Chapter III

An Efficient and Effective Approach to Developing Engineering E-Training Courses

Judy C.R. Tseng
Chung Hua University, Taiwan

Wen-Ling Tsai
Chung Hua University, Taiwan

Gwo-Jen Hwang
National University of Tainan, Taiwan

Po-Han Wu
National University of Tainan, Taiwan

ABSTRACT

In developing traditional learning materials, quality is the key issue to be considered. However, for high technical e-training courses, not only the quality of the learning materials but also the efficiency of developing the courses needs to be taken into consideration. It is a challenging issue for experienced engineers to develop up-to-date e-training courses for inexperienced engineers before further new technologies are proposed. To cope with these problems, a concept relationship-oriented approach is proposed in this paper. A system for developing e-training courses has been implemented based on the novel approach. Experimental results showed that the novel approach can significantly shorten the time needed for developing e-training courses, such that engineers can receive up-to-date technologies in time.
INTRODUCTION

In recent years, technologies have advanced at an amazingly fast pace; therefore, almost all of the high technical engineering knowledge and skills need to be updated or replaced with very high frequency; for instance, the engineering knowledge of the semiconductor and the electronics industries. One of the most important management strategies of the modern enterprises is to keep on improving the knowledge and skills of engineers via frequent training and practice. Take Motorola, for instance. The company budgets $120 billion annually for conducting employee training programs. American IDC (International Data Corp.) predicted that the e-learning market all over the world will triple in the next two years, and will share 40% of the entire training market.

The advantages of e-learning have been documented by researchers (Hwang 1998, 2002; Sun & Chou, 1996), including the feasibility of anytime and anywhere education, the availability of various learning styles, the reduction of education cost, the reusability of well-constructed and well-managed subject material modules, and so forth. Most of the engineering training programs that enterprises scheduled were designed and planned within their own organizations. Senior and experienced engineers of the organizations usually play the role of training instructors and course designers. That is, the responsibility of sharing experiences, skills, and knowledge heavily rely on those experienced engineers. As most of the engineers are not trained for tutoring, it is usually time consuming for them to design learning materials, and the training programs for those up-to-date technologies are often seriously delayed.

To cope with this problem, we shall propose a concept relationship-oriented approach to assisting the engineers in developing e-training courses. A course design system, CRETS (Concept Relationship-based Engineering Training System), has been developed based on the novel approach. Experiment results showed that the novel approach can assist experienced engineers to design quality e-training courses efficiently, and hence inexperienced engineers can receive up-to-date information of those rapidly advanced technologies.

RELEVANT RESEARCHES

Engineering training is not only a frequent activity but also a heavy burden to enterprises, owing to the rapid advance of new technologies. As engineering courses need to be replaced or updated frequently, researchers have attempted to apply e-training technology to efficiently and effectively develop and manage the learning materials and the training process. For example, a system that can assist in organizing system knowledge and operational information to enhance operation performance was proposed by Vasandani and Govindaraj (1991, 1995); moreover, a system that automatically determines exercise progression and remediation during a training session based on past student performance was presented by Gonzalez and Ingraham (1994). Meanwhile, various techniques and tools for developing intelligent tutoring systems have also been proposed, including the use of a neural networks technique to model student behaviors in the context of intelligent tutoring systems (Harp, Samad, & Villano, 1995), planning methods, consistency enforcement, objects and structured menu tools to construct intelligent simulation-based tutors for procedural skills (Rowe & Galvi, 1998), and technology for detecting online status of students to establish interactive intelligent tutoring system (Hwang, 1998; Giraffa, Mora, & Vicari, 1999). It can be observed that such e-learning or e-training systems have been widely applied to schools and industries recently (Ozdemir & Alpaslan, 2000; Hwang, 2002).

E-training approach has shown its superiority, such as the fact that skills and knowledge
of experienced engineers can be retained and transferred to new employees, the learners are allowed to receive training courses without being limited by space and time, and so forth. However, the rapid advance of engineering technologies also reveals several problems of applying them, and one of the most challenging issues is to efficiently design quality learning materials to keep the skills and knowledge of senior engineers up-to-date and to train the new engineers (Tseng, Tsai, & Hwang, 2005).

Engineering training program contents are usually designed and planned by senior or experienced engineers. The training contents focus mainly on realistic needs of the industry. The procedure for designing a training course usually consists of several stages, A0–A10, where A0 is the preparation stage, A1 is the stage to determine the training topic, A2 is the stage to define course outlines, A3 is the planning and analyzing stage, A4 is the information collecting stage, A5 is the course design stage, A6 is the purchase request stage, A7 is media design stage, A8 is the media making stage, A9 is the testing stage, and A10 is the training stage. Usually it will take nine to twelve months to complete an e-training course unit, which is obviously unacceptable for practical needs, especially for timely needs of new engineering skills.

To cope with this problem, a more efficient and effective approach for developing e-training courses is needed, and the relationships among those concepts to be learned seem to provide a natural way for engineers to represent their experiences and knowledge. In many pedagogic and psychological literatures, “conception” is defined as the common attributes of same category and the objects or events which are given the same names (Ausubel, 1963, 1968; Ausubel, Novak, & Hanesian, 1978). During tutoring, students learn new concepts and new relationships among previously learned concepts, and this knowledge can be represented as a concept map (McAleese, 1998). Salisbury indicated that learning information, including facts, names, labels, or paired associations, is often a prerequisite to efficiently performing a more complex, higher level skill (Salisbury, 1998). For example, the names and abbreviations of chemical elements and their atomic weights must be thoroughly learned to comprehend scientific writings or chemical formulae. Such concept relationship-oriented approaches have been used in education, policy studies, and the philosophy of science to provide a visual representation of knowledge structures and argument forms. They provide a complementary alternative to natural language as a means of communicating knowledge (Shaw & Gaines, 1992).

In the past decade, the notations of “concept” and “concept relationship” have been applied to the development of various systems or tools to support large volumes of multimedia materials generated in a variety of contexts, such as knowledge acquisition (Gaines & Shaw, 1992), large-scale project support (Gaines & Norrie, 1994), and diagnosis of student learning problems (Hwang, 2003; Hwang, Hsiao, & Tseng, 2003). Some researchers have attempted to develop a general visual language technology supporting customizable interactive concept maps (Gaines & Shaw, 1993) and semantic networks (Gaines, 1991). Such concept relationships may be used as stand-alone documents or embedded as interactive pictures in active documents (Gaines and Shaw, 1993); that is, it is an open architecture, and user interaction with the concept relationships may be programmed to initiate any available operation on the host system. Moreover, each set of concept relationships can be linked to other sets for retrieval purposes, and may be used to retrieve, play, and edit multimedia materials via remote access.

Representing knowledge as concept relationships is helpful to people in restructuring prior knowledge as well as organizing new experiences; that is, it is an effective way to represent knowledge and the learning process (Okebukola, 1984; Roth & Roychoudhury, 1992, 1993, 1994). In the following sections, a concept relationship-oriented
environment for developing quality e-training courses is presented and some experimental results are given to depict the effectiveness of the novel approach.

CONCEPT RELATIONSHIP-ORIENTED APPROACH FOR DEVELOPING E-TRAINING COURSES

In this section, we shall present an engineering training material development environment, CRETS (concept relationship-oriented engineering training system). As shown in Figure 1, CRETS consists of a course management module, a concept management module, a course-concept relationship management module, a concept content management module, and a Delphi-based negotiation module.

Course management module is used to define the course profile, including title and description of the course, and the names of the authors. Concept definition module provides an interface for the authors to define a set of concepts that are relevant to the course. Concept relationship management module can assist the authors in describing the relationships among the concepts. Subject material management module allows the authors to import subject materials from other tools or edit the existing subject materials.

Moreover, a Delphi-based negotiation module is provided to assist the authors in making consistent decisions in defining concepts to be learned and the relationships among concepts if there are more than five engineers participating in creating new learning materials. Delphi has been defined by Delbecq, Ven, and Gustafson (1975) as “a method for systematic solicitation and collection for judgments on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses,” which contains three features: (1) anonymous group interaction and responses, (2) multiple iteration or rounds of questionnaires or other means of data collection with researcher-controlled statistical group responses and feedback, and (3) presentation of statistical group responses (Murry & Hammon, 1995). Figure 2a depicts the questionnaire of the Delphi-based negotiation module.

To properly translate the course structure defined by the authors to SCORM or HTML format, five types of concept relationships are defined to efficiently represent the layout of the course structure, that is, “subclass,” “relevant subject,” “application,” “sequence,” and “reference”:

![Figure 1. System structure of CRETS](image)

- Course structure generating module
- Subject material generating module
- Delphi-based Negotiation Module
- Concept definition module
- Concept relationship management module
- Subject material management module
- Course structure & row materials database
- Teaching material database
• **SUBCLASS**: is a kind of relationship. If concept $C_i \subset C_j$, we say that $C_i$ is a subclass of $C_j$. In generating the subject materials, the main (super) concept will be treated as the upper level of selection item, and the subconcepts will be treated as the lower level concepts. In an e-training Web page, a subclass represents a “subitem” or “subunit” linking relationship, and will be located in the menu area as shown in the illustrative example given in Figure 2b.

• **RELEVANT SUBJECT**: is an instance of relationship. If $e_k \in C_j$, we say that $e_k$ is a subject material belonging to $C_j$. That is, the lower level concept $e_k$ is an illustrative example or a part of the upper level concept $C_j$. In the e-training Web page, the lower level concepts are treated as the presentation materials of the upper level concept that is usually depicted as a selection item. In this case, a hyper link from selection item $C_j$ to presentation material $e_k$ is generated to represent such a concept relationship. An illustrative example of the relevant subject relationship is also given in Figure 2.

• **APPLICATION**: possible applications or demonstration examples of some technique or concept. If $e_k \rightarrow e_r$, we say that $e_r$ is an application of $e_k$. That is, a hyper link is generated to link from presentation material $e_r$ to $e_k$. Figure 3 shows an illustrative example of applying the application relationship to the presentation material of Figure 2.

• **SEQUENCE**: a set of ordered concepts that forms a sequential description to introduce a technique or concept. If $e_1 < e_2 < \ldots < e_k < \ldots < e_n$, we say that $e_k$’s form a sequence relationship. Therefore, a sequential presentation for the lower level concepts will be given if the corresponding upper level concept is selected. An illustrative example of the sequence relationship is given in Figure 2.

• **REFERENCE**: a link from a concept to another concept. The reference relationship enables the learner to jump from one learning material to another. In Figure 3, there are several reference links, such as the “RNA,” “Protein,” “Carbohydrate,” and “Fat” icons.

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**Figure 2a. Questionnaire of the Delphi-based negotiation module**

![Questionnaire of the Delphi-based negotiation module](image-url)
Figure 2b. Web page of the e-training course with four types of concept relationships

Figure 3. Illustrative example of the application relationship
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It can be seen that those five types of relationships enable the authors to construct learning materials with a variety of different structures, including the hierarchical and the mesh structures.

DEVELOPMENT OF CRETS

CRETS was implemented on the Windows Server 2000 environment. In the following subsections, a practical application is used to demonstrate the functions of CRETS. The training course is titled “nano material and nano structure,” which is designed for training inexperienced engineers in an electronic company.

Traditional Course Structure for “Nano Material and Nano Structure”

Traditionally, this course was structured as three chapters. The first chapter, titled “Nano Self-Assembly and Bio-Self Assembly,” includes the concepts of definition of nano self-assembly, fundamental structure unit of self-assembly, formation of self-assembled order structure, and recognition biomolecule self-assembly. The second chapter, titled “Physical Self-Assembly” includes the concepts of definition of physical self-assembly, Electrostatic directed self-assembly, self-assembly directed by octadecyltrichlorosilane hydrogen bonding, LB film self-assembly, micelle self-assembly, copolymer self-assembly, supramolecular self-assembly, and dendrimer self-assembly. The third chapter, titled “Chemical Self-Assembly,” includes the concepts of formation of self-assembled nanointerface, quantum dot self-assembly, and self-assembly of charged powder. The concepts within each chapter have been designed as sequential units or sections.

Concept-Based Course Structure for “Nano Material and Nano Structure”

With the guidance of CRETS, experienced engineers can structure the concepts of a training course via a systematic step-by-step procedure. Figure 4 shows the first step of constructing the course.

Figure 4. First step: Enter title, description, and author name of the course
training course, to enter the title and description of the course and the name of the author. As shown in the example, the title of the course is “Nano Material and Nano Structure Self-Assembly.”

The second step is concerned in the management of the concepts in the course. The author can define new concepts or edit the existing concepts via this interface. Figure 5 shows the concepts that are relevant to the course. The concepts given in this step include nano self-assembly, bio-self-assembly, chemical self-assembly, physical self-assembly, fundamental structure unit of biosystem, protein self-assembly, structure of cell membrane, recognition biomolecule, biomolecular self-assembly, nanostructure self-assembly, electrostatic directed self-assembly, self-assembly directed by octodecyltrichlorosilane hydrogen, LB film self-assembly, micelle self-assembly and MCM-41, copolymer self-assembly, supramolecular self-assembly, dendrimer self-assembly, biomedical, formation of self-assembled nanointerface, quantum dot self-assembly and self-assembly of charged powder.

The third step is to conduct the management of the relationships among the concepts given in the previous step. Figure 6 shows the CRETS interface for selecting the concepts that are relevant to chemical self-assembly (the upper level concept). The relationship is “relevant subject” and the selected lower level concepts include fundamental structure unit of biosystem, protein self-assembly, structure of cell membrane, recognition biomolecule, biomolecular self-assembly, and nanostructure self-assembly.

After all of the relationships among the concepts have been defined, CRETS system generates a concept relationship graph as shown in Figure 7, such that the author of the course can review the correctness of the relationships already defined. In the graph, each node represents a concept and each link represents a relationship between two concepts. Each type of relationship is depicted in a different color. It can be seen that the graph has presented a natural way for designing the linking structure of a Web-based teaching material.

After defining the course structure, the author is asked to provide the subject contents for each
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Figure 6. Third step: Conduct the management of the relationships among concepts

![Image of a concept relationship graph](image1)

Figure 7. Illustrative example of a concept relationship graph generated by CRETS

![Image of a concept relationship graph](image2)
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The subject materials can be imported from other Web page development tools, such as Front Page and Dream Weaver, or developed by using the CRETS editor. The subject contents are presented in HTML format. Figure 8 shows an illustrative example of editing subject contents the lower level concept of protein self-assembly that is relevant to the upper level concept ‘bio-self assembly in the course “Nano Material and Nano Structure Self-Assembly.”

After completing the subject contents, the final learning materials are saved by clicking the “Finish” button (see Figure 9). To facilitate the usability of the generated learning materials, CRETS supports two types of teaching material formats, SCORM format and HTML format. Figure 10 demonstrates the learning materials generated by CRETS in SCORM format.

**EXPERIMENTS AND EVALUATION**

To evaluate the performance of the novel approach, an experiment has been conducted on two engineering training courses, “Electricity Analysis” and “Heat Management for Electronic Products.” Four experienced engineers (labeled E1, E2, E3, and E4) participated in the experiment.

In the first phase of the experiment, E1 and E2 were asked to work together to design the learning material for the “Electricity Analysis” course by using traditional tools, while E3 and E4 were asked to design the same teaching material by using CRETS. The actual working hours accrued by both groups of the engineers designing the learning materials were recorded. After both of the groups completed the design process, the engineers were asked to review the work done by the other group to ensure the quality of the developed learning materials. In the second phase of the experiment, both of the groups were asked to design the learning material of the “Heat Management for Electronic Products” course. This time E1 and E2 were asked to use CRETS, and E3 and E4 were asked to use traditional tools.

Tables 1 and 2 show the experiment results. It can be seen that no matter which one of the groups employed CRETS, the time needed for
Figure 9. Interface for finishing the course content design and generating learning materials

Figure 10. Learning materials in SCORM format
designing the learning materials was significantly reduced. In designing the learning material of the “Electricity Analysis” course, working hours were reduced by 50% by using CRETS; in designing the teaching material of the “Heat Management for Electronic Products” course, working hours were reduced by 51%. Consequently, we conclude that the concept relationship-oriented approach is helpful to those experienced engineers in shortening the time needed for design quality e-training materials.

Note that in this experiment, there are only two engineers in each group; therefore, it is not necessary to employ the Delphi-based negotiation module. When many engineers are asked to work together in designing a large scale of learning materials, the negotiation module might be helpful to them in making consistent decisions on the course structure, which need to be proven by conducting further experiments in the future.

### Table 1. Experiment on “Electricity Analysis” course

<table>
<thead>
<tr>
<th></th>
<th>Time required to design the e-training material</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1&amp;E2 - Traditional Method</td>
<td>96 hours</td>
</tr>
<tr>
<td>E3&amp;E4 - CRETS</td>
<td>48 hours</td>
</tr>
<tr>
<td>Time saved (%)</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Table 2. Experiment on “Heat Management for Electronic Products” course

<table>
<thead>
<tr>
<th></th>
<th>Time required to design the e-training material</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3&amp;E4 - Traditional Method</td>
<td>85 hours</td>
</tr>
<tr>
<td>E1&amp;E2 - CRETS</td>
<td>42 hours</td>
</tr>
<tr>
<td>Time saved (%)</td>
<td>51%</td>
</tr>
</tbody>
</table>

**CONCLUSION**

This paper proposed a concept map-oriented approach to developing e-training courses. An e-training course design system, CRETS, has been implemented based on the novel approach. Experiment results have shown that our approach can significantly shortened the time needed for developing e-training courses, such that naive engineers can receive new technologies from experienced engineers as early as possible.

Currently, CRETS has been adopted by an electronics company in Taiwan to preserve experiences and knowledge of experienced engineers and to train the inexperienced engineers and operators. In the future, we plan to extend the functions of CRETS, so that several experienced engineers can work together to design quality e-training materials via network communications. In addition, large-scale experiments are going to be conducted to more precisely evaluate the performance of CRETS.

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