AC 2007-1808: INTERACTIVE COMPUTER-BASED VIRTUAL CLASSROOM FOR ENGINEERING COURSES

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Interactive Computer-Based Virtual Classrooms for Engineering Courses

Abstract

New paradigms in engineering education have emerged in recent years. These educational models emphasize a visual lecturing style and correspond with the growing trend of online courses. A main objective in modernizing engineering education is bridging the gap between academia and industry[1-4]. We propose a new teaching approach, based on these paradigms, that is specially designed for engineering courses. We have developed interactive, self-paced computer-based lectures in which students learn abstract concepts on their own. In this approach, classrooms have been allocated for problem solving, student-teacher interaction, and industry-related applications. The proposed teaching methodology combines the constructivist approach—which enables students to acquire knowledge meaningful to them through interaction—and the objectivist approach—in which students passively receive information via computer-based lectures. Computer Based Virtual Classroom (CBVC)—a computer program that mimics traditional classrooms by presenting lectures in chronological order, an approach critical to the success of engineering curriculums—was developed as a new educational model. CBVC employs computer animation and other virtual visual tools that cannot be employed in traditional classroom settings. In CBVC, interactive questions are integrated within lectures—a model that reinforces the assimilation of fundamental topics. Surveys conducted on the efficacy of CBVC show that 80% of students questioned benefit from using CBVC, and 20% believe CBVC may replace conventional classrooms.

1. Introduction

At present, many engineering courses mandate the use of computers[1.]. Computers are increasingly playing a major role in the learning process, and the number of college students who own a computer is on the rise. The OpenCourseWare (OCW) Program at MIT[2]—an internationally recognized computer-based lectures' program—provides a variety of online courses to the public for free. Not all educators embrace the virtual classroom model. There are those that question the effectiveness of computer-based lectures. Some are concerned that computer-based courses will replace traditional classrooms. There is a rift between traditional educators known as *objectivists* and contemporary educators known as *constructivists*[3]. Objectivists question the effectiveness of replacing traditional classrooms settings with online courses. The objectivist standpoint supports a learning process led by the instructor in which students passively receive information, as in a conventional classroom setting. Objectivists support the model in which instructors interact with students during lecture by asking questions and generating discussions and dialogues. In this approach, instructors sense the students' comprehension on the fly and adjust their lectures accordingly. The objectivist approach calls for the instructor to lead the learning process and ease the challenges of learning abstract topics.

The physical presence of the instructor is critical to the learning process, especially in highly structured engineering courses.

Constructivists, by contrast, believe the learning process must be controlled not by the instructors, but by the students[3] themselves. The learning process itself attains significance when students' become involved in shaping it. In the constructivist model, the instructor's main task is to monitor and guide students through the learning process. We support a different strategy for developing effective computer-based engineering courses. Engineering is an exact science, where marginal error can prove catastrophic. As a result, passive learning settings have been the mainstay of engineering curriculums. But engineering is also an applicable science that requires creativity, innovation, teamwork, critical thinking and social skills, in addition to rigidity of math and science skills. Our proposed new teaching model, specially designed for engineering courses, combines the constructivist and objectivist approaches. In this new approach, students passively learn abstract concepts on their own using computer-based lectures. This is coupled with traditional lectures in which students interact with their instructors and peers. This teaching method has been employed in Circuit I, an introduction to electrical engineering course at San Francisco State University. Preliminary survey results show the CBVC method to be more effective than traditional teaching methods.

The paper is organized as follows: section 2 presents the challenges and solutions of traditional engineering classroom settings, section 3 discusses computer-based virtual classrooms, section 4 presents the proposed virtual classroom environment, section 5 presents our experiment and resultant data, and section 6 concludes the paper with discussion and futuristic trends.

2. Traditional engineering classrooms: Challenges and solutions

Traditional engineering classrooms adopt the objectivist approach—the instructor leads the learning process and students passively receive information. Students' learning is evaluated using a combination of homework, quizzes, projects, and exams. The problem with such an assessment approach is that it limits the students' incentives to learn beyond grades. we argue that traditional classrooms are effective in some respects such as when lectures focus on presenting defined and agreed-upon facts and skills14.

New themes have emerged with the intention of improving the efficiency of teaching and reducing educational costs. Computer-based lectures, though more cost effective than traditional lectures, need to be made more creative to survive in the long-run. Computerized lectures must emphasize motives for learning. In general, engineering courses convey practical, factual information whose professional significance motivates students to learn. Computerized lectures would be more effective if they focused more on practical and industry-related applications
Many engineering concepts are founded on mathematical principles. Students need to employ imagination and develop an intuition in order to assimilate these rigorous concepts. Lower-division engineering courses are generally considered very challenging, as most students are still developing their 'intuition.' Animated computer-based lectures, presented in a standardized setting, could facilitate this development process.

Professional engineers rely on computers for various purposes (design, verification, testing, etc.). Traditional engineering classrooms, however, are technologically unequipped to teach the computer skills required by industry10. This is primarily a result of limited lecture time. In the traditional classroom model, the instructor's lecture time is limited to teaching mathematics and theoretical concepts. It is common for students to learn computer skills on their own, or within the framework of a laboratory assignment outside the classroom. Students are often frustrated by this learning process, as these computer tools are designed for professional and industry settings. Between the limited lecture time, and unproductive time spent learning new computer tools, engineering students have less time to hone their analytical thinking skills. One proposed solution has been providing laboratories for specific classes. More courses, for instance, are now being jointly taught with labs. Courses such as VHDL, DSP, control, and communications are routinely being taught with a lab, to cover industry related tools that are not covered during lectures. Another learning approach is one in which students learn theoretical topics on their own, and lecture time is designated for practical discussions and problem solving using industry-based tools. This learning methodology requires additional lecturing techniques, such as computer-based lectures. Another approach has also emerged in recent years, one that provides research opportunities for undergraduates. Programs like Research Experience for Undergraduates (REU), supported by the NSF, provides learning experience for undergraduate students in non-traditional classroom environments. Despite its effectiveness in engaging participants in highly creative research environments, several drawbacks are noted as follows: Only a limited number of students are admitted into the program. The REU program is too costly to accommodate a majority of students, and students do not have enough say in choosing topics of interest. Another challenging problem in traditional engineering classrooms is that of the high number of freshman and sophomore students who either drop out or change majors. The phrase "weed-out courses," referring to lower division math and engineering courses, is notorious among engineering students in most US colleges and universities.

Engineering courses are highly structured and more advanced topics build on prerequisite courses. Courses are typically structured into lectures that must be presented in chronological order, with topics within each lecture presented in sequential order. If a student does not effectively comprehend a particular concept in a particular course, though passes the course with a marginal passing grade, he or she is likely to struggle in all subsequent courses. If this is the case, the student must exert extra effort to "break the prerequisite chain." Instructors tend to review material previously-covered in different courses to ensure that students are up to speed with the topic at hand. This further reduces lecturing time. As science and technology advance, lecture time per topic is diminishing, a result of more topics needing to be covered. Because of the sequential structure of courses, students who are not sufficiently focused during lecture spend additional time studying outside the classroom, at the expense of developing creativity and problem solving skills. Such skills, as well as critical, analytical thinking, teamwork, and communication skills are required in industry settings. In order to accommodate these requirements, engineering classrooms must focus more on developing students' creativity , problem solving, and team work skills.

Our proposed solution allows students to passively study abstract theory on their own time, and designates lecture time for problem solving and stimulating critical and analytical discussions. In this approach, abstract/theoretical lectures are delivered via CBVC. The success of CBVC depends on its ability to mimic the traditional classroom environment, while also providing features that traditional classrooms do not offer.

3. Computer-based virtual classroom (CBVC)

CBVC must mimic the actual classroom learning environment if it aims to surpass the conventional classroom experience. In an actual classroom setting, for example, the instructor leads the learning process while students passively receive the presented material. To approximate this experience, as in an actual classroom, CBVC uses a whiteboard device for summarizing concepts, solving problems, and drawing diagrams . Students are encouraged to take notes. CBVC allows a student to control the duration of each lecture—the student may replay any segment of the lecture as needed. This accommodates students with differing attention spans. If a student is having difficulties understanding a topic, he or she can replay the portion of the lecture in question until he or she fully grasps the concept. Although the student is in full control of the amount of lecturing in CBVC, CBVC must support academic advising to let the student know that he is in full control of the quality of his education.

In traditional classrooms settings, educators encourage students to copy lecture material into a notebook. Taking notes during lectures is believed to be an effective learning tool; the student learns by redundancy, in hearing, visualizing, writing down, and rereading the material. CBVC presents animated notes similar to actual classroom lecture notes. Fig. 1 illustrates a typical CBVC whiteboard; organized colored notes are animated at a rate similar to that which materials are presented in a traditional classroom.

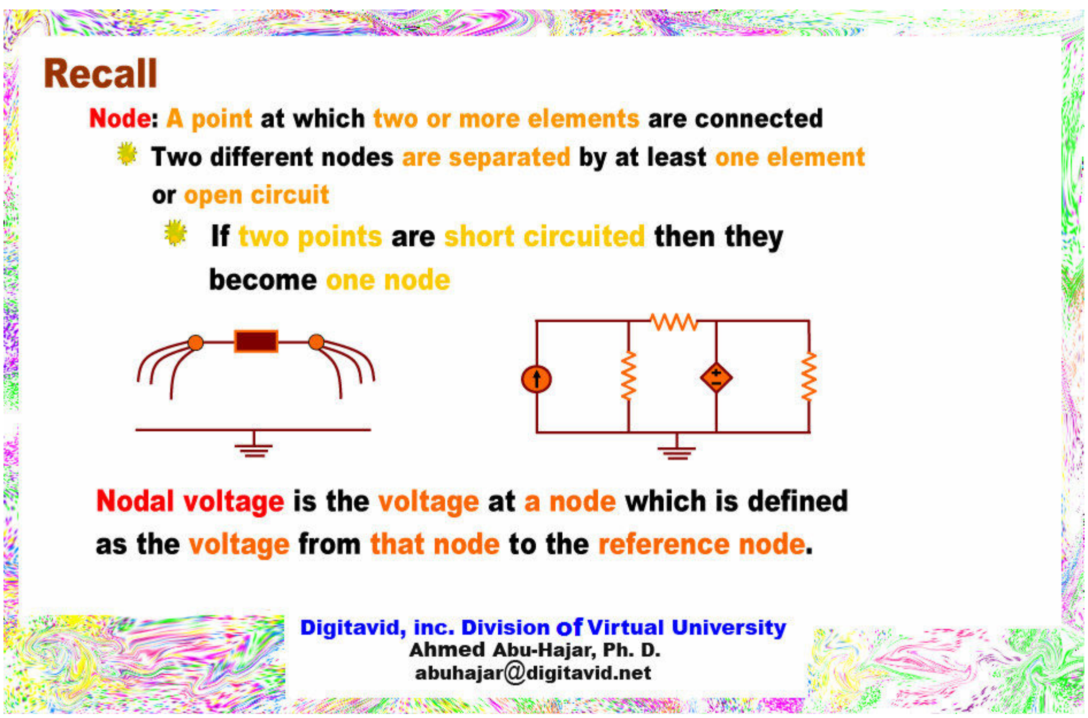

Fig. 1. Organized colored notes are used to emphasize key points.

It can be argued that the quality of the content CBVC delivers exceeds that of conventional classrooms, in its use of animation, more organized notes, and in its elimination of time constraints. In traditional classroom settings, the instructor and the students interactively ask questions for clarification, stimulation, and assessment purposes. CBVC employs cutting edge software technology to deliver interactive content that interacts with the students throughout the lecture. We have proposed a software environment called Virtual Classroom (sponsored by Digitavid Inc.) designed for engineering students. We have developed this package for Circuit I, the first course in electrical engineering. This course, usually taught by graduate students or part time faculty, is required by most engineering programs and is regarded as challenging by most students. Many schools, such as University of South Florida (USF), provide help sessions for this course. These sessions aim to help students understand obscure concepts and complete homework problems. Many universities recognize this need to assist students outside the classroom. Help sessions are not cost effective, however, and the quality of these sessions usually suffers as a result of being led by untrained graduate-students. Virtual Classroom provides help sessions that interactively assist students in grasping concepts. Each help session is developed by a trained instructor and complies with current lecturing methodologies.

Virtual Classroom combines the best of both worlds—the constructivist approach, which uses visual interactive teaching, and the objectivist approach, which uses well-structured and organized lectures. Many engineering faculty believe that learning occurs when the student is able to draw or create an image of learned concepts9. We believe that visual thinking in collaborative, virtual learning environments is vital to the future of learning. Virtual Classroom collaborates across multi-disciplines to convey this methodology. The main drawback of computer-based lectures is related to the varying attention spans of students. Designing lectures that accommodate variations in students' attention spans is a challenging endeavor. To combat this problem, CBVC lectures have been segmented into small sections called Slides, in which each slide can be viewed independently.

4. Software environment of CBVC

The software environment (SE) of the proposed CBVC is developed using Visual Basic Net (VB.Net). VB.Net is a flexible language employing reusable, object-oriented codes. Object oriented coding is an attractive tool for this application, as it avoids having to reinvent the wheel. The SE is decomposed into three major sections, as shown in Fig. 2: the user interface unit, the control unit, and the data base unit. The user interface unit is the one responsible for interacting with users. The data base unit is responsible for managing and accessing archival files, and the control unit, which controls the entire program, is the brain of the environment.

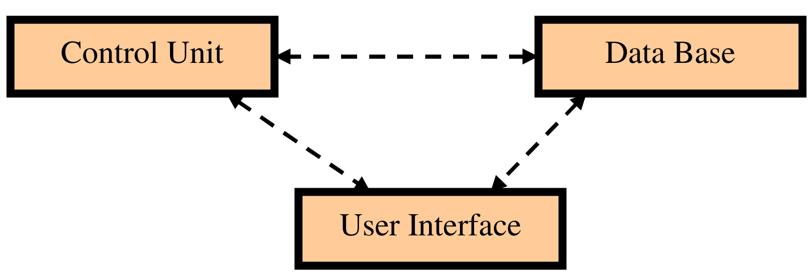

Fig. 2. The software environment of the proposed CBVC.

A: The Interface Unit

The interface unit communicates with the user by providing graphical information via the computer's monitor. This enables the user to interact with the program via the mouse or key strokes (see Fig. 3). To ease the user's interaction with the program, the interface unit was deliberately designed to be simple. This unit contains only a few menu options: FILE, VIEW, E-FLASH CARD, and CONTACTS. The FILE menu allows the user to play selected lectures, play a particular help session, or quit the program. The VIEW menu provides sizing options for the display window, and the E-Flash Card menu provides display options for the electronic flash cards used in specific lectures. The main interface is designated for showing the lecture. The lecture is stored as a video sequence—played upon user's request. The bottom buttons, on the left side of the user interface, provide stop, play, rewind, and fast forward options. This is a very important control feature. It enables the students to replay parts of the lecture that may be confusing to them. Lectures are divided into several segments, called slides, and each slide houses a major lecture theme. The student can easily move to a particular slide via the next slide and previous slide buttons located at the bottom right portion of the interface. The slide construction allows for easy modification of lectures, as new slides can be added to a particular location, in the event that new material may need to be added to a particular lecture at a future junction.

The help session provides computer based tutoring. This is implemented using a simple neural network structure. The student interacts with the computer in solving a particular problem. The student enters the answer into the computer. If the answer is correct, the computer will move on to the next problem; otherwise, the computer will interact with the student to solve the problem one step at a time, until the problem is solved. The interaction between the student and the computer is executed via dialog boxes. In addition, electronic flash card was implemented. Sample of the electronic flash card is shown in Fig. 4. the flash card summarizes the lectures key points and poses questions. The questions may be factual thus requiring memorization, or trivial which requires understanding, or analytical which requires critical thinking.

B: The Control Unit and Database Unit

The control unit is the brain of the CBVC software. Its main functionality is to control and monitor the flow of the program. The control unit also executes commands received from the user interface and database units. Based on the received input, the control unit accesses data and files from the database unit, then executes these commands. For example, when the control unit receives a user's request to play a particular lecture, the control unit obtains the files from the database that includes that particular lecture. It then plays the first file of that lecture and displays the application on the monitor. The control unit is also responsible for timing. Timing is used for executing the designed-time for interactive questions. Time limits for questions are assigned by the instructor and stored in the database. The control unit tracks time limits for each question. It then accesses the appropriate question from the database and waits for the answer. Once the answer is submitted, the control unit accesses the appropriate response.

The database is organized in chronological order identical to the order of the lectures. The database of the developed course is divided into two parts. Part one includes DC circuit analysis, and part two includes transient response and sinusoidal circuit analysis. Each part is divided into seven lectures, where each lecture represents one academic week. Each lecture has its own directory which contains a separate subdirectory for animated lectures in video format, flash cards, a help session, and exams. And each subdirectory contains the data which may be accessed by the user and/or the control unit.

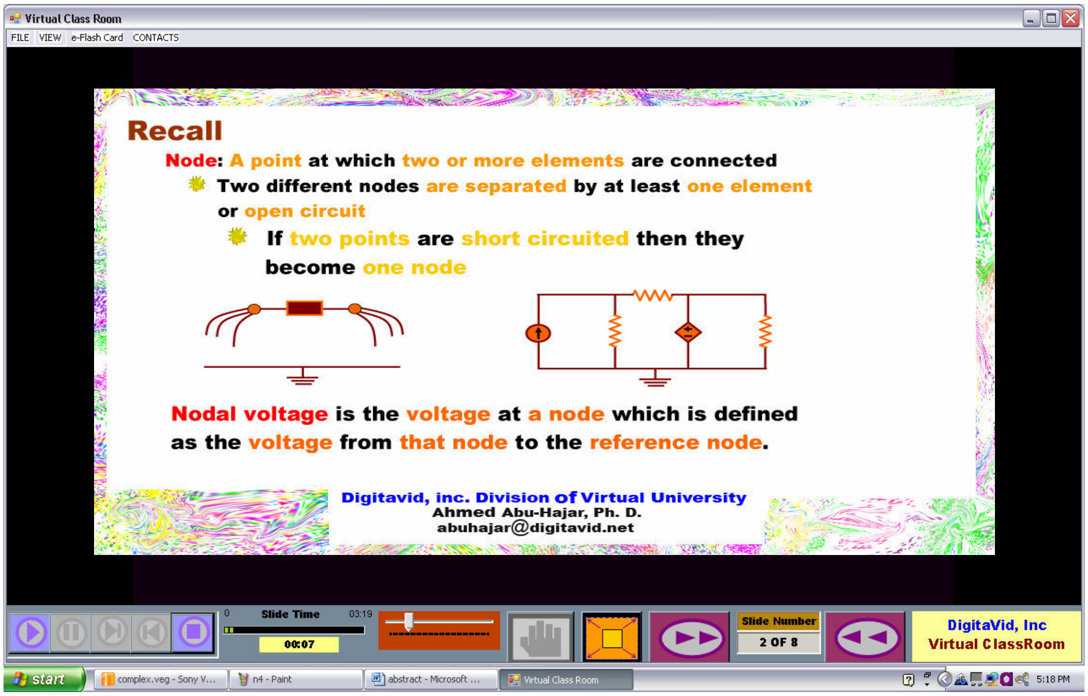

Fig. 3. The user interface of the virtual classroom.

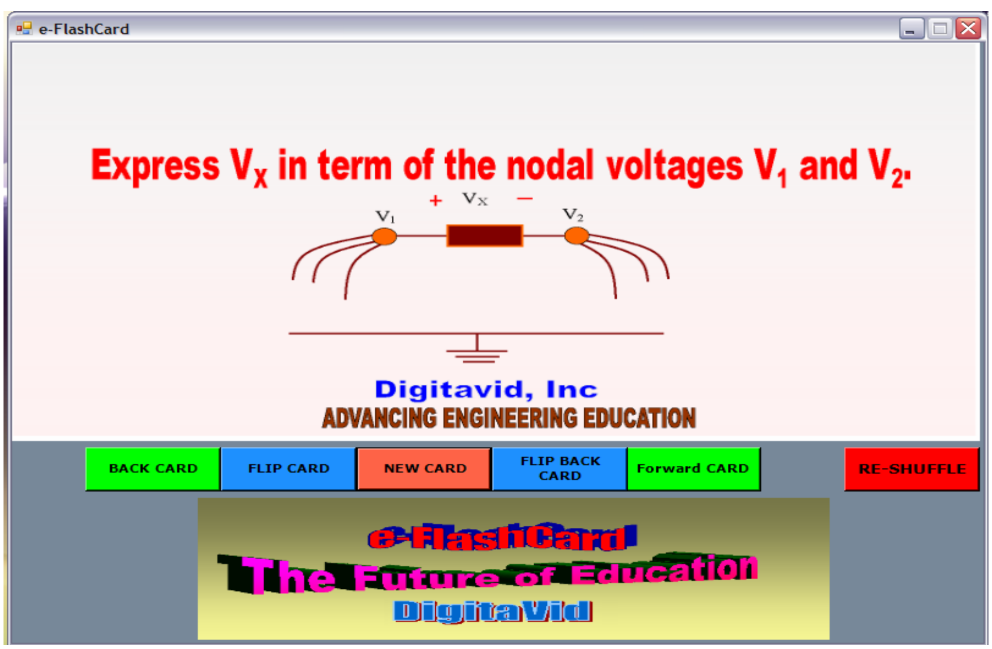

Fig. 4 The electronic flash card

5. Experiment and data

Our main objective is to measure the effectiveness of our proposed teaching methodology using CBVC. Hence, we developed the first electrical engineering circuit course that is taught in most universities using CBVC. This course is considered challenging by most students and the course is required for all engineering students at most universities. San Francisco State University's School of Engineering offers this course under the official course name: ENGR 205: Electric Circuits. A joint recitation lecture is also offered by the school. The recitation lecture is optional and roughly half the students who are enrolled in the circuit course are also enrolled in the recitation lecture. We have conducted our experiments to students who are enrolled in the recitation course. Their performances will be benchmarked with the students who are not enrolled in the recitation lecture. The recitation session focuses on problem solving, critical thinking, and building creativity. In our experiment, the recitation lecture is designed so that the student studies abstract lectures on their own time, and they would carry on problem solving and discussion during the recitation. We have conducted a questionnaire to assess the efficacy of CBVC. The questionnaire is shown in Fig. 5, and the results are shown in Table 1.

Survey for CBVC

Please select numbers from 1-5
1-Strongly Agree 2- Agree 3- Nuetral 4- Disagree 5- Strongly Disgree

Questions:

1- The presented lecrutes in Virtual ClassRoom increased my understanding of Electrical Circuits.
1 2 3 4 5

2- Virtual ClassRoom improved my grades in the course
1 2 3 4 5

3- Virtual ClassRoom may completely replace actual lectures in class room
1 2 3 4 5

4- Learning due to animation was effective
1 2 3 4 5

5- Learning due to colored and well organized lecture notes was effective
1 2 3 4 5

6- If Virtual classroom is required by the instructor, I would used it.
1 2 3 4 5

7- Virtual CalssRoom is not needed and it was waste of my time.
1 2 3 4 5

Fig. 5 Questionnaire for evaluating the effectiveness of CBVC

Table 1. The results of the questionnaire in Fig. 5

Question number	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	7	10	10	3	1
2	7	11	10	2	1
3	5	5	5	8	8
4	8	9	8	5	1
5	11	13	4	1	2
6	8	13	7	2	1
7	4	1	5	11	10

Question One examined the level of understanding perceived by the students. Over half the students believe that CBVC improved their understanding to the subject and about 15% believed otherwise. These numbers are consistent with Question Seven, where students believe that CBVC was waste of their time. Question Two investigated the efficacy of CBVC to improve their grades. Also, the majority of the students believed that CBVC improved their grades. This data is also consistent with Question One. Question Three showed very interesting results. Most students believed that CBVC do not replace the actual classroom. We believe that the lack of confidence in seeking knowledge among students especially at lower division courses reflects the need for instructor. More interestingly, 20% of the students believe that CBVC may completely replace actual classrooms. Questions Four and Question Five showed very interesting results. In both questions, the majority of the students believed animation and well organized lecture notes are affective. However, there is reverse correlation between the two. About 50% of the students who selected Strongly Agree in Question Four they selected Agree on Question Five and vice versa. We argue that animation is affective to students who are unable to visualize motions, and then animation may be used to assist students. Yet the majority of the students agree on the need of organized lecture notes for effective learning. This is because organized notes use redundant steps for rereading and/or rewriting which increase the effectiveness of leaning. Finally, Question Six showed that students would adopt CBVC if it is required by the instructor. It showed that students look at the professor as trusted figure for seeking knowledge.

6. Discussion and futuristic trends

The vision for this project is to advance engineering education by improving the effectiveness and efficiency of learning, while reducing costs. Our proposed teaching methodology recognizes the rigidity and abstract nature of engineering courses which requires passive learning. Yet, we also recognize that engineering profession requires creative, analytical and collaborative thinking in addition to decision making skills. We developed a computer-based classroom that mimics the conventional classroom environment. The students engage in factual lectures via computer, on their own time, while still attending traditional lectures. Traditional lecture time is dedicated to interaction, problem solving, and creativity building. Preliminary experimental data show that most students favor the project. About 20% of the students believe that computer-based learning will replace conventional lecturing altogether.

Computer based courses require a special type of academic advising, one that focuses on motivation. Unlike conventional courses, in which students are motivated by competition and social interaction, computer based courses use different motivational strategies, such as self actualization and career advancement. We have found convenience to be a negative reinforcement—students skip lectures and are easily distracted.

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