

On Distance Learning in Engineering

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Abstract

Engineering programs have been offered to off-campus students for many years. Most of the successful programs have been concentrated in metropolitan areas with large numbers of engineering companies or at military installations. Current technology and demographics present new challenges and opportunities in reaching many engineers who work for small companies and need to continue their education while on the job.

The effectiveness of televised instruction has been measured by comparing test scores and other achievement measures of students who are taught in traditional classrooms with those students who are taught by televised classes. A majority of these comparative studies show that students taking televised classes do as well, if not better, than those who are taught in traditional face-to-face type of environment.

The need for providing higher education to part-time students working in industry is growing. Delivery methods include live televised courses, videotapes, and the Internet. These methods depend on cost effectiveness and university support. Long-term, sustaining efforts that can grow and be a part of the education business are needed.

Colleges are moving toward a point where students may be matched with a particular delivery medium based on their learning styles and on their lives. For distance learning to succeed, it has to have institutional reward systems that reflect distance-learning activity. This paper provides a comprehensive review of the use of distance learning in engineering curricula and continuing education.

I. Introduction

Technology has enabled a radical shift in the way education for people of all ages can be addressed. In an age of life-long learning and increasing globalization, distance learning alternatives appear destined to become even more important to educational institutions of all types. Distance learning technologies provide the means whereby learners can interact with peers, resources, and experts to build knowledge and develop skills. Networks enable the teacher to become a facilitator, providing educational structures, and guiding the learner in accessing the data and organizing the information into knowledge. These systems serve to give learners increased control and agency in the knowledge-building process [1].

Establishing some form of personal contact with distance-education students and letting them know what is required in a distance course are both essential. Successful instructors frequently give their often overloaded students some flexibility in assignments and test-taking. Instructors are also optimistic that as they grow more comfortable teaching online and technologies become more sophisticated, their retention rates will improve. There is significant variation among institutions—with some reporting course-completion rates of more than 80 percent and others finding that fewer than 50 percent of distance-education students finish their courses. Several administrators concur that course-completion rates are often 10 to 20 percentage points higher in traditional courses than in distance offerings.

There has got to be recognition in the rewards system that this is just another legitimate and straightforward means of delivering education to a quality of student that is frankly not all that much different from the classroom student. Some professors stated that administrators incorrectly assert that putting courses on the Web is easy, straightforward, and inexpensive, proposing that any administrator making such a claim should be required to put a course online—over a weekend. Faculty members badly need more support—not just new hardware and software, but also training in how to use them and how to change teaching strategies to take advantage of them. Most institutions, including wealthy ones, do relatively little to help professors in that area.

Many interesting discussions are available in the literature about the advantages and limitations of distance education methodologies and technologies, namely web-based teaching and learning [2, 3]. Despite some limitations, distance education and training has an important role to play in the offer of universities as one of the frameworks provided for their target audiences. This is especially true as an alternative way, and often as the unique way, to provide access to qualified education to isolated populations or to part-time students.

Engineering educators are beginning to place importance on teaching as well as course content in the classroom. Educational researchers in engineering are examining how students learn and how teachers teach [4] and on how to incorporate cooperative learning in the classroom [5]. In addition, there is a trend for school administrators to look more closely at the results of faculty members' teaching, i.e., outcomes-based education.

Distance education offers great potential to improve access to educational programs and resources, enhance the quality of academic instruction, and improve the productivity of educational institutions. The driving force behind distance education initiatives appears to include the public demand for cost control in higher education, increased demand by potential students for services, and a push to move institutions towards a virtual learning institution. Another major influence in the decision to offer distance learning programs is the threat of competition from *for-profit* institutions [6]. Students are quickly changing their higher education demands to include the delivery of academic programs at any time and any place [7]. In addition, lifelong learning has become a reality for Americans [8], and distance education strategies have the potential to overcome significant barriers to lifelong learning [9].

II. PC-Based Video Conferencing

PC-based video conferencing allows graduate and undergraduate courses to be presented at multiple locations across campus, to be shared with distant colleges and universities, and to be piped to corporate sites. With inexpensive hardware and software, courses in jeopardy of insufficient enrollment can draw from a larger pool of students, and courses which would be geographically inaccessible can be made convenient.

Unlike asynchronous courses a conferenced course affords public, real-time discussions among the instructor and students. Conferenced courses do not require the creation of an elaborate self-study guide. Several papers in the literature provide guidelines for course conducting and managing [10-14].

Success in delivering video-conference courses is normally due to the excellence of the support staff, instructors' availability and responsiveness to the students, and the students' maturity, constructive attitude, and cooperation in making it work. What follows are some practical observations [15].

III. Computer Assisted Collaborative Learning

Computer assisted interactive demonstrations and activities were integrated into two introductory linear systems courses provided over two-way compressed video from UMass Dartmouth to UMass Boston [16]. The combination of methods used, as well as the basic design of the classroom, were modeled after those used in RPI's studio physics classes [17]. They were also heavily influenced by the large amount of literature on cooperative learning and active learning [18, 19].

The combination of collaborative learning methods and computer assisted, hands-on activities have proven to be very effective in the sequence of linear systems courses at both the live and remote sites. Students motivation in the classes appeared to be high. They obviously liked the class format and commented favorably about it. In addition, students often stayed after class to experiment with a computer based activity.

Most students at the live end of the video link seemed to enjoy the addition of remote students to the class. The majority of students at the remote site in Boston were somewhat older than the students at UMass Dartmouth and their different perspective added to class discussions. Despite some of the difficulties such as later exam and homework returns, approximately 42 percent of students of both classes at UMass Dartmouth indicated in the exit survey that having the remote site actually helped the class, while an additional 42 percent of them said that the addition of the remote site made no difference.

IV. Large-scale Distance Teaching

Large-scale trials of Internet-based university-level distance teaching have been reported [20]. The use of technology, and more specifically the Internet, has been an important advance for distance education. However, simply translating material from familiar media into electronic

form is rarely productive — and is certainly inadequate for supported distance education which aims to engage the student in a *community of learning*. The value Internet technology brings to distance education lies not in direct translation from other media but in transformation of support mechanisms to exploit its potential range. The Internet has the potential to meet the changing social and educational needs of students — in particular the need to choose their own time, place, and style of study. Universities respond to societal trends, and it is natural that they should follow the trend to use technology [21]. Also, universities are having to re-examine their ways of working, stimulated by developments towards an information superhighway and the ease of accessibility to non-discursive global information resources [22]. Educators are looking to technology to solve many of their problems — including increasing student/staff ratios and diminishing funding — while at the same time seeking to improve their teaching to provide a better student experience [23-25].

Making the shift to Internet presentation effective requires cultural change by both students and teachers. Students must take responsibility for their own learning and take initiative in bringing problems to the notice of teachers. Instructors must adapt their expectations and practices to accommodate a remote, often invisible student body. Internet presentation may further require culture change from the university, for example by reorganizing the tutor network away from the current regional structure.

The real key to successful application of technology is good teaching, using technology only when it is a cost-effective servant of pedagogy. Experience has shown that it is easy to propose an electronic solution that is more expensive and time-consuming than the paper-based system it is supposed to improve upon [26]. Existing processes must be analyzed deeply and critically in order to provide fully- and appropriately-realized Internet teaching that serves learning at least as well, and at least as economically as conventional methods.

Time and location independence only scratch the surface of flexible learning. The student may learn faster and more thoroughly based upon previous exposure to the subject or the fit of the presentation medium and methods to his or her learning styles. This highlights the potential advantage in self-paced learning which provides a flexible time frame within which the experience is completed. Variation in the level of exposure provided to each student based upon the needs of the student can be utilized to the extent of diagnosing the knowledge level, learning style, and ability of each individual student and reacting to provide a learner-tailored experience.

V. A Corporate Approach for Flexible Delivery Education

There are many examples where individuals and groups have embraced new technology to enhance learning and capture new markets. Invariably difficulties arise from infrastructure requirements, lack of standards and the inertia of faculty and student populations to change. RMIT University, formerly the Royal Melbourne Institute of Technology, Australia, recognizing the need to change and the threat of inaction has developed and implemented a corporate strategy. The change has been achieved through: a corporate Teaching and Learning Strategy focused on student centred approaches; a conscious identification of flexible delivery and assessment through the use of computers; the need to define and deliver graduate attributes

consistent with professional practice and accrediting bodies. The Information Technology Alignment Program (ITAP) and the Distributed Learning System (DLS) have been established to provide a standard university wide infrastructure and interface for program development and delivery. Changes of this magnitude and nature are not possible over a very short period [27].

The top-down approach taken by senior management of RMIT University has ensured that academics and teachers work seriously to improve teaching and learning. There is no refuge in hoping that the focus on teaching and learning would pass, just as other management *fads* had passed [28]. Across the whole University, staff are using a consistent language and talking about issues that do contribute to improvements in teaching and learning. It is noticeable that there is considerably more debate about learning processes. This is particularly significant in an engineering faculty where traditionally the mind set is on the technology content. On the other hand, the university is engaging in a cultural change of considerable magnitude and some staff just do not share the vision; for them change is slow. With pressure coming from the top there is, however, encouragement for educational innovators and direction for those who meander in conventional ways.

The corporate approach, with emphasis on flexible delivery and use of technology in learning, has created a climate and widespread major effort to address the identified four agents of change: government, student attitude, life style and global competition. In Engineering, the structured approach via topic learning guides is gradually moving staff to improve the linkage of objectives with assessments. Eventually they will include performance criteria that capture the graduate capabilities which engineering accreditation bodies are looking for in their assessment. It is believed that the corporate approach has the best chance of addressing the imperatives of change.

Challenges of Program Delivery

Minor problems always arise in ordinary on-campus course delivery. Students have difficulty finding books and supplies, getting computer accounts, finding their instructors, distributing voluminous notes—the list is endless. On campus, the network of students, peers, faculty and staff solves these problems in a very routine fashion; hardly anyone really notices. It is a different story off campus. Many of these problems, but not all, are anticipated. It is necessary to respond quickly to email messages and telephone calls indicating unexpected problems. It was necessary to be nimble and capable of rapid response, characteristics not normally associated with a university [29].

Teaching undergraduates is different from teaching graduate students at a distance. There is no significant difference in motivation or eagerness to learn between graduate students and the undergraduates. However, greater variability exists in the off campus undergraduate population than in the on campus undergraduate population. The best of the off campus students perform at a level equal to or somewhat above the on campus best students. Their overall performance is somewhat higher, and their motivation and sincere dedication really show and affect the on campus students. Few of the off campus students have failed or withdrawn from a class, but they have found the courses to be major challenges because of variability in their backgrounds.

It appears that many students should only enroll in no more than one class a semester. This is encouraged as appropriate.

Classrooms that have the video equipment, computers and other technological aids to instruction, give the instructor the capability to enhance instruction by using computational equipment and demonstrations that simply are not possible in the ordinary classroom. The in-band fax capability allows last minute transmission of a few pages of notes to the off-campus student.

Evaluations of potential students are critical. They take time and must be done on an individual basis. Transcripts must be available. The age of courses and possibility of unexercised study skills must be considered.

Not all of the students presently have Web access from their homes and/or workplaces. This inhibits use of the web for such distribution, but as this capability increases, web distribution will become more popular and effective.

VI. Rewards Remain Dim for Digital Scholarship

Many faculty members and administrators remain skeptical about the quality and effectiveness of online research and teaching. That skepticism—in some cases, outright hostility—can discourage young faculty members from using online media. Other issues include the extra time online projects take, as well as opposition in some quarters to attempts by faculty members to designate their work in digital instruction as a form of research.

Administrators and faculty members in various universities say they are committed to expanding the use of digital technology in research and teaching. However, efforts should be made to explore ways of rewarding digital scholarship by both senior and junior faculty members. A survey of faculty members by the National Education Association was conducted on how the rewards offered to instructors shape their use of information technology. It was found that established professors, rather than those without tenure, were more likely to use online technology in teaching. It was suggested that junior faculty need to invest their time in things that are going to get them tenure and that in most cases, spending time on cutting-edge digital projects will not have that payoff. Digital scholarship is still so new that it has not been worked into the criteria for promotion and tenure [30].

Lack of Evaluation Tools

Academe has not developed methods to evaluate online courses adequately. It is hard to evaluate the course based on criteria such as “the quality of the interaction.” Scholars have only a limited vocabulary for evaluating the characteristics of online instruction. They should develop a culture of reflective practice that would enable them to discuss how online instruction influences students’ learning.

Some faculty members worry that online instruction will replace them. But such concerns were unfounded because online instruction cannot forge a personal bond between a teacher and a

student. Such a connection is required to “turn on the light bulb” for a student. It should be realized that the incorporation of technology in the university is inevitable, and that it is something to pay attention to. However, the fundamental issue is the quality of what the professor does and whether or not students learn from it, not whether online technologies are used. A university’s reward structure—including tenure decisions—should be flexible enough to encompass both excellent teachers who do not use technology and excellent teachers who do.

Online scholarship changes other factors in the tenure process as well. Universities seek evidence that tenure applicants have developed national reputations. But the Internet’s global reach can change the way scholarly reputations are developed. Many university administrators want to promote more online scholarship, but they need to find ways to evaluate the novelty and significance of a scholar’s online work. The climate is receptive; the problem is in documentation and evaluation. What the instructor has to do is demonstrate impact that is reflected in peer judgments.

University administrators and faculty members should think through and articulate the issues surrounding online scholarship. In order to reassure young faculty members, some very clear processes should be evolved on how this material will be judged. Unless that happens, the tenure equation will penalize and intimidate young scholars who work with online media [30].

Roadblocks to Distance-Education Growth

As with any change, particularly the alteration of such an entrenched paradigm as traditional classroom instruction, the distance learning effort has met roadblocks. Conflicts between remote and local schedules have highlighted the need for asynchronous delivery. The inertia of the current method of operating includes changing instructor roles and faculty security concerns as remote classes are consolidated with local ones. As the instructor and students learn and attempt to become comfortable with new methods and technologies the learning curve will extract time and dedication. Coordination of remote activities will burden the course coordinator during the initial startup but should become minimal as the learning curve flattens for all involved. The quality of the experience of students who no longer have extensive personal contact with the instructor should be monitored closely [31].

Learning Styles

Colleges are moving toward a point where students may be matched with a particular delivery medium based on their learning styles and on their lives. The rise in the number of online courses and the increasing sophistication of technology will ultimately improve retention in distance education.

Some instructors remain confident that fully utilizing the Internet will help them improve retention. When one professor switched to a more interactive Internet program that allowed him to hold regular chats and organize e-mail messages more efficiently, his course-completion rates jumped from 62 percent to 90 percent. The improvement required a major investment of the instructor’s time. The key to having successful completion in the online medium is the ability of instructors to keep the students engaged, and that requires quite a bit of effort from the instructor’s point of view.

VII. Strategies for Institutions and Instructors

Distance learning students are faced with the challenges of tracking down the appropriate contact person for administrative questions; they must obtain registration materials, transcripts, and other official business in a timely manner through telephone or e-mail contracts; and, they must seek out their own guidance and career assistance from outlets removed from the campus. These can be challenging obstacles, and often lead to the high attrition rates associated with distance learning. By taking the following steps, institutions can avoid such attrition, and ultimately, the failure of their distance programs [32].

- Provide a toll-free telephone number specifically for distance students. This number should allow them to be transferred to any department or individual they may need to contact.
- Provide a contact person or distance-education liaison who maintains regular hours and availability. The person should answer questions regarding administrative details of the students enrollment and progress.
- Devise mechanisms whereby distance students are easily provided with an identification card or number.
- Provide career assistance and guidance through electronic means. Workshops and lectures should be video streamed and archived on the institutional Web site.
- Develop delivery mechanisms with campus or other bookstores, or ensure that course texts are available. Students should be able to procure their texts as easily as on-campus students can, and this may require a toll-free order line and direct delivery without additional delivery costs.

Faculty and instructional staff in higher education are relearning their roles in the face of distance learning. Buchanan [32] has offered a series of questions and considerations individuals should consider before they agree to teach online. Such qualities include a comfort level with multiplicitous perspectives, active questioning from students, the ability to convey emotions through the written word, dedication to the online class above and beyond a traditional class, and a sound commitment to *listening* and relinquishing the *stage on the stage* role, among others.

VIII. Discussion

Distance education may provide a win-win solution for colleges, students, and taxpayers. As teaching techniques are improved and people's attitudes change, students will not need to travel as often to campus for classes and, therefore, constant expansion of on-campus buildings and facilities will become less important. Once the infrastructure for distance education is in place, the marginal costs of teaching additional students should be relatively low [9]. Issues related to this movement towards distance education are far reaching and impact the entire educational institution including faculty, students, and support services.

Universities are autonomous institutions, however, in the knowledge economy, entrepreneurial universities will be as important as entrepreneurial businesses. The *do nothing* universities will not survive—and it will not be the job of government to bail them out. Universities need to adapt rapidly to the top-down influences of globalization and the new technologies, as well as the

bottom-up imperatives of serving the local labor market, innovating with local companies, and providing professional-development courses that stimulate economic and intellectual growth [33].

Interest in distance learning is at an all time high especially with the popularity of the World Wide Web, Internet, and Intranets. This interest has led many authors to report in the literature on best practices, technology used, personnel roles, company policies, design methods, and teaching methods. In distance learning, it is not enough to do one course as an experiment. A one-time experience is costly and time-intensive, but when a course is offered for the third or fourth time, initial time and cost investments become worthwhile. It should be realized that whether the course is distance-learning or otherwise, it takes time to prepare it, it takes time to deliver it, and there are only so many students that a faculty member can handle reasonably and do a good job. When a distance-learning course is offered for the first time, it probably takes twice as long to put it together as it takes to put together a normal classroom effort, because the instructor has to organize more completely, and be more prepared in advance.

Multi-national corporations are facing several challenges when deploying policies, methodologies, and tools to their global work force. Instructor travel is increasing the cost and time experts are away from their primary functions. Technology driven change to policies, methodologies and tools used by the global work force is occurring at an increasingly rapid pace. An emerging solution to these problems is the utilization of existing telephone, video conferencing and computer networking equipment to implement training on policies, methodologies and tools. By working together in a partnership, the needed resources and expertise can be pooled to exploit more fully than any single institution can the huge possibilities offered by new technologies, and the Internet in particular, to establish a world-class provider with global reach.

Distance education is a core educational strategy. It holds great potential on a number of levels. Yet, the potential for failure, or for mediocre distance programs is high. Developing proactive, strategic plans requires the commitment of entire institutions. Going that extra mile will ensure pedagogical integrity, student satisfaction, and ultimately, the success of distance education programs.

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