Multimedia-Based Instruction in Engineering Education: Strategy

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Abstract: Effective education depends on effective communication. In the past, it was necessary to structure engineering education around the available communication media, specifically the lecture and the textbook. Technology has added new communication media, most noticeably the computer. Further advances in communication technologies offer opportunities for changing engineering education in a way that will vastly improve our consumer and product—the entry-level engineer. Interactive multimedia (IMM) is a communication technology that can potentially replace the large-class lecture and textbook as the communication medium central to engineering education. The potential advantages and possible disadvantages of IMM are discussed. A multiparadigm strategy for packaging IMM is presented. Such a comprehensive strategy will be necessary if IMM is to reach its potential as a central element of engineering education.

INTRODUCTION

Multimedia has been referred to as the marriage of the computer and the television. Actually, it is more than the sum of the two, especially interactive multimedia (IMM). It is a medium that combines a variety of communications elements, with the advantage of each individual element emphasized and used to minimize the disadvantages of the other elements.

The elements of a multimedia system can include the following: audio, text, two-and three-dimensional graphics, animation, still pictures, and motion pictures. The system can present real-time action or nearly real-time simulated action. The time parameter can be compressed or expanded to improve visualization of a slow or fast event. Multiple-screen presentation enables several of the multimedia elements to be used simultaneously. This would enable the student to simultaneously view the real-world functioning of an engineering system and the corresponding design element. For example, still photographs of various stages of a flood could complement the graphical development of a stage-discharge curve, with the mathematical model presented as text. The simultaneous presentation of concepts should increase understanding and enhance knowledge retention by students.

The elements of multimedia affect both the cost and the complexity of the application. Existing computers easily handle text and graphics. Still pictures and animation introduce more complexity and increase in cost. Audio, especially stereo, requires more costly peripherals, and moving pictures require considerable storage, which can be costly. Although development costs are an important consideration in program design, the hardware costs of the user should also be considered (Meyer et al. 1994). Only the elements necessary to present the material should be used because the number of potential users will decrease as the cost increases.

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HOW DOES MULTIMEDIA AFFECT TEACHING?

Engineering education has traditionally taken place using the text-lecture-laboratory-test paradigm. To a certain extent, it was molded by the availability of communication media, and in most respects has been very successful. But should this success dictate that this educational paradigm be continued without modification? In the last decade, attempts have been made to make significant changes in the way that engineering is taught. Computer-aided instruction (CAI) is probably the most noticeable change, but this has not been as widely adopted as originally expected nor has it been sustained and expanded in many programs where it has been tried.

Computer-aided instruction is significant because it introduces a new communication medium into the learning process. But why hasn't CAI become the standard and made greater inroads into the traditional educational paradigm? Certainly the availability of resources has been a factor, and some might point the finger at the reluctance of faculty, especially the older faculty, to adapt. Some might argue that the software has been too passive-learning oriented and that, although it allows the student to move at his or her own pace, it has not made the transition from behaviorist learning to constructivist learning. Furthermore, the software has largely been unidimensional in that it has been text-oriented.

Multimedia communication offers the potential for changing the focus of engineering education (Borkowski et al. 1994). Instead of behaviorist learning, where the students mimic the behavior of the text, lecture, and prepared laboratory procedures, students can participate in constructivist learning, where they construct the knowledge by performing simulation and virtual experimentation. Interactive multimedia communication enables learning to be active rather than passive. The multidimensional nature of multimedia provides a participatory educational experience where the engineering student learns engineering in much the same way that the practicing engineer does in engineering design work.

STRENGTHS AND WEAKNESS OF MULTIMEDIA

Multimedia education has numerous advantages. Its strengths can be separated into categories, such as (1) advantages in development; (2) advantages in application; (3) advantages related to learning attitude; (4) advantages in learning style; and (5) advantages related to knowledge retention. The advantages in each of these groups are as follows:

The effectiveness of any educational material depends on the teacher's familiarity with the material. Multimedia instruction enables the teacher to be the author, thus ensuring that the instruction will follow the format preferred by the teacher. In developing multimedia packages, the teacher will have access to a wide array of visual and audio resources. Thus, the multimedia-based program can help compensate for the lack of physical resources.

There are a number of advantages that relate to application. These advantages are common to the advantages of computer-aided instruction. Specifically, the instruction can be self-paced, which should result in optimal retention of the material. In addition, the software can be designed to meet the needs of each student, thereby eliminating one of the biggest problems in lecturing to large classes. The instruction medium is portable in both time and space; given the software and the appropriate hardware, the student can access the instructional material at any time at any location.

In the past, learning media paralleled media used for entertainment; textbooks were used in school when students read novels as a leisure pursuit. Similarly, computer usage in the classroom has increased at the same time that computers have become more common as part of recreational activities, such as computer games, and on the nightly news. Therefore, people are developing a positive attitude to this communication medium, and its use in educational settings is natural and should encounter little resistance. Another positive aspect of multimedia is that it has the potential to decrease boredom because of the diversity and interactive nature of the communication elements.

One of the primary advantages of multimedia is its potential for interaction. Active learning has numerous advantages over passive learning, and multimedia interactive learning has significant potential for enabling students to construct knowledge, not just passively mimic the book examples and lecture notes. With IMM, students can formulate and test some hypotheses on their own initiative. Interaction allows the students to participate in the decision process much the same way that they would in a group, as in engineering practice.

As an educational tool, the primary purpose is to improve the student's retention of the material. Though specific studies have not shown that IMM increases retention, there is no reason to believe that it wouldn't be at least as efficient as the traditional paradigm. Retention should increase because IMM enables students to observe real-world phenomena through motion or still pictures simultaneously with text that shows theories, definitions, and mathematical models of the underlying processes, thereby reducing the abstraction in the mathematical models. Simulation enables the students to observe phenomena that are inaccessible because of danger, prohibitive cost, or unlikely events. Simulation also enables students to experience responses to a wide array of input conditions and values of system parameters.

There are numerous advantages of multimedia, but there are also some drawbacks. The biggest problem related to the use of a multimedia system is the initial time investment by the instructor. It should be recognized that the traditional text-lecture-laboratory-test paradigm, by far, requires the least amount of preparation time from the instructor. Training of teachers to use the hardware is necessary and, in some cases, it is necessary to overcome the resistance of the faculty to the new technology (Hotchkiss 1994). Because inclusion of IMM software into their courses will require changes in course content, they may not want to expend the time and effort. The combination of unwillingness to invest the time and fear of or unfamiliarity with computers will undoubtedly account for a significant percentage of instructors. If IMM indeed increases learning efficiency and retention, then a portion of these instructors may be willing to relinquish the traditional educational paradigm in favor of the new one.

Another disadvantage is the cost associated with IMM. Although cost is likely to decrease substantially as the demand increases, equipment updating, based on past experience, is a real concern. As computer technology advances, existing hardware and software quickly become obsolete. Hardware replacement and support staff will increase the budgetary requirement significantly. Without a financial commitment to support this change, it will almost certainly fail.

Hardware limitations are a concern to the developers and users. These limitations, however, are quickly overcome as computer technology advances. For example, at the present time, 24-bit color motion pictures are limited to approximately 5 min per compact disk (CD) at 50 frames per second. By using data compression, 60-min capacity is at the horizon and will soon be available.

Finally, production time can also be a major effort. Production requires experienced personnel and a major time commitment. In addition to programming the linkages of the IMM elements, production is complicated by the difficulties in timing. Editing often requires a significant portion of the production budget.

STRATEGY IN USING MULTIMEDIA TOOLS IN CAI

Although the advantages of CAI are many, failed attempts to exploit the computer is the norm rather than the exception. The most compelling reasons for this high failure rate are the lack of planning and support on how CAI should be used and the lack of proper evaluation. Often, the author of a CAI tool creates it on his or her own initiative. Such tools are typically fancy electronic page turners that are redundant to the textbook and lecture. And invariably, students can't use it as a self-paced learning tool because it does not contain sufficient examples that students so rely on to do their homework problems. The result of this redundancy and lack of example quickly make these CAI tools obsolete as students find them time-consuming and ineffective. Three educational paradigms may avoid these classical problems: computer-assisted class notes; self-paced learning tools; and simulation and virtual experimentation tools. The following paragraphs give an exposition on how IMM tools can be employed in these three paradigms.

PARADIGM I. COMPUTER-ASSISTED CLASS NOTES

In the computer-assisted class-note paradigm, the IMM tool is primarily used by the instructor. Redundancy is eliminated because the IMM tool becomes part of the lecture and does not require additional effort by the students. Generally, it does require additional preparation time by the instructor, especially when it is used for the first time. The advent of electronic communication tools such as Mosaic can reduce the instructor's preparation time by enabling the use of materials developed and used by others (Vaughan-Nichols 1994; Markoff 1993; Wintsch 1989). Teaching and learning efficiency may increase significantly by reducing the time needed to draw figures; improve visualization; incorporate video, audio, animation, and still graphics for background and case studies; use simulation to show alternative scenarios. The result is to emphasize and increase conceptual understanding.

How students will adapt to a significant change in their normal mode of learning—passive transfer of lecture notes—must be addressed. Students may feel the necessity to copy the lecture notes even though it is in a nearly nontransferable format such as animated simulation. Given the importance of the student's interaction during the presentation, easy context switching to return the class to an interactive problem-solving mode is a necessary ingredient to success in this paradigm.

Another important ingredient is the adaptability of the material. Can lecture material be changed or corrected easily?

To be successful, IMM presentations will need to adapt to the student's need for additional material. For example, if the lecturer recognizes that students have misconceptions during an IMM presentation, the system will need to be sufficiently flexible to introduce new, unprepared material in an IMM format. Marking on the projected image or the computer screen is indispensable because it makes the prepared lecture adaptable to student needs.

Finally, it should be pointed out that the preparation and proper use of the IMM material is very important. We have all experienced lectures in which prepared slides have far too much information and were advanced at a pace at which comprehension was minimal. From the students, perspective, these lectures are of little to no value. Comprehensive preimplementation evaluation is critical to avoid this problem.

PARADIGM II. SELF-PACED LEARNING TOOLS

Self-paced learning tools were one of the initial implementations of CAI. The PLATO system developed and used at the University of Illinois was successful because it took virtually no effort to learn the touch-screen interactive system (Bennett 1973; M. Amarel, unpublished technical report, 1975; Bitzer 1986). Ease of use is a primary factor controlling learning efficiency, and it must be present in order for a CAI tool to be successful. Other factors contributing to the success of PLATO included student's curiosity, active participation, and schedule independence. These four factors are important for the success of a CAI tool. A self-paced learning tool also has the advantage that students may review the material as many times as necessary until they have thoroughly mastered the subject. In addition, self-paced learning tools can be implemented to adjust the level of difficulty to match the students' responses. Such adaptability is important and is missing from large classes in which the lectures are typically targeted at the slower students.

If students can be persuaded to use a self-paced learning tool, lectures may be turned into interactive problem-solving sessions in which they are active participants rather than passive copiers. One way to persuade students to use this learning medium is to add an evaluation mechanism to the end of each unit, then make their grades dependent on their performance on the test. The bottom-line question: Is it sufficient for students to learn from these tools, or do they still need the textbook? If they still believe that it is necessary to use the textbook to be able to solve examination problems, then students would most likely develop negative feelings toward IMM. Testing at the end of each learning session should increase the student's concentration during the IMM presentation, thus improving their comprehension. This will make it less likely that problem-solving sessions will be necessary to bolster their ability to solve examination problems.

PARADIGM III. SIMULATION AND VIRTUAL EXPERIMENTATION

Muppet and Cuple are examples of simulation and virtual experimentation type CAI tools (Redish 1989). Many simulation programs have been written for engineering and science education. A partial list includes work by Huston et al. (1994), Song (1992), Magin and Reizes (1990), Cleaver (1988), Levary (1986), Koen (1985), Whitman (1985), Hinton (1977), and Bailey and Kain (unpublished paper, 1973). These tools allow students to test their own ideas and see results almost instantly (Smith and Pollard 1986). Such near-real-time response has been shown to increase conceptual understanding. Most educators agree that laboratory experiments are an integral part of learning engineering principles. The question is whether students learn as much with virtual simulation as compared to hands-on experiments. Although the answer to this question can only be found through a longitudinal evaluation of students, we attempt to list the advantages of each approach.

The advantage of using a hands-on experiment is obvious: students learn the experimental procedures and gain firsthand experience in equipment usage, data interpretation, and analysis. Although students miss this hands-on experience in a simulated virtual experiment, learning efficiency can nevertheless increase because (1) experiment preparation time is minimized; (2) students can be taught to be critical of video media by being required to base opinions on real measurement done on video; (3) experiments can be performed in slow motion, fast motion, and backward and forward movement, if necessary; and (4) experiments can be repeated to ferret out problems that may occur during data reduction. Simulation and virtual experimentation should enable students to test many more alternative conditions than when using the laboratory. They can also be encouraged to design their own experiments to test their own theories and understanding. In addition to these salient features, virtual experimentation demands the student's active participation, similar to that necessary when they perform a hands-on experiment. The result is improved conceptual understanding and increased learning efficiency.

Another good use of simulation is to incorporate experiments into class lectures to demonstrate theories and show the correlation between "real" phenomenon and theoretical models. Clearly, virtual experimentation requires a significant amount of preparation time from the instructor. If teaching efficiency is measured by the amount of time spent to teach a particular subject, then the use of simulation and virtual experiments undoubtedly lowers teaching efficiency. By this measure, lecturing directly from a text is the more efficient method. However, teaching efficiency must be assessed using more criteria, such as the amount of time that an instructor can meet one-on-one with students. Perhaps this use of a single criterion explains why so many attempts to use CAI have been discontinued. This problem can be mitigated and teaching efficiency improved using an efficient dissemination method so that simulation developed by one instructor can be quickly and easily distributed to other instructors on the network.

MULTIMEDIA PACKAGING

Past attempts to use CAI have mostly followed one of the three paradigms listed previously. These paradigms should not be considered mutually exclusive when developing IMM packages. In fact, an efficient use of IMM tools should contain elements of all three paradigms. If the three paradigms are to be elements of an IMM package, then it is obviously necessary to commit greater resources to the program. Failure to provide these resources can reduce the effectiveness of the IMM package. Resource assessment is, therefore, an important element of program evaluation.

The ultimate goal of IMM should be to increase students' learning efficiency while minimizing the extra work load of faculty. This requires strict coordination between the three paradigms. For example, self-paced learning tools should not be redundant with lecture materials. The medium that can be best used to motivate and explain a particular concept must be strategically placed to maximize the students' learning efficiency. Simulation and virtual experimentation tools must be easy to learn and the procedures thoroughly explained so that students spend most of their time learning the concept rather than learning how to use a program or software.

It is well known that many students are most concerned about examination scores and course grades. The past experience of these students may drive them to concentrate their effort in learning how to solve "examination-type" problems. These students are often satisfied with a large number of examples provided by textbooks while ignoring the fundamental principles provided in the text and lectures. How can the use of IMM tools succeed in this environment? The IMM package must provide the examples desired by students, but must simultaneously emphasize the connection between the solution formulation and the fundamental principles. This is necessary if students are to overcome their poor learning habits.

Another custom that students may not want to relinquish is taking notes. Simulation and video presentations are not amenable to this practice. Traditionally, students have not taken notes during moving pictures shown in classrooms, possibly because the moving pictures are often not quantitative and thus students do not concentrate on their content. This attitude may originate as early as middle school, but it is firmly ingrained. Thus, the simulation graphics and moving pictures should simultaneously be supplemented with on-screen text material that focuses the student's attention on the central points of the dynamic communication.

Recognizing that questions will arise during an IMM lecture, all IMM tools needed to produce lecture notes should be available for the teacher to use during class time. A mobile multimedia system is preferable so that classes are not restricted to special computer laboratories. Mobile systems also facilitate class preparation by the instructor because they can be easily accessed from home or away from office.

Based on these criteria, one possible packaging of IMM tool is the following: (1) Create a set of self-paced learning tools with its own evaluation to be completed before the lecture to ensure that students are well prepared when they come to class; (2) incorporate video of background material and experiments into computer-aided lecture notes to motivate the study of the material; (3) incorporate simulation tools to demonstrate concepts into IMM lecture notes; (4) make lecture notes and simulation software available to students outside of the classroom; (5) use part of the lecture as a problem-solving session to satisfy the students' need to perform examination-type problems; (6) make available both hands-on laboratory experiments and virtual experiments so that students get both a critical look at the theoretical model and hands-on experience; and (7) develop and use teaching practices that are appropriate for use with IMM materials. Packaged in this manner, redundancy of teaching material is kept to a minimum, and IMM can be a more effective teaching medium.

SUMMARY AND CONCLUSION

Multimedia is seen by many as a tool that can effect improvements in education. However, piecemeal implementation of materials on the multimedia environment will probably result in as many problems as solutions to engineering education. A proper implementation should include both curriculum and course-level changes. The use of multimedia in a new paradigm involving computer-assisted lecturing, self-paced learning tools, and virtual experimentation tools was outlined.

In the past, engineering education has made use of the available communication media. IMM is a new and powerful communication medium that is changing many aspects of society and it needs to become an integral part of engineering curricula. It offers many advantages, and if properly packaged has the potential to improve engineering students' knowledge of the fundamental principles as well as their grasp of how the transition between being an engineering student and an entry-level engineer. The IMM will enable the graduating student to more quickly adapt to engineering practice.

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