AC 2007-2828: FEASIBILITY OF A FULLY ONLINE UNDERGRADUATE MECHANICAL ENGINEERING DEGREE FOR NON-TRADITIONAL LEARNERS

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Feasibility of a Fully Online Undergraduate Mechanical Engineering Degree for Non-Traditional Learners

Abstract

Although there are a number of online degrees available online today from some of the most respected educational institutions in the US, very few of these are accredited undergraduate engineering programs. Of interest here is an online program specifically designed and developed to address the many mid-career employees and non-traditional students who have yet to earn an undergraduate engineering degree, especially those in business and industry and at military installations. In this paper, we present the results of a study which seeks to address how best to develop, implement, and assess a fully accredited online undergraduate engineering program. Of particular importance is to identify and address critical elements of such a program, including: potential student populations, faculty requirements, curriculum requirements, admissions criteria, accreditation requirements, implementation resources (faculty, technical equipment, financial), collaboration with other institutions, and laboratory requirements.

Successful development of such a program will enable access to superior engineering education by under-represented populations, students in remote locations, and students who are otherwise constrained with regard to traditional undergraduate engineering programs due to family or employment obligations. If successful, such a program could become a model for other undergraduate science and engineering curricula and programs offered online.

1.0 Introduction

Although there are a number of online degrees available online today from some of the most respected educational institutions in the US, few accredited undergraduate engineering programs exist. Particularly lacking is an online program specifically designed and developed to address the many mid-career employees and non-traditional students who have yet to earn an undergraduate engineering degree. To address this need, our institution has sought to address the feasibility of the development of an innovative ABET[1]-accredited online undergraduate mechanical engineering degree program. Of particular importance is to identify and address critical elements of such a program, including: potential student populations, faculty requirements, discipline selection, curriculum requirements, admissions criteria, accreditation requirements, implementation resources (faculty, technical equipment, financial), collaboration with other institutions, laboratory requirements, etc.

As discussed in more detail in two recent review articles,[2,3] undergraduate engineering education has lagged behind other fields in generating online degree programs. Thus, while there exist a significant number of online engineering programs leading to Master's degrees,[4] very few online programs leading to Bachelors degrees in engineering have been developed to date (see Table 1). Among these existing programs, only the University of North Dakota (UND) offers ABET accredited degrees in the traditional disciplines of chemical, civil, electrical and mechanical engineering.

Other institutions have attempted undergraduate engineering programs online that have encountered certain benefits and obstacles.[5] Recognizing that this presents an opportunity for an innovative and agile institution to assume a national leadership role in undergraduate engineering education, our institution has secured the support of faculty and staff as well as ABET to pursue this objective. The envisioned program seeks to provide access to undergraduate engineering education for mid-career, non-traditional technical personnel at corporations and military installations who are engaged in technologically-based activities in both the corporate and military arenas. Because of the nation's need to build a more robust science, engineering, and mathematics professional corps, the benefit of drawing from its mid-career workforce is clear. The close relationship that our institution enjoys with industry and military partners, as well as the high-quality online learning offerings currently available (and nationally recognized) at the graduate level, provides a unique perspective from which to identify the feasibility of such a program.

Table 1: Existing online Bachelors degree programs in engineering

SCHOOL	DEGREE TITLE(S)	MAIN FEATURES
Colorado Technical University[6]	Software Engineering	• Accredited by NCA Higher Learning Commission • Online academic library • Courses taught in multimedia format
Michigan Technical University[7]	Engineering	• Offered mainly to industrial partners • Course delivery includes videotaped delay, Web-based instruction and Internet video streaming
National University[8]	Construction Engineering; Information Systems; Information Technology	• Interactive courses with required chat sessions
Rochester Institute of Technology[9]	Electrical/Mechanical Engineering Technology; Telecommunications Engineering Technology	• Mainly Web-based courses, though some of them use videotapes, audiotapes, and CD-ROMs.
University of North Dakota[10]	Chemical Engineering; Civil Engineering; Electrical Engineering; Mechanical Engineering	• ABET Accredited • Course delivery combines audio, whiteboard, computer and video outputs delivered in a RealOne Player file.

2.0 Benefits of a fully online program

Following Socratic principles, educators have long valued face-to-face interaction with students as the most effective learning method, engaging learners and generating critical thinking. However, today higher education professionals agree that, given the advances in teaching technology, the online mode of learning may be an effective alternative, especially when and where face-to-face teaching is not possible or available. As current literature supports, online learning is now recognized as an equally effective instructional mode as the face-to-face classroom and one that can even surpass face-to-face in academic quality, rigor and outcomes.[11] The advantages and benefits of online learning include:

Enhanced accessibility for non-traditional students: The introduction of an undergraduate online engineering program is expected to enhance accessibility for non-traditional students who wish to initiate or complete their undergraduate engineering studies. For example, the collaboration with industry and the military envisioned within the program will allow the student-employee to merge academic instruction and training with on-the-job experience. In addition, for older/mid-career workers who withdrew from their studies or only completed an Associate's degree prior to entering the workplace/military, the anticipated focus on workforce development will provide an opportunity to complete their undergraduate education.

Increased student completion rates: During the introduction of our graduate online programs in the last five years, experience has shown that 92% of our students who start online courses complete them. This represents a finding that appears to be replicated almost universally in online programs elsewhere. Consequently, the proposed program is expected to offer an opportunity to increase retention by providing the opportunity for students to complete their engineering degrees online.

Flexibility to students: A significant number of potential students envisioned for the type of online undergraduate engineering program described here are working adults. Demands of their home life and employment, especially for military personnel who, due to different assignments, are required to relocate on a two-to-three year basis, make it almost impossible for them to attend physical classrooms. Such students must manage family/parental duties, work assignments, job travel requirements, etc. Asynchronous online learning allows them to take courses anytime, day or night, and from anywhere around the globe.

Stimulation of interactivity: Modern education reformers emphasize the enormous benefits and attraction of interactivity, collaborative engagement and constructivist principles.[12] Online learning builds on these modern educational strategies, allowing for interactivity and collaboration through peer support and response. In his article, "Ten Ways Online Learning Matches, or Surpasses, Face-to-Face Learning,"[13] Kassop emphasizes the high interactivity of online discussions, with many online students indicating that "this is the first time they have ever 'spoken' up in class" and with the level of online discussion fostering higher quality responses since students have time to post well-considered comments. Online students are "expected to respond, respond intelligently and respond several times."[13]

Blended learning solutions: A successfully developed program will enable delivery of blended learning solutions, allowing the optimum use of classroom and laboratory space, while broadening learning opportunities to non-resident students who will work from home. Students recruited from industry may be given the opportunity to perform laboratory work at their respective companies where research and laboratory facilities may be available for them, in addition to having access to remotely accessible online and virtual[14] laboratory facilities. Furthermore, online methods will enable faculty and students to do things not possible in a traditional engineering classroom setting. These experiences will be key in moving online education closer to mainstream engineering pedagogy.

Incorporation of outside expert faculty for curriculum materials: Through the online undergraduate engineering program, the expertise of outside faculty may be integrated into the traditional program offerings of our institution. Currently, online faculty from Canada, the U.K. and the Far West teach courses through our graduate online programs. In this manner, new areas (such as nanotechnology, bioengineering and others) can be introduced into the curriculum as a result of the re-evaluation of courses necessitated by the design and development of the online undergraduate program.

Elimination of geographic barriers: Access to education is provided for students from any part of the country and any part of the world.

3.0 Suitable laboratory and design experiences within the online undergraduate engineering program

We anticipate that a major challenge in developing an online undergraduate engineering program is the appropriate incorporation of suitable laboratory/design components throughout the curricula. While a number of successful online graduate programs have been developed (including the nationally recognized programs at our school), for most engineering disciplines the level of laboratory and design work at the graduate level is minimal. However, it is our hypothesis that these intensive hands-on types of experience may not be as critical to the types of non-traditional students who have significant exposure to engineering in their professional careers, such that these students already “know what engineering is”. (By comparison, we feel that it is unlikely that a fully online program would be optimal for the traditional college-age undergraduate student who lacks such exposure to engineering; such students would likely need the benefits, supports, and interactions best provided by the traditional undergraduate experience.) Obviously this hypothesis warrants detailed assessment and evaluation as the online program is developed.

Specifically, in traditional engineering degree-offering programs, students perform the experimental activities on-site. However, integrating such laboratories will cause significant challenges in the distance learning context since they would require the students to be present on campus for the time period necessary to complete the laboratory component. The principal alternatives for delivering a laboratory experience to students as part of a distance learning offering are pure computer simulations, experimental kits (“at home experiments”), as well as on-site and remotely accessible laboratories. As shown in Table 2, pure simulation laboratories offer some operational cost benefits, but the lack of student exposure to actual physical equipment and real experimental data prevents broad acceptance by the academic community. Simple experimental kits that are distributed to or assembled by the students have been developed efficiently for some subject areas, but they may not match the level of sophistication that experimental laboratories can offer, and logistical challenges further limit their scalability. Remote laboratories utilize the Internet to enable sophisticated experiments to be conducted anytime from anywhere.

As demonstrated by a variety of publications[15-24] and research implementations,[25-32] various universities have been working on remote experimentation for some time. Further, a technology platform for remote experimentation has been developed[33-40] that exhibits a number of advantages compared with traditional laboratories and research implementations of remote laboratories, including:[41]

- *Affordability* – low system cost through standardized hardware and software components
- *Ease of use* – appeal to any user group through application of familiar user interfaces
- *Reliability* – integration of automatic fault detection and error handling functionality
- *Compatibility* – usage of and compatibility with existing communication standards
- *Computer platform independence* – usage of Java, Perl, HTML, etc.
- *Modularity and reconfigurability* – system architecture allowing component mix and match
- *Scalability and expandability* – standardized interfaces between system components

Table 2. Alternative modes of delivery for student laboratories

	Computer Simulation	Experimental Kits	On-site Laboratories	Remote Laboratories
Physical Presence	not required	not required	partially required	not required
Experiment Type	simulation only	simple	sophisticated	sophisticated
Scalability	yes	limited	partially	Yes
Development Cost	Very high	high	high	High
Operating Cost	low	low	very high	Low
Upgrade Cost	low	low	very high	Low

It is anticipated that a major obstacle to realizing a truly successful online undergraduate engineering curriculum is the development of an appropriate combination of virtual experiments (simulations), laboratory exposure through on-site visits, simple experiments conducted at home, and remotely accessible laboratory experiments, which is necessary to contribute towards enhanced learning in accordance with the respective ABET criteria. The vital importance of a comprehensive laboratory experience in the engineering curricula is widely acknowledged by all constituents and reflected prominently in the ABET Engineering Criteria 2000.[42] ABET has already begun the process to establish criteria for assessing the laboratory experience in online programs, including a recent workshop on remote laboratories[43] that focused on formulating a list of learning objectives for traditional engineering laboratories[44] and adapting them for the special situation of remote delivery of laboratory exercises.

4.0 Issues addressed in the design of an online undergraduate engineering curriculum

The significant and rapidly growing impact of online learning in higher education has so far not made major inroads into the domain of traditional undergraduate degree programs. This is particularly true for engineering fields of study.[45] Online learning has primarily targeted non-traditional students who are seeking a flexible approach to enhancing their skills and education. The bulk of for-credit distance learning, primarily by online delivery, takes place in the humanities, social and behavioral sciences, business and management. There is also a significant amount of non-credit online training offered, especially in the information technology field.[2] Some illustrative data, if somewhat outdated from 1997/98, are available from the NCES.[46] Before implementation of such a program can proceed, however, there are a number of policy, infrastructure, and pedagogical questions that need to be addressed.

The obvious question is why has undergraduate engineering education lagged behind in adopting comprehensive online formats, in most cases only appearing in upper-level elective courses that fall at the interface between graduate and undergraduate education? For this trend to change, online courses must be equal to or better than in quality than the traditional classroom and available when needed without geographic limitations. The Education Program for Gifted Youth (EPGY) at Stanford University[47], which is tailored towards pre-college children, has been able to enroll more than 3,000 students capitalizing on its online capabilities. We envision our program selectively adapting the methods used by EPGY and other similar programs for entry-level engineering students.

Engineering curricula are designed to provide what students need to know in order to effectively function as entry-level professionals within their discipline. In addition to accomplishing this goal, online engineering education at this level will also assist students in learning how to learn and with that will provide to the profession "certified" life-long learners. A recently published extensive study of online engineering education highlights the following points:[2]

- Online teaching and learning will improve steadily as teaching and learning technologies improve.
- Online methods in engineering education will increase in breadth and scale.
- Specialty areas will leverage expertise among institutions.
- Online methodologies can be the driver that will enable collaboration between institutions, which in turn will improve the quality of education (by ABET standards) while driving costs down.

Successful implementation, however, will require that the issues identified below be adequately addressed.

4.1 Identification of the Participants and Constituents

In order to evaluate the feasibility of an online engineering degree program, it will be necessary to identify the participants and gauge the extent to which they are willing and able to engage in support, development and implementation of such a program.

Corporate and Department of Defense (DOD) Personnel. We are currently in the process of identifying potential collaborations with corporate and military establishments, the level of their support for an online undergraduate engineering program, and whether the needs of both employers and employees may be satisfied entirely by an online undergraduate engineering program. Several generic backgrounds and profiles of different students who may be typical of those participating in the program are being developed with which to study how a potential online program would address their needs.

ABET and Other Accrediting Bodies. The Accreditation Board for Engineering and Technology (ABET) is the body that accredits undergraduate engineering programs in the US and is linked to the various engineering professional societies who set the individual program accreditation requirements over and above the general ABET mandates. ABET has already recognized that it must take action in this area and will contribute to our discussions on the feasibility of delivering online engineering programs. The ABET Board[48] has taken on the task of addressing the issue of "emerging technologies, changing disciplines and the blurring of boundaries among technological disciplines challenge traditional approaches to educational delivery and assessment." ABET has already begun to establish criteria to judge laboratory experiences for off-campus students.

An additional accreditation consideration will assure alignment with the requirements of the Middle States Commission on Higher Education, our school's accreditation oversight body. Our institution has recently received accreditation from Middle States for our online graduate programs and so has established a track record in this regard.

University Faculty. Inasmuch as our institution has training personnel in place to provide for faculty development for online courses, it will be necessary to address additional faculty requirements and resources for an undergraduate online engineering program. Topics currently being addressed include:

- Understanding the need for developing different teaching strategies
- Requirements for instructor personnel resources
- Academic rewards and professional development metrics that incorporate online teaching and development activities

4.2 Formulation and evaluation of the online curriculum

A benefit of adapting courses to effective online delivery is to provide the opportunity for a fresh look at how to teach the material, and indeed what to teach, which can at the same time also benefit our traditional curriculum. Participation in developing an online program offers the corollary of an attractive vehicle for faculty development. New areas of nanotechnology and bioengineering may be introduced into the curriculum as a result of the re-evaluation of courses that is taking place as we consider the specifics of a design of the online undergraduate program.

From an operational standpoint, students will need access to the appropriate suite of software tools and hardware with the equivalent functionality currently readily available and supported within the on-campus computer laboratories. This aim may require a computer/software leasing arrangement structured separately from the on-campus programs. Here, the ability to leverage existing online resources developed for graduate programs will be beneficial.

In addition, as discussed earlier, it is anticipated that one critical obstacle that must be overcome is the incorporation of meaningful laboratory experiences within the online curriculum. Such experiences may expand or extend existing remote undergraduate laboratories being developed and used at a number of institutions (including our own). As described earlier, we will also investigate the possibility of alternative laboratory options, including special kits, simulations, industry-supported laboratory activities to complement the remote laboratory experiences.

Another significant point that distinguishes the development of an online undergraduate degree from that of a graduate degree is the need to incorporate and facilitate design activities within the undergraduate online curricula. In this respect, in order to facilitate communication among team members separated geographically or working on different time schedules within an online offering one must focus on enhancing the participants' understanding of data communications and train them on how to work effectively with their colleagues using appropriate modern data communication tools and technologies. They will use these tools to work in virtual teams, solve problems and communicate engineering ideas and information. In this manner, valuable experience and confidence will be gained in the work environment of the future.

One method to address this issue is as follows: One week prior to the beginning of each semester students will meet on campus with their instructors and fellow students to prepare for the upcoming courses. Here, they will have the opportunity to use, explore and gain confidence in all of the learning and collaboration tools that comprise the online campus. They will also be able to obtain practical tips for efficient distance learning and have opportunities to work through any software/hardware/network configuration problems. Table 3 illustrates the topical areas that would be emphasized during this training. Challenges relating to time management and balancing employer expectations, personal and family needs, and course responsibilities will also be addressed during this period.

Finally, any proposed accredited online program will need to meet all appropriate ABET criteria, both the general criteria and the specific program criteria for assessment and student outcomes. As a first step, our comprehensive School of Engineering Assessment Program will be applied to an online program in the same manner as it is applied to a comparable on-campus program through the oversight of the appropriate Program Committee, Liaison to the School of Engineering, External Advisory Board, etc. The Assessment Program evaluates educational outcomes by a variety of means to ensure consistency with the program goals that have been established in consultation with the relevant. In this manner, it is intended that high-quality online programs will be delivered that are comparable to those taken in the traditional fashion at our institution. A study of online evaluation and outcomes was recently conducted at the State University of New York (SUNY), which published its outcomes of student satisfaction with online courses.[49]

Table 3: Topics for on-campus training

SETUP	INFORMATION MANAGEMENT	LEARNING AT A DISTANCE	DESKTOP SKILL AND GROUPWARE
○ Install, update and test software ○ Get started with course communications ○ Backup and troubleshooting ○ Network security considerations	○ E-mail effectiveness ○ Using online document management ○ Instant messaging ○ Professional Web searching ○ File management	○ Learning in online discussion forums ○ Succeeding as a distance learner ○ Working effectively within collaborative design environments	○ Understanding file types and file formats ○ Sharing data between applications ○ Effective Web conferencing ○ Mastering CAD/CAE and collaborative design tools

4.3 Student services

Admission. Admission to the program will be based on standard transfer criteria. However, in recognition that many students may be well past their college years, it is anticipated that competency in key foundation subjects will need to be evaluated and appropriate remediation provided through ramp-up courses and other non-credit foundation courses. As is typical with programs that cater to mature students, documented evidence of suitable life experience will be evaluated in awarding transfer credit.

Advising. Advising will be a key element to enable successful educational outcomes from an online engineering education. A recent NSF report[50] reviewing the literature on distance education points to the challenges faced in online education. It requires a level of student discipline that a more structured on-campus environment does not. It is also shown that contact with faculty as well as with other students is critical. It is therefore important that the online program provide a supportive environment, both through instructor-student communication and through the development of an online student community. The latter can be facilitated by collaborative learning approaches such as project-based coursework and other virtual team-based activities. Information technology tools exist to aid in this community building, and the fast pace of development in Web-based streaming video and voice-over-IP will further assist communication among participants in the program.

Examinations. Assessment of student performance in an online course is a challenge. We are now collaborating with Prometric, a company within the Thomas Learning division of the multinational Thomson Corporation, for providing online proctored examinations. Alternative means of administering examinations will also be investigated.

5.0. Summary and ongoing work

We are currently in the process of implementing our feasibility study, with a partial list of research issues listed in Table 4. Within our efforts, we are also seeking opportunities for collaboration with other engineering schools as well as with regional and national community colleges.

Table 4. Evaluation of the feasibility of an online undergraduate engineering curriculum

AREA	ISSUES TO BE STUDIED	METHODOLOGY AND PLAN
Student Population	Determine demographics, particularly number of potential students at corporations and in the military	Create interview forms with questions; conduct telephone & personal interviews; review DOE demographic data
Faculty	Measure the impact on faculty workload; assess additional resources	Coordinate conferences with deans and faculty
Corporations / Military	Extent to which corporations and the military will support and participate in the program	Conduct telephone and personal interviews with senior corporate & military personnel
Curricula and Learning Objectives	Determine how to achieve Web-based learning objectives; re-examine existing curricula, programs, and issues	Conduct group and individual conferences with deans and appropriate faculty
Equipment	Review hardware and software requirements and associated costs	Specify current capabilities; evaluate outside vendors and internal IT requirements
Admission	Establish criteria for admission	Conduct group and individual conferences with deans, faculty, and admission personnel
Advising	Review best practices and determine path that is likely to lead to the most effective results	Conduct a review of online literature and consult with e-learning experts
Accreditation	Conduct a review of accreditation requirements with ABET	Consult with ABET in a review of accreditation criteria
Assessment and Outcomes	Determine best practices to guide policies for assessing student competencies	Conduct a review of the online literature and consult with e-learning experts
Remote Laboratories / Laboratory Options	Identify what will be required as well as associated costs and delivery	Conduct a review of the online literature and consult with experts
Design Aspects within the Curriculum	Determine the sequence of communication, virtual collaboration, design and engineering software tools for sequence of design courses	Conduct a review of available software tools and survey best practices of other online programs

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