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Viewpoint: Using Information Technology to Enhance Engineering Education*

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This paper reviews three learning models and information technologies that can be used to support the effective application of these learning models in engineering higher education. The effectiveness of an information technology is analysed through the appropriateness of the technology in supporting a particular learning model. The mapping of information technologies to learning models identifies technologies in which engineering schools should invest in order to improve their educational environment and quality.

INTRODUCTION

IN MANY engineering schools the blackboard, chalk and overheads still remain as the primary teaching technologies, even while the merits of information technology to improve efficiency and quality of communication are widely recognized by engineering professions and researchers. As engineering schools experience increased competitive pressures in maintaining students numbers and teaching quality, information technology becomes an area that schools should explore in order to improve educational environments and qualities.

However, although computer hardware and software have already permeated into engineering classrooms in many universities, information technology is still largely used as a functional tool to support technical topics of engineering subjects. It appears that there is clearly a lack of understanding and guidelines of how information technology can be applied to achieve teaching and learning improvement. In order to address these issues, this paper examines models of learning that are commonly advocated, and discusses how information technologies can be interwoven with the learning models to improve engineering education.

THREE MODELS OF LEARNING

A review of the literature and research in the area of cognitive learning reveals that there are three predominant models of learning processes:

1) the objectivist model of learning;
2) the collaborative model of learning;
3) the constructivist model of learning.

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These three models are discussed in detail as follows.

The objectivist model of learning

The objectivist model of learning is based on Skinner's stimulus-response theory: learning is a change in the behavioral disposition of an organism that can be shaped by selective reinforcement [1]. This model assumes that there is an objective reality, and the goal of learning is to understand the reality and modify behavior accordingly [1]. The purpose of teaching is to facilitate the transfer of knowledge from an expert to learners. During the learning process, the mind is to act a mirror of the objective reality rather than as an interpreter of the reality [1]. In other words, learning is a process of uncritically absorbing objective knowledge of the reality. The objectivist model is still seen as the most widely used model in teaching well-established factual or procedural knowledge of engineering. This model is extensively practiced in engineering higher education. Instructors convert the reality into abstract or generalized representations that can be transferred and recalled by students. The instructor is in control of the material and pace of learning. The efficiency of learning is assessed by the instructor via questions and examinations.

The collaborative model of learning

The collaborative model of learning views learning as a social process that occurs more effectively through co-operative/collaborative interpersonal interactions [2]. This model assumes that knowledge is formulated as it is shared, and the more it is shared by individuals, the more it is learned. Although the major goal of collaborative learning is the sharing of understanding through interaction with other individuals, it implies that communication, listening and participation are key factors in improving learning efficiency. Studies [3] show that a group of students are more likely to attain the same (or similar) level of understanding and mastery through collaborative learning efforts, while such results are not achievable through individual learning efforts.

In a collaborative learning environment, the role of teaching is to maximize the sharing of information and knowledge among learners. Through conversations, discussions and debates, participants expose their interpretations and resolutions to problems. This leads to active development of meaning and understanding. Numerous studies have demonstrated the superiority of collaborative learning over traditional objective learning [4]. However, a challenging issue is to implement a collaborative assessment strategy. Traditional competitive assessment strategies are no longer applicable in a collaborative learning environment. They do not encourage the sharing of information and may disable collaborative learning: a learner may be motivated to withhold knowledge that would otherwise be shared with peers.

The constructivist model of learning

The constructivist model of learning emphasizes learning process as an active, goal-oriented, and constructive process [1, 5]. This model advocates that knowledge is created by learners, rather than transmitted to learners. The model assumes that each individual firstly constructs his or her interpretation of an objective world, and gradually departs from a world of personal experience to the formation of abstract concepts which represent the real world [6].

According to the constructivism, individuals perform better in learning when they are forced to discover things themselves rather than when they are instructed. In a class, the teacher serves as the creative mediator of a knowledge construction process to help learners construct their own perception of reality. However, in undergraduate engineering education, the constructivist model often limits students to searching for the pre-ordained engineering knowledge that could be more efficiently transmitted via the instructor. This is particularly true in teaching classical engineering subjects. For postgraduate teaching, it is found that greater benefit results when learners are engaged in a process of constructing new engineering knowledge through scientific exploration [7]. Therefore, a constructivist model is more suitable for postgraduate learning rather than undergraduate education.

In summary, the objective model emphasizes that the instructor should be in control of the learning environment, and learning is dissemination of knowledge via abstract representation of the reality. Collaborative model relinquishes the control of the learning environment to learners. Learning is a process of sharing information so that disparate and discontinuous points of view can be evolved into consistent conceptions. Constructivism assumes that the learning environment should be controlled by an individual learner. Learning is the creation of knowledge.

Empirical studies [4, 8, 9] show that no particular model is the best approach to all learning circumstances. Which model will be more appropriate is dependent on the course content, student experience, maturity and intelligence. However, the instructor should be aware of the difference of the models and be able to choose a model for a given learning environment. In particular, the instructor should understand how information technologies can be adopted to achieve the effective use of the learning models in engineering education.

MAPPING INFORMATION TECHNOLOGIES FACILITATING TO LEARNING MODELS

Central to the discussion in this section is how information technologies can be adopted to enhance learning efficiency. In an IT-enabled learning environment, the role of information technology is to provide operational savings and improve quality by performing structured teaching/learning tasks reliably and efficiently.

IT-enhanced objectivist learning model

It is now practically feasible to include text, graphics, simulations, video images and sound into a single learning module. The module can be provided to students so that they can review lecture and tutorial material as many times as is required. This module can also incorporate assessment methods to provide students with immediate feedback on performance. The following example shows how the teaching materials of a Building Measurement subject can be included into a computer-based learning (CBL) module using Authorware.

The Building Measurement subject introduces students to principles of basic building measurement for preparing bills of quantities. The CBL module for this subject has three main user interfaces, or forms: Content Form, Lecture Note Form, and Tutorial Form. The module operates in a networked MS Windows environment. Students need to log into the network using their names and ID numbers. After loading Windows and double-clicking the icon representing the CBL module, the student is prompted with the Content Form as shown in Fig. 1.

Students can browse through the lecture topics and select the one to view. By double-clicking the selected topic, the Lecture Note Form (see Fig. 2) is loaded with the content related to the selected topic.

Each lecture is associated with a number of questions which provide students a means to assess their learning performance. An example of

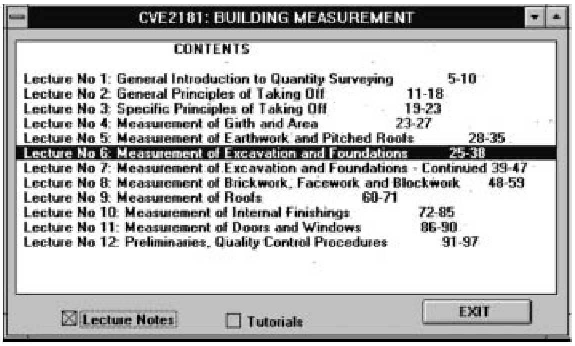

Fig. 1. The content form of the building measurement CBL module.

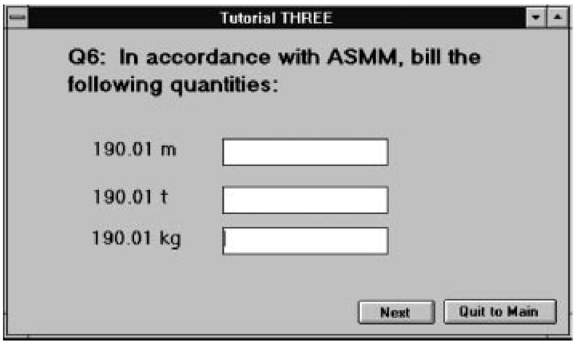

Fig. 3. The tutorial form.

tutorial questions is shown in Fig. 3. Answers for the question are required in the blank boxes and students' inputs are recorded and stored in a file accessible only to the instructor. The results can be imported to a spreadsheet for statistical analysis in order to identify common problems.

It is clear that the role of CBL technology is to increase the ease of knowledge dissemination, rather than the creation of knowledge. The technology imposes a structure into the learning process that may not otherwise have existed. However, despite the common brief that structured and vivid presentation of knowledge enhances learning efficiency [10], we found no significant difference in student performance. But there was evidence of significant improvements in student attitudes to the content of the subject. As a consequence, we believed that even though the CBL module may hold little advantage over the traditional chalkboard method in terms of knowledge transfer, it can influence student attitudes toward the quality and organization of teaching and learning. On the other hand, the CBL module may enable students to process information at their own pace which is usually rigidly controlled by the instructor in a traditional objectivist learning environment, hence making the learning process more individually tailored.

IT-enhanced collaborative learning model

Collaborative learning model emphasizes that the sharing of information, communication, and participation are crucial to learning. The goal of using information technologies is to facilitate and enhance student-to-instructor communication as well as student-to-student communication. Several studies identify communication problems in education. For instance, it is acknowledged that in a large class (more than 30 students), students are inhibited about talking in front of others [11], but they feel quite comfortable to express themselves anonymously. Another study shows that students prefer to raise questions to their instructors electronically than through face-to-face conversation [12], akin to the finding that employees in business organizations feel more comfortable sending messages than talking to their superiors [13].

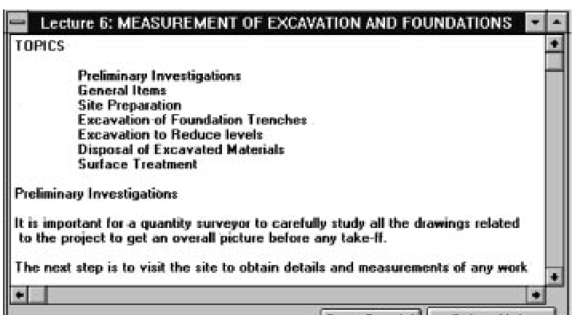

Fig. 2. The lecture note form.

In order to identify the effect of using information technologies in enhancing collaborative learning, we experimented the use of Groupware in tutorials to facilitate communication. There were 46 students in a second-year Engineering Material Science class at Monash University. The students were divided into two tutorial groups (Group A and B), each with 23 students. Tutorials in Group A were organized in the traditional way without using any IT tools. Tutorials of Group B were conducted in a classroom where each student had a computer with Groupware running in the MS Windows environment. Groupware allowed student to write messages anonymously onto a common screen. When a topic was given, students in Group B could ask and answer questions by typing sentences through computers in front of them.

A comparison of the students performance in the two tutorial groups indicated a significant difference in students participation: the average number of questions raised in Group A were about 15, whilst the average number of questions from Group B were nearly 40. It was also found that students in Group B were more active at answering questions from their peers. Final examination results also indicated that students in Group B had better performance than students in Group A. This experiment convinced us that technology-enabled collaborative learning improved the learning performance. Students working collaboratively via anonymous communication were more active and performed better in the learning process.

Another technology that can stimulate communication is electronic mail between instructors and students outside the classroom. Electronic mail allows students to ask questions as they are reviewing learning materials outside of class. One disadvantage is that students cannot get immediate answers from instructors. The delay in feedback from instructors is undesirable, but the flexibility to ask questions as they arise may offset the disadvantage of the delayed response. It is, however, still unclear to us whether electronic mail communication outperforms the traditional verbal question-and-answer method. Further study is needed to identify the actual effect of this technology to engineering higher education.

IT-enhanced constructive learning model

The constructive model forces learners to discover things themselves rather than through what they are told. The role of information technologies in this learning environment is primarily to maximize the availability and accessibility of information that will lead learners to constructing new knowledge. There are several technologies that can be used to assist a constructive learning environment. Shared databases, World Wide Web (WWW), simulation software packages, and virtual reality are a few examples that will be discussed below.

Many engineering subjects require students to perform manipulation and analysis of empirical data. For instance, in learning construction cost estimation methods, students need to use current construction material and labor prices. One way to give students the maximum access to this information is to locate the cost data in a database accessible by all students via network. Students gain understanding of cost estimating from using the information in the database to solve estimating problems.

World Wide Web is another platform that can be used to support information seeking and analysis. WWW provides a nonlinear means of browsing and sorting through keywords. Similar to databases, WWW can be used to gather and display learning information. The hypermedia format of WWW encourages students to search information in a way that suits their logic need. The potential of the WWW to serve as an information resource in engineering education seems immense, and research examining the use of WWW in engineering education is much needed.

Simulation technology has long been used as a media of knowledge construction. Simulation can expose students to a condensed or vicarious experience of a specific learning topic. In fact, many simulation programs are used in engineering education. For instance, we used a computer program BID-GAME [14] which simulates the construction bidding process in the Construction Estimating and Tendering subject. Each week the program generated a number of tenders available in the week. Students in the class were grouped into seven teams, each team representing a contractor tendering the jobs available in the week. Bids prepared by teams included construction costs and markup percentages, and they were entered by the instructor into the program. In the following week, the program generated the win/lose list, cash flow reports, profit and loss account reports, etc. Several games were played in one semester. Students acquired the knowledge of competitive bidding as the games compelled them to learn how to 'survive' by winning jobs.

Virtual reality is a technology that can assist students to construct knowledge from virtual experience. One example is the use of virtual reality in architectural design [15]. Students can create a virtual reality of a building where they can enter and 'walk' through the building. In designing the virtual reality, students are actively involved in constructing their knowledge in building design. This knowledge is consolidated by continuously working on the appearance, size and shape of the virtual reality building.

THE IMPACT OF IT ON ENGINEERING EDUCATION

The previous discussion of the relationship between learning models and information technologies suggests the mapping shown in Table 1. Technology serving objective learning is computer-based learning modules. These modules structure learning processes and information in a way that promotes efficient transfer of engineering knowledge to students. In this learning environment, the impact of IT is limited to the ease of factual/procedural knowledge transfer by letting students control the pace of learning.

Technologies that assist collaborative learning move away from knowledge dissemination to knowledge sharing; the instructor is no longer the sole creator of knowledge. Rather, students develop knowledge through shared information. The role of information technologies is to establish a communication medium over which students can contribute to the knowledge formation.

The role of information technologies in assisting constructive learning is to provide a source of information that can be accessed by students in a manner uninhibited by time and location. This

Table 1. Mapping between learning models and information technologies

Objectivist Model	Collaborative Model	Constructivist Model
CBL modules	Groupware supported synchronous communication	Shared databases; WWW
	Electronic mail	Simulation Virtual reality

allows students to construct knowledge from shared information sources in a dynamic structure. The structure is dynamic in the sense that individual students may construct slightly different understanding and conception from the same information. The task of the instructor is to collect and develop information that is appropriate for knowledge creation.

The use of information technologies to enhance the delivery of teaching materials is only part of the equation in achieving flexible learning environments. As the costs of developing flexible learning packages are very high, it almost becomes prohibitive for individual educational establishments to develop the whole sets of the flexible learning packages. What is needed is an educational network of educators prepared to share the task of developing flexible learning materials.

We propose to establish a URL home page at an educational establishment to facilitate the sharing of information on developing flexible learning materials for engineering education. The network will enable educators to contribute to the base of learning materials and fetch from it for specific learning purposes. It will serve as a platform for promoting and exchanging materials for flexible learning.

CONCLUSIONS

This paper presents a discussion of learning models used in engineering higher education, and the opportunities for implementing IT to enhance engineering education. It demonstrates that information technologies can enable the effective application of objective, collaborative and constructive learning in engineering education. Specifically, this paper identifies that computer-based learning (CBL) modules enhance the delivery of learning materials by embedding a structure into a learning process. Hence CBL modules are rooted in the objective rather than collaborative or constructive model. IT-based communication techniques facilitate the efficient share and exchange of information, and the use of such techniques improves the learning efficiency in collaborative learning environments. Publicly accessible databases, WWW sites, simulation and virtual reality are identified as technologies that support constructive learning environments, because they can be used as sources for information sharing, gathering and processing.

However, numerous challenges remain in the area of improving engineering education, many of which require the use of information technologies. In particular, attention needs to be given to developing technologies to support the integration of the three learning models. It will also be interesting to understand how electronic mail between instructors and students can assist learning efficiency. Similarly, research is needed to identify the impact of using WWW in enhancing engineering education. Finally, it should be noted that with the rapid evolution of information technologies, an ongoing effort is needed to identify new technological developments and apply them to enhance engineering education.

We proposed that there is a need to establish a URL site to bring together the disparate disciplines into one network dedicated to the sharing of expertise in the development of flexible learning materials. This will enable the best materials to be available to learners electronically over the Internet.

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