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# Enhancing engineering education using multimedia web-based techniques

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## ABSTRACT

This paper describes the motivation, methodology, implementation, operation and testing issues related to developing web-based engineering courses. It presents the motivation and need for new educational tools in engineering by highlighting the power and advantages of multimedia web-based techniques. Then, it provides an analysis of such techniques as educational delivery systems and the challenges facing their application, both as complete distance - education tools and as complementary - educational assistants to formal university courses. Next, it describes a generic methodology that can be adopted to design and implement multimedia web-based educational tools. Finally, it describes an assessment method to measure and improve students' satisfaction and the effectiveness of a web course.

**Keywords:** education; engineering; management; multimedia; web.

## INTRODUCTION

Over the last several years there has been an increase in www-based educational environments that facilitate the objective of providing new opportunities for interactions with the course material, the instructor, and the students. The new opportunities are in the form of alternatives and/or supplemental models to the traditional educational models currently in use. With the web's multimedia capabilities and global networking, a great world-wide source library of information is created that is tempting all educators and learners to access it and join in. Besides the ongoing advances in web and multimedia technologies acting as motivators for considering alternative models for education, the challenge is to meet the educational needs of an increasingly diverse student population with a limited resource of instructors, administrators, and physical classrooms. These educational needs include getting quality education and in-depth understanding in a motivating and challenging environment.

Traditional educational methods and tools, such as chalkboard lectures and textbooks, do not satisfy these ectraordinary needs. For example:

- They do not readily retain a student's attention for significant periods of time.
- They do not allow the student to interact with the information (the student acts primarily as a passive receptor of the information).
- They do not allow students to progress at a pace convenient to them (lectures proceed at a single pace and students must wait for feedback on questions unanswered by course packages and textbooks).

Ideally, new educational technologies are required that provide the following attributes:

- an ability to create, nurture, and sustain interest in technology oriented disciplines, with the objectives of attracting (and retaining) quality students and increasing their motivation to learn;
- rapid learing of large bases of knowledge;
- simplified understanding of complex concepts and ideas;
- enhanced retention of knowledge;
- mechanisms that allow private study to occur at any location, at any time and to proceed at any pace;
- mechanisms that allow study sessions to tap directly into external sources of information such as the world wide web;
- mechanisms for rapid communication of information, questions, and review of work between students and instructors at remote locations;
- remote conferencing between groups of students and instructors;
- alternative/automated tutoring tools when the primary instructor is unavailable;
- applicability to both group learning and private study environments; and
- interfacing with, and enhancing conventional methods of education, such as classroom lectures, discussions, and presentations.

The Internet and the www have become an effective and timely student-to-instructor and student-to-student communications facility in ways undreamed of just a few years ago. These tools host teaching and learning materials for both the teachers and students when used for web-based courses (Huang *et al.* 2001) They provide facilities to improve not only the accessibility but also interactivity within the classes.

Basic features of such tools include: storage on CD-ROM for convenient access; the integration of a rich selection of media (including animated interactive graphics, audio and video information, and interactive simulation); and interfacing with the Internet to permit distance learning and the establishment of a *virtual classroom*. These tools are designed to complement and fit within a formal university course, largely replacing the course textbooks, course packages, and traditional classroom presentational media.

This paper discusses the motivation and methodology for developing new educational tools that satisfy the above requirements. It presents issues related to the use of multimedia and www techniques in online and offline courses. Most of these issues are a result of a thorough literature review and the authors' own experiences in developing and incorporating such technologies in their courses.

## MULTIMEDIA-BASED EDUCATIONAL SYSTEMS

A fundamental philosophical change about the way people learn is altering the way instructors present information. Until recently, formal training methods usually have relied on lecture-based training sessions. Nowadays, multimedia methods are being increasingly used to provide a new model for training that depends upon users' *participation* and their ability of association to develop interactive skills and links to memory (Kozma 1994).

Participation in this context means the media requires input from the user to advance the training procedures. This process takes the trainee out of the passive role of "listen and respond" to make the individual *interact* with the lesson. Participation also demands the attention of the individual to continue progressing through the lesson; passive listening does not necessarily guarantee that the trainee is paying attention or comprehending. The primary advantage for the student using multimedia educational tools is *enhanced interaction, self-paced learning, autonomy* and *self-regulation* in the learning process. These characteristics in combination can amplify student performance.

### Levels of Interaction

Participation in multimedia-based models now has three recognized levels of interaction:

Level 1: The media activates a number of senses besides simply hearing. "People remember 20% of what they hear, 50% of what they see, and 70% of what they see and hear," is a familiar phrase that illustrates the benefits of involving multiple senses in the learning process. Yet, the user still assumes a passive role.

Level 2: The user has limited input that advances the lesson. For example, a lesson may require responses to questions before going on to new material. This affirms the user's attention.

Level 3: The user is allowed to effectively choose the order and the content of the lesson which most suits his/her interests. Thus the lesson is not a rigid course of staged sequences like a lecture. This procedure allows the user greater freedom with the training material, which often evokes a sense of responsibility for oneself in learning the substance of the lesson. this allows a user to constructively divide his or her time, spending less time on issues that they already understand, and spending more time with areas new to that person.

Students are more enthusiastically motivated by what they are currently seeking than by receiving more of what they already know. The ideal level of flexibility and control for the user is controversial. Some educators argue that an environment allowing the user freedom without direction or suggestion leads to "garden path digression" that is detrimental and frustrating to use. For the systems developed in this project, excessive digression has been avoided by placing the multimedia facility within a structured course framework (with, for example, scheduled reading assignments and classroom review sessions), and by the provision of a tutor/guide with structured lessons within the multimedia facility.

## Memory Association

A popular theory of how memory works is that of *association*, which is based on the idea that a person understands new information only by "linking" it within a framework of similar or related information. This process is enhanced when, as with multimedia environments, a number of senses are used to link this new information into the familiar framework of past experiences. Most people are familiar with the feeling of having a sudden "flashback" or memory recall of a past experience. This is known as a *stimulus and response impulse*.

Other factors can affect the development of associative links. Both *response* and *repetition*, for example, can reinforce the mental links to new information. Requiring a user to respond to questions after listening and watching the training material introduces several factors that will affect this person's memory. First, questioning new material as one goes along requires that the individual listen and comprehend information as they proceed through the lesson and, second, it charges the session with some sense of emotion which will strengthen the memory link of new information. The person may feel a sense of responsibility for learning the information themselves, and they may also feel some anxiety to get the question "right". That is, the person will get a sense of

"achievement" by completing the task correctly, or "discontent" if they get the answer wrong. Pragmatically, providing questions to the material as the person progresses allows the person to know where they have problems (immediate feedback). this can speed up the learning process. Questions also allow some from of repetition for the user. Repetition allows the person to "revisit" this new information until it is not new any more. Familiarity with an issue provides some sense of "comfort" to this information which again charges the memory with emotion. These factors build upon one another to develop the process of memory by association (Robbins 1991).

The development of computer applications in recent years has responded to this form of memory theory. The Graphical User Interface (GUI) was developed to interact with computers based on visual stimuli and response. With GUI, users respond to an iconographic image (icon) on the visual output of a computer to command certain actions. Certain icons have become universal to many applications reducing the energy required to learn to operate different systems. This means a user can focus more on completing tasks and problem solving.

Using iconography as a means of inputting information, as is the case for the multimedia web-based textbooks, requires the user to develop an association between the visual symbol and some concept of what operation should be performed by that command. Making some symbols universal to several computer applications develops an expectation for a similar response (repetition). Soon, users become familiar with a certain operating method allowing the user to focus on tasks and problem solving.

## Information Management

According to Kozma (1994) learning is an active, constructive, cognitive and social process by which the learner strategically *manages* available cognitive, physical, and social resources to create new knowledge by *interacting with information* in the environment and integrating it with information already in memory. computer technology today provides an opportunity to coordinate multiple possibilities for influencing the way information is presented and processed. Advancements with memory, graphics, and multimedia techniques, like audio and video, allow training and education programs to draw on a number of resources that in combination will give a trainee the capability to better manage and interact with the information. Thus, the adult leaner, through multimedia, will increase his/her capacity to interact with data and enhance the learning process through the speedy transformation of that data into information.

Multimedia delivery allows instructors and students to "simulate" and be exposed to environments which may otherwise be hazardous or are not readily accessible. such methods can help a student *visualize* a process or product. Visualization is the representation of information consisting of spatial, nonarbitrary, and continuous characteristics, and our sense of vision is arguably our most diverse source of information of the world around us (Reiber 1995). Visualization is not only considered to help memory, it can also be used as a cognitive development and problem - solving tool.

## WEB-BASED ENHANCED LEARNING

The web provides students with opportunities for self-directed, activity-oriented and task-engaging work which allows students to construct their own meaning from the work undertaken (Eklund & Eklund 1996). The hypertextual organization allows materials at different levels of detail or difficulty to be made available to students without imposing a pre-determined path for them to follow (Polyson *et al*. 1996). The hypermedia web invironment and learner's cognitive models have been noted for their similarity to the models of how people acquire, store and retrieve information, knowledge, and concepts (jonassen 1996, Spoehr 1994, Marchionini 1988). The acceptability of this notion is based upon the acceptability of the learning theory of the constructivist tradition, that is, an individual's knowledge is being constructed according to his/her particular knowledge state (Jonassen & Wang 1993).

The adoption of student-centered learning in technology-based teaching has three main motivators (Eklund & Eklund 1996):

- Students differ in their learning skills; therefore, the availability of different and alternative learning environments assists in satisfying different needs.
- The empowerment provided by the use of IT is in some senses its own motivating force, and makes the traditionally structured lessons less important.
- Due to the rapidly changing nature of information and documentation, the web challenges the learner to use a range of information handling skills, such as search tools and critical thinking skills, in an effective way.

Beside being effective in two main ways, instruction and reference, the web has many other capabilities that are useful in developing personal communication skills, which is an important aspect in managing construction projects. This is possible through the collaborative work that hypermedia systems promote (Yang & Moore 1996, Jonassen 1996, Ruberg *et al*. 1996). Studies have shown that learners profit immeasurably from environments which

encourage shared learning (*Polyson et al*. 1996). The web was originally conceived for the purpose of collaborative research and continues to be useful in this regard. The idea behind collaborative construction projects and assignments is to provide students with opportunities to develop their skills and abilities in working in a team. Collaboration can be synchronous in real time and immediate, such as with Internet Relay chat (IRC) and video conferencing, and it can be asynchronous, such as with e-mail, newsgroups, and www pages. chatting programs in web-based courses, where a certain time and date can be fixed for a ''live'' questions and answers session, can be especially useful near exam periods. Educators need not be in the office the whole day to entertain students at different times, but instead can answer questions at one particular time even within the comforts of his home in front of a PC (Ridwan *et al*. 2001). Video conferencing can add both parcticality and excitement to the education process by allowing students and educators to talk and see each other. Collaboration with top experts from other universities, and even industries, can be called upon to give some kind of talk to add ''spice'' to the teaching and learning experience.

The Internet and telecommunications can enhance education in a wide range of areas, such as web-based courses, educational administration, electronic publishing, resource information and references, professional networking, research and development (Davies 2000). The range of areas of Internet application in education is increasing and taking different and innovative forms due to the continuing advancements of multimedia tools. Examples of such tools include RealAudio for audio and video, Shockwave plug-in for animation and simulation, and PhotoShop for graphics. Using a variety of media (text, graphics, audio, and video) in education may also accommodate individual styles of improvement and enhancement to the educational process.

Primary research figures from industry groups have compared the benefits of multimedia-based training to instructor-lead training. companies such as Federal Express, IBM, General Motors, and other industry leaders have long seen the computer's ability to *manage information* as a potential benefit to long-term training solutions. Now, with the development of interactive applications to guide and formulate training material, companies in many industries see computer-based training as a means for effective and efficient training for their employees (Bentley 1997, Hall 1995, Adams 1992).

## CHALLENGES OF INTERNET USE IN EDUCATION

The use of the web technology in education has its barriers, disadvantages, and challenges that cannot be ignored. Some of the drawbacks of instructional hypermedia that were identified by Yang & Moore (1996) and McKenzie (1996)

include: students' lack of knowledge about the learning process, web navigation ambiguity cognitive overload, and too much information. Also, interference to the learning process might arise from the economic barriers to web and multimedia applications, especially in developing countries, since not every student or teaching institution can afford the price tag of this technology. According to Owston (1997) and Mike (1996), development and maintenance of Internet-based material can be costly. In addition, web-based courses could become time-consuming compared to face-to-face (F2F) instruction (Montgomerie & Harapnuik 1997). Legal and ethical issues are also of major concern to the implementation of web technology in education.

Most of the above challenges or disadvantages are present with using web-based courses in distance educaiton, i.e., virtual courses. Therefore, it is important to note that these interactive and accessible web courses are created not to replace existing methods of teaching, but rather to complement and reinforce them. The crucial question has become not how to imporve teaching but how to improve learning, and these tools have proven effective in meeting the increasing demand for new knowledge, skills and life-long learning.

## GENERIC METHODOLOGY FOR MULTIMEDIA WEB-BASED TEXTBOOK DEVELOPMENT

During the last four years, the authors have designed, developed and evaluated two multimedia web-based textbooks for the following engineering courses: CE202 Engineering Statics and CE437 Concrete Equipment and Methods (Kartam & Al-Reshaid 2001). Along each step of the development, volunteer faculty as well as construction experts were incorporated in brainstorming sessions for their opinions regarding the overall design of the system. Special emphasis was placed on the knowledge base content and user interface. From the authors' experience gained and the efforts devoted to developing such interactive textbooks, this section describes generic methodology steps for designing, implementing and evaluating web-based multimedia courses (Fig. 1).

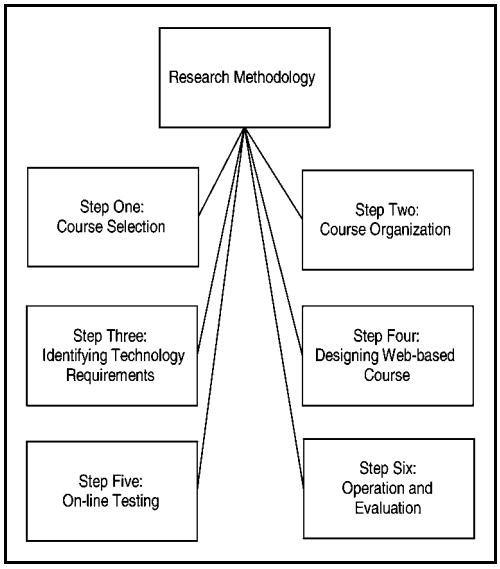


**Fig. 1.** Research Methodology

## Course Selection

The first step of the methodology is to select a course and the requirements that would better enhance material comprehension by the students. Instructional goals and objectives are are determined first before deciding on the appropriate technology to support them (Barron & Orwing 1995).

There are many reasons for selecting a particular course for conversion onto the web. Multimedia and web technology are most beneficial to courses requiring visualization, animation, site visits, student-teacher and student-student interaction, a variety of readings and reference materials, collaboration with industry, and/or hazardous exposure. Such courses will require video data collection and editing, and the development of animated graphic modules, simulation/gaming modules, help modules, and knowledge-management modules.

## Course Organization

Courses on the web could be organized in a couple of ways depending on the materials and the lecturer's style of teaching. Also, it is a process dependent on the experiences of the designers and their preferences (Gassaway *et al.* 1996). due to the large volume of information that will comprise a multimedia-based textbook and the complex orchestration required of that information, effective techniques for organizing information, such as those of cinematography, management information systems, and GUI design should be used. Focus should be on graphical animation, sound, interactive discussion, and links to appropriate sites over the non-graphical materials, such as detailed text contents. This would lessen the confusion of searching and optimize the web's space and speed.

## Technology Requirements

A plan should be developed to outline the technology requirements for web-based course systems. Technological resources must be chosen to fit the curriculum, not vice-versa (Peterson 1989). Nowadays, significant advances have been achieved in computer hardware at affordable prices, including fast processor speed, high storage devices (e.g., CDWR, DVD, Zip disk), high-resolution flat color monitors and panels, and an improved degree of networking and communication standards, especially Internet web connections. The identified requirements of a web-course determine the type of media to be included in the web system. As for determining the software requirements, certain issues are considered including: web-course objectives, training (cost and ease), and total development and maintenance costs. The software requirements

might include: 1) website development (e.g., MS FrontPage), 2) graphics (e.g., Adobe PhotoShop), 3) animation (e.g., Animator Shop), 4) questionnaire and test design (e.g., Infopoll Designer), 5) video (e.g., Platypus Animator), and 6) optical character recognition (e.g., Omini Page).

## Course Design

According to Dyer (2000), there are four major criteria that should be considered in designing web courses, and they are: *readability, availability, suitability,* and *accessibility* of course materials, information, and documentation. Other considerations to the web-based course design include: *Interactivity* between the teacher and students (McNabb 1994), and *active learning* (Savery & Duffy 1995).

It is important to identify relevant learning psychology that can be exploited in the design of an efficient multimedia web-based textbook. O'Conner (1995) provides the following key issues that instructors should be aware of when designing learning modules:

- The system should be flexible enough to allow students to bypass material and to grow with their increased understanding.
- They need to develop course materials which are responsive and encourage participation and group learning.
- They should be mindful that bandwidth/browser limitations and supported hardware/software may restrict instructional methodologies.
- They should take advantage of external resources of information (i.e., hypertext links).
- They should create navigational pages such as directiories and table of contents pages to assist students in finding information.
- They should be prepared to revise learning modules based on student feedback.

Considering the previously mentioned issues, a course can be designed to become a web-based classroom metaphor for all engineering classes. In addition, the model should stress the integration of on-the-web interaction with engineering communities at the educational and professional levels.

The design and development of a web site for any course should include all necessary educational materials that the instructor intends to give the students, as well as those materials that the students should retrieve on their own from the library or external references. Having access to such materials on line is not only a matter of convenience to students, but also a matter of saving much of their

effort and time. Such web-based courses provide an on-line interactive environment for students to obtain homework assignments, submit their solutions, and for professors to grade homework and send results along with feedback to students. Several online course components and tools should be considered in designing the course home page. Major course components might include: 1) lectures, 2) tutorials and class simulations, 3) communication tools, e.g., e-mails, message boards, discussion groups, chat rooms, feedback forms, 4) administrative tools, e.g., course syllabus and schedule, FAQ, 5) testing tools, e.g., quizzes, tests, homework, 6) references, e.g., useful links, previous exams, and 7) helping tools, e.g., a search of the course homepage, arithmetic and engineering tools.

***Design Steps*** *(see Fig. 2)*

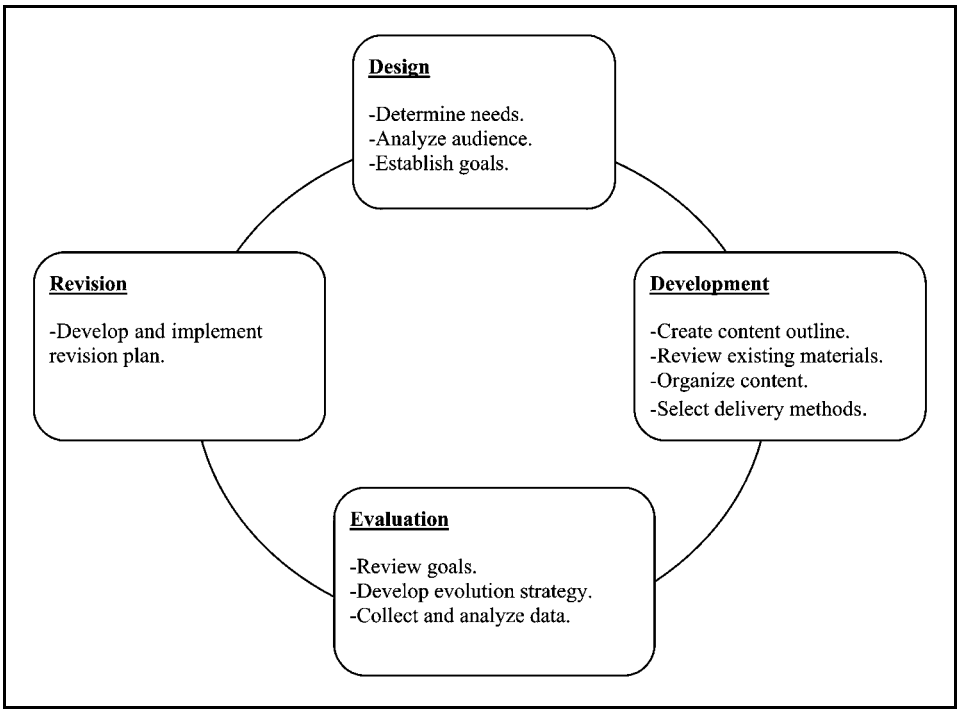


**Fig. 2.** Design Steps

- As always, evaluate other web sites to find out what works and what does not (a good starting point is *The World Lecture Hall* (http://www.utexas.edu/world/lecture/).
- Identify to yourself the goals of the web page.

- Plan a site overview on paper.
- Decide from the beginning how much interaction/assessment there will be in the site and at what point it is presented to the user.
- Assemble the data you will be using in the course and establish from the beginning which parts will need copyright clearance.
- Create the web pages, possibly using conversion tools, or HTML editors (like MS-FrontPage).
- Test the site using as many browsers and different specifications of hardware as you have access to.
- Evaluate the web site.
- Advertise your site (assuming you wish to let remote users in) on appropriate discussion lists and web-based submission pages.

## On-line Testing

The end product is then tested for technical functionality on the web and simplicity of use for students. Whenever the system fails to carry out any of its functions, it is taken back to the design stage for further technical reviews and modifications. Both students and teachers should participate in this testing process.

## Operation and Evaluation

The developed multimedia web course should be tested for its ease of use and effective conveyance of information to the student. This can be undertaken using the naïve-user method of analysis. In this method, a person with no previous exposure to the system and limited understanding of the knowledge contained within, is asked to browse through the system to determine the answer to a set of questions. The naïve user is observed during this process with the intent of identifying ergonomically unfriendly and awkward elements in the organization and design of the system. Following the trail, the naïve user is interviewed in an attempt to identify further unfriendly features in the system and to provide advice on how the system may be better organized. This process should be performed at several levels in the organization of the system, starting with the individual modules as they are developed, and progressing to higher level components as they are assembled from the modules.

The performance of the multimedia web-based system should be evaluated by testing it on students, operating within a formal course environment. The course should be tested on two different student sections, one of which should be

taught utilizing the multimedia web-based system, while the other should act as a control group being taught the same course, but by using traditional teaching methods (by the same instructor and with all other factors set equally as far as possible). The relative performance of the groups should be monitored throughout the semester to identify differences in learning rates, development of problem solving skills, and development of visualization/analytical skill.

At the end of the semester, the students should be asked to complete a questionnaire aimed at assessing their attitudes towards the respective teaching methodologies, difficulties they encountered during the course, their levels of motivation, and the procedures they adopted in conducting their studies. An analysis of these findings should then be made to determine the merits and drawbacks of the multimedia web-based teaching method, and to identify any systemic and/or component level improvements that could be made to the tool.

At a later stage, it is recommended that a cross-section of students of different perormance be interviewed (selected randomly from within each group) with the aim of assessing the extent of their knowledge retention. The true ojbective of this step should be withheld from the students prior to the interviews to prevent the introduction of bias through student revision of subject matter.

Students who took web courses reported many benefits over traditional teaching methods, e.g., web courses are more effective and convenient in accessing all course materials anytime and anywhere (Kartam & Al-Reshaid 2002). Extra time and effort were devoted at the beginning of the semester to getting students acquainted with such a new environment of learning for the first time, compared to other traditionally taught courses. Once used to the web-based application, the students appreciate the time saved and the excitement of receiving educational and practical knowledge through a variety of multimedia tools at their finger tips.

Every web-based course requires continuous improvement and expansion to make it more interesting, attractive and useful to the students. Such revisions are done based on students' and instructors' feedback, and they may include: 1) animation and visualization examples to enhance understanding by offering better 3-D conceptualization rather than just 2-D applets; 2) simulation techniques mimicking real-life operations; 3) increasing the number of self-evaluation quizzes and assignments; 4) expanding the knowledge base of the course material with appropriate web links and readings; and 5) enhancing the user interface allowing faster information access.

## CONCLUSIONS

It is anticipated that incorporating multimedia web-based educational techniques relative to conventional educational tools would significantly increase a student's learning curve. The rich set of presentational media provided in the multimedia web-based techniques (animated diagrams, construction simulation, video, audio, and interactive gaming, for example) and its facility for self-study, will improve a student's motivation to learn, increase the rate of learning, promote a deeper level of understanding of complicated concepts, enhance problem visualization and problem-solving skills, and improve knowledge retention. Student's learning improves with, among other factors, their motivation to study, their receptivity to acquiring new knowledge, and the ease of interpretation of the new knowledge presented. It is expected that all these factors would be greatly enhanced by a medium that is highly graphical, animated, interactive, and includes a rich complement of forms of information presentation. For private study sessions, the facility could be powered-up at points in time that are convenient to the student, and sessions could be stored, enabling resumption or review of the session at a later point in time.

Technology must never interfere with the delivery of education, rather it must be used to augment and support the learning activity. Being CD, DVD or web-based and capable of running on today's laptop and desktop computers, the facility would be highly portable and cost effective. Consequently, it would be conducive to learning within a fragmented schedule providing packets of information on-tap. Continued improvements in both computing power and communications speeds will make the world wide web a central educational-delivery tool.

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# تحسين طرق التعليم الهندسي باستخدام وسائط العرض المتعددة والإنترنت

**نبيل قرطم و إن فلد**

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ص. ب 5969 الصفاة 13060 الكويت

## خلاصة

يتطرق هذا البحث إلى جوانب عدة تخص استخدامات تكنولوجيا الإنترنت في تدريس تخصصات الهندسة وعلومها. وتتكامل هذه الجوانب فيما بينها لتشمل: دوافع ومنهجية البحث، ومقترحات للتطبيق، ونماذج من التطبيقات، وقياس درجات النجاح، وإبراز جوانب القوة والإيجابيات التي تم إبرازها ضمن التوصيات. أما عن جوانب القوة وإيجابيات استخدام تكنولوجيا الإنترنت فإن هذا الجانب سيعزز من جدية تبني طرق جديدة ومتطورة لتدريس علوم ومقررات الهندسة. كما وأن هذه المؤشرات الإيجابية التي يعززها التحليل العلمي ستدفع في مجالات التعليم من على بعد بدرجاتها المتفاوتة، وهو أمر منشود عن قياديي التعليم العالي في الكويت لما له من انعكاسات إيجابية على تحقيق عنصر الفاعلية في تكاليف العملية التدريسية وعنصر الوقت بشكل عام. وبالرغم من أن البحث يستعرض خطوات علمية مبسطة في حال الرغبة في تبني تطبيقات الإنترنت في تخصصات الهندسة وعلومها، فإن المنهجية المقترحة أيضاً يمكن أن تكون نافعة ومجدية لأن تطبق في مجالات أكاديمية أخرى غير الهندسة لكونها سهلة الفهم والتطبيق. كما وأن هذه المنهجية تحوي على طريقة علمية لقياس تقييم عمليات التطبيق.