evaluation tool by the curriculum developer.

Results

Teaching Case and Raised Problem

The teaching case and raised problems for the case are elaborated as follows. The course of energy conservation involves areas of thermal dynamics, material science, and applied mathematics. The case selected for case-based teaching can be either a real case or a designed case which actually reflects the experience of real world.

The current cases are specified as "Saving electricity cost by half through energy conservation" and "What is climate change", which are the open questions without a common solution. In the first case, the teacher requests the students to review their monthly electric bills while asking them a leading question: How to save the electricity cost by half. The knowledge that students need to answer the question involves various calculations, such as the conversion of electrical appliances and electricity consumption rates. The authors will help the students to know the basic concept about the method of power saving for residential place.

In the second case, the climate change can be discussed by the inquiry-based questions, as shown in Table 1. This problem helps the students to construct their ability to identify the problems.

Table 1

The Inquiry-Based Questions of "Climate Change"

Item thinking	Factual evidence	Answer
Identification	The Earth's climate is changing: (1) Assumption 1: It is mainly comes from methane gas emissions; (2) Assumption 2: It is mainly comes From carbon dioxide gas emissions.	(A) Assumption 1 exists; (B) Assumption 2 exists; (C) Both assumptions 1 and 2 exist; (D) Both assumptions 1 and 2 do not exist.
Induction	The surface temperature gradually increased in the past three years? (1) Inference1: The Earth's climate is changing; (2) Inference 2: The Earth's climate may be changing.	(A) Inference 1 is reasonable; (B) Inference 2 is reasonable; (C) Both inferences 1 and 2 are reasonable; (D) Both inferences 1 and 2 are not reasonable.
Interpretation	A. The earthquake could trigger tsunami; B. Earthquake may be a movement from the Earth's plates. (1) Conclusion 1: The Earth's plate movement may lead to tsunami; (2) Conclusion 2: Tsunami may come from the movement of the Earth's plate or from the impact of the earthquake.	(A) Conclusion 1 can be set up; (B) Conclusion 2 can be set up; (C)Both conclusion 1 and conclusion 2 can be set up; (D) Both conclusion 1 and conclusion 2 cannot be set up.
Explanation	A. Infectious diseases have been increasing in recent years. B. There is a slight temperature increase in the last three years. (1) Explanation 1: The temperature increase caused the increase of infectious diseases; (2) Explanation 2: This is because the increase of infectious diseases which caused a slight increase in temperature.	(A) Explanation 1 is reasonable; (B) Explanation 2 is reasonable; (C)Both explanation 1 and explanation 2 are reasonable; (D) Both explanation 1 and explanation 2 are not reasonable.
Argument	Based on the observation, the icebergs of the arctic are melting, Therefore, should we sign the Kyoto Protocol or not? (1) Argument 1: Yes, if we do not sign the Kyoto protocol, then it will not be able to control the greenhouse gases; (2) Argument 2: No, to reduce the greenhouse gas emissions do not necessarily to sign the Kyoto protocol.	(A) Argument 1 is strong; (B) Argument 2 is strong; (C) Both argument 1 and argument 2 are strong; (D) Both argument 1 and argument 2 are weak.

Student's Response to Concept Maps

In this stage, students must attempt to find possible solutions to this case without using prompt; the system will give exercises to students and let them find the answers. The answers provided by the system can be used by the students to compare. By the philosophy of "learning by doing", the students can construct their own knowledge of energy conservation. The students have to explain the relationship among different concepts. And from this system, it is integrated into a systematic knowledge of energy conservation. Figure 1 is the typical example of the response from the students. Each figure was drawn by the students.
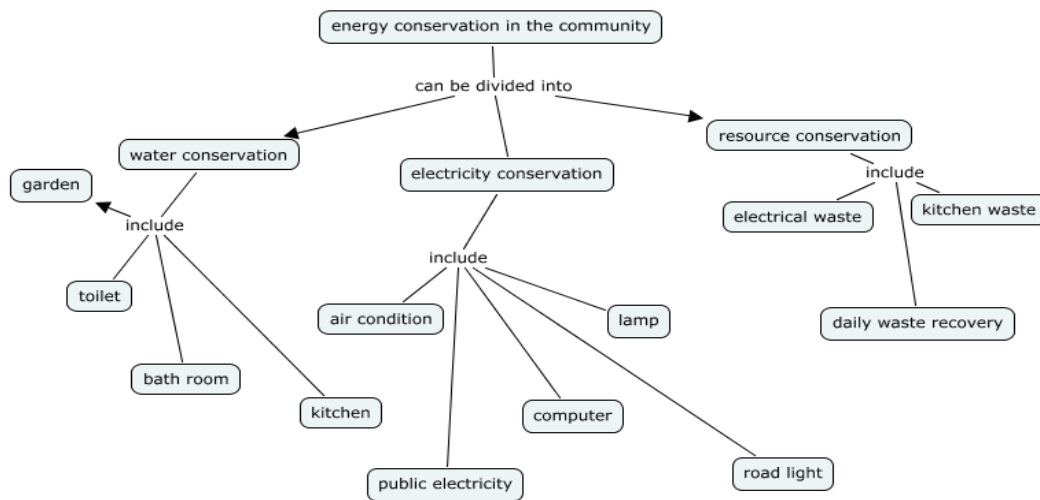
Figure 1. A simplified concept map for energy conservation in different teaching cases.

Web Environment and Course Design Example

An e-learning system developed based on the theory of constructivism is shown in Figure 2. A whole semester course was shown in Table 2.
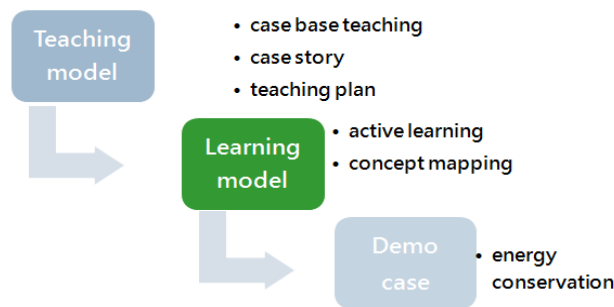

Figure 2. Web-environment of this system.

A course of "climate change" designed by case-based teaching and inquiry model was shown in Table 2. As shown in Table 2, teachers can use the way of the five critical thinking processes to teach students. The five categories of critical are identification of assumptions, induction, interpretation, explanation, and argument evaluation.

Table 2

Designed "Climate Change" Curriculum by Inquiry Learning Method

Course module	Questioning approach by inquiry-oriented learning
1 Global warming	Do you believe in global temperatures rising?
2 Sea-level rise	Do you believe that Taiwan's sea level is rising?
3 Melting of glaciers	Do you believe that the glaciers of the Arctic have been melting?
4 El Nino	Do you think that the abnormal weather of the earth is more and more obvious?
5 Typhoon Disaster	Do you think that the typhoon disasters and climate change do have the relationship?
6 Landslides	Do you think that landslides and climate change have the relationship?
7 Tsunami	Do you think that Fukushima tsunami and climate change are related?

(Table 2 continued)

8 Earthquake	Do you think that the climate change will cause more earthquakes?
9 Greenhouse effect	Is Carbon dioxide the cause of climate change?
10 Environmental pollution	Will climate change cause more serious environmental pollution?
11 Disease	Will climate change make more disease?
12 Energy	Can energy savings really make climate change slow down?
13 Resources	Can resources conservation make climate change slow down?
14 Dust storm	Does dust storms relate with the climate change?
15 Planting trees	Is it really possible to prevent climate change variety of tree?
16 Renewable energy	Is it possible to reduce global warming by using the renewable energy?

Evaluation Tools

To evaluate teaching performance, the number of correct answer on concept map was counted. The teaching performance can then be formulated by the following Equation (1) as:

$$\eta = C/T \tag{1}$$

where C is the number of correct answer, and T is the number of questions on the concept map.

The concept map offers a convenient way to evaluate teaching performance. A comparison of the difference among different teaching models can be made based on the following Equation (2):

$$P = P_A - P_B$$
$$= \sum_{i=1,n} \frac{\eta_A(i)}{n} - \sum_{i=1,n} \frac{\eta_B(i)}{n} \tag{2}$$

where P is the difference between teaching performance of model A and B, P_A is the teaching performance of model A, and P_B is the teaching performance of model B. $\eta_A(i)$ is the percentage of correct answer of the ith student by model A, $\eta_B(i)$ is the percentage of correct answer of the ith student by model B, and n is the total number of students.

Conclusions

This study presents a new teaching model using concept map for teaching and evaluation. It is a student-centered instruction through case-based teaching for the course of building energy conservation. The teaching procedure can be separated into three stages: The first stage is mainly to direct students to identify problems by observation and to apply concept mapping technique to establish their own problem-solving strategy. The second stage requests curriculum designers to establish an auxiliary system to guide students to construct their knowledge about energy conservation. An evaluation is also conducted at this stage. The third stage involves case-based teaching by teachers to help students integrate all the concepts they have learned.

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