Looking into Future: Online Engineering Education

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Online Engineering Education –Experience Revealed

Abstract

The emergence of online education and the fast growing trend of using eLearning environment have been of great interest to the teaching faculty of institutes of higher learning. The use of such a platform for educating students in the various disciplines of engineering has, in particular, triggered much interest. In fact, many academic institutes are now turning to online engineering as the panacea to combat the issue of low enrollment. This latest trend has led to significant structural changes worldwide in engineering education. However, this shift to the eLearning environment has failed to successfully solve issues relating to quality, effectiveness, and the feasibility of conducting online laboratory experiments. The rapidly changing technological landscape has also forced educators to devise, implement, and later evaluate innovative pedagogical approaches without rejecting the positive aspects of traditional skills and approaches. In this effort remotely accessible experimental setups are being developed and implemented. Tools such as podcasting, synchronous sessions, and threaded discussions are used to further enhance students' learning experience of online education without sacrificing the traditional advantages of online learning which include the flexibility of taking courses anytime, independent of geographical boundaries.

This paper summarizes the step-by-step approach that was adopted by SETM for the design, development, implementation, and assessment of our online engineering degree programs. Some of the various features that were used, such as online laboratories, tablets with inking technology, serious game development, and synchronous discussion sessions have succeeded in making our online programs very unique and attractive to both traditional and non-traditional students.

Background

National University (NU), an independent, nonprofit institution of higher education has dedicated itself to providing educational opportunities to a diverse population of working, adult learners since 1971. The School of Engineering, Technology and Media (SETM) at National University (NU) was established in July 2002, and has attracted a current student body of over 1300 whose profile generally mirrors that of the university itself. NU, the second largest private non-profit university in California, has over 23,000 mainly non-traditional students: students whose average age is over 30. The university also boasts of a large population of students from traditionally underrepresented groups, such as women and minorities. Typically, most of these students, whether at the undergraduate or graduate level, are re-entering an academic environment after having been out in the working world for some time. SETM offers nine undergraduate and eight graduate degree programs with several specializations. Over 90% of these programs are offered both in the online and on-ground modes. SETM has over 10 years of experience in online education.

Many educational institutions that use the Internet as a platform for teaching offer a flexible and accessible alternative for busy people who want to pursue higher education. However, questions have been raised as to whether online instruction can replace the traditional approach to teaching any time soon, particularly, in engineering schools [1, 2, 3, 4]. In fact, many members of the

teaching faculty have often questioned if online education has the capability to effectively communicate
important concepts without compromising on quality. At the same time, faculty members involved with traditional programs hesitate to readily denounce online education since they do recognize that it is the best option for some people to complete a degree program.

The use of the Internet and web for learning and teaching has changed the way in which the degree programs are offered in today's competitive world. This change is primarily the shift to computer based instruction and interaction (e.g., bulletin board systems, VoIP instruction, podcast, asynchronous and synchronous chat sessions). It is the availability of these various modes of instruction that has facilitated the Internet/Web to produce phenomenal growth in the extent and scope of online engineering education.

As technological capabilities have continued to expand, more and more traditional and big name schools are embracing online education. However, traditional engineering education still depends on hands-on laboratory work and continuous interaction between students and instructors while delivering complex subject matter. Although it may be true that many entry-level courses that are traditionally taught in vast lecture halls are often characterized by little to no individual interaction between students and professors, the options to interact within a face to face environment has to be made available while teaching engineering subjects online. In addition, complex subjects taught via the Web has to reflect an environment where student progress can be monitored. The engineering laboratory exercises where students learn applications have to be made available online. Finally, very effective online methodologies have to be put in place to ensure the effectiveness of online learning of engineering subjects.

Human interactions have changed over time from exclusive face-to-face interactions (including the exchange of physical materials such as letters and the like), to include the use of direct real-time distance-separated interactions via voice or images over phone lines or airwaves, as well as the use of virtual real-time or time-delayed interactions via intermediary digital networked-based media (as can be found on the World Wide Web). The use of digital network-based facilitation of human interactions is becoming an increasingly important part of distance learning, but there are still many severe limitations on the ease of use, efficiency, accuracy, and reach of the facilitation process [5, 6]. Four of the most problematic processes of human interaction facilitation via digital network-based processes are the following:

1. The process by which mathematical, graphical, and descriptive programs can be conveyed/displayed.
2. The process by which an individual can initiate the facilitation process by indicating/describing their interests/response.
3. The process by which an individual can locate information that has been made available by others.
4. The process by which national language and other borders/barriers across which there is a need for such facilitation of human interactions are bridged.

Traditionally, engineering education has been content-centered and design-oriented. It also primarily involves problem solving skills. Traditional pedagogical methods do not provide the necessary impetus for students to get a feel for complex engineering subjects. The higher levels of engagement require novel teaching methodologies such as games to fully understand the subject matter fundamentals. Hence an online engineering education requires an integrated system and method for the easy, efficient, accurate, and far-reaching facilitation of human interactions, effective laboratory exercises, and novel pedagogical methods such as games. In addition, the effectiveness of such methodologies has to be assessed on a continuous basis so as to ensure the student learning and effectiveness of instruction. Bourne et al [7] have observed that the quality of online courses must be comparable to or better than the traditional classroom in order to be effective. In addition, the course layout should be designed to optimize learning by providing learning mechanisms for as many learning styles as possible. Since the engineering students cover a wide span of learning styles, the course design must carefully accommodate a wide variety of learning styles as shown in Table 1 [8]. For example, the Verbal/Linguistic learner's primary learning style is through written and spoken words. So, much of this individual's learning will come from the required reading and the lectures and lecture notes that form part of the topic lectures. In addition, the linguistic learner will profit by following Internet links in the course documents to other related material, or from going to a physical library and reading additional material. The Logical/Mathematical learner benefits greatly from the inherent logic, which relates to the learning outcomes, required reading, topic lectures, and course documents. In addition, mathematical notations and formulas in the text are also likely to benefit this learner [8].

Learning Style	***Online Course Component***
Verbal/Linguistic	Required Reading; Topic Lectures – Notes, Synchronous VoIP Chats
Logical-Mathematical	Learning Outcomes; Required Reading; Topic Lectures – Notes; Course Documents Including Online Laboratories
Bodily-Kinesthetic	Assignments (Projects), Game Development
Visual	Topic Lectures – Charts; Course Documents (Links to Videos, Relevant Articles and News), Development of Games
Musical	Course Documents (When Applicable)
Interpersonal	Assignments (Group Projects); Discussion Board
Intrapersonal	Assignments (Individual Projects), Required Reading

Table 1 – Mapping of Learning Styles to Engineering Course Layout [8]

Figure 1 provides an overview of online course layout adopted by the School of Engineering, Technology and Media (SETM). They have also been designed to meet the five pillars of online learning described by Bourne et al [7] which include learning effectiveness, student satisfaction, faculty satisfaction, access, and cost effectiveness. Course components in the week by week layout include reading assignments in the course textbook as well as other assigned reading, a set of topic lectures that cover key points and related to the learning outcomes, sets of questions for discussion during class meetings and for synchronous discussion via a Voice over Internet Protocol (VoIP) chat room for the course, and a set of assignments, including both work to be done on an individual basis and work to be done in project teams [8]. For online courses, National University is making use of the Voice over Internet Protocol (VoIP) System built within the eCollege learning platform. This has the following features [8]:

- Voice over IP (VoIP)
- Two-way audio and video conferencing
- Application sharing
- Interactive whiteboards
- Synchronized Web browsing
- Electronic hand raising, feedback and Q&As
- Viewable class lists
- Instructor-led floor control
- View student screens
- Breakout groups
- Participation meters
- Multimedia courseware with third-party authoring support
- Group text chat

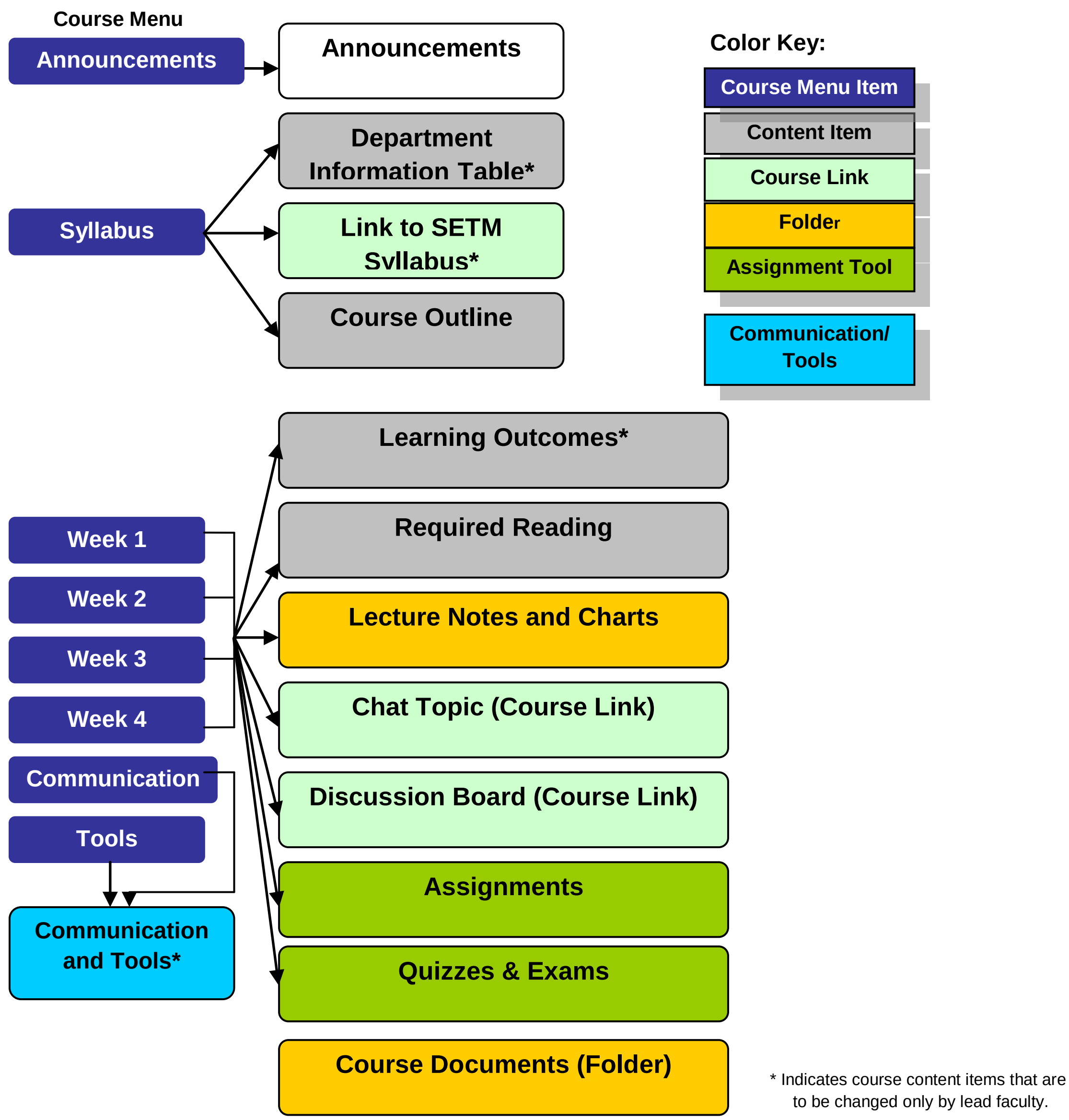

Figure 1 - National University School of Engineering, Technology and Media (SETM) Online Course Layout

Inking Technology

Denning, Griswold, and Simon [9], Koile and Singer [10] as well as a number of others, have reported positive impacts from the use of Tablet PCs in the higher education classroom and in expanding the modes available for communication between instructors and students. Researchers at the University of Washington have acknowledged that they use Tablet PCs with Classroom Presenter software in their higher education classroom. Anderson et al [11] have reported that use of similar learning devices in the on-site higher education classroom has helped enhance student engagement in the learning process. Similarly, Thomas and Carswell have observed [12] that collaborative learning, which this technology allows, has proven to be a powerful tool for distributed environments. The relation between active learning and the use of digital ink, reported by Kowalski, Kowalski, and Hoover, is of particular interest [13].

The use of inking technology to teach complex topics including mathematics was experimented both in our online and on-ground classes. Each instructor and every student was given access to a Hewlett Packard Tablet PC equipped with the Microsoft Windows XP operating system, the full Microsoft Office suite including PowerPoint, Excel, Word, and both DyKnow Vision™ and DyKnow Monitor™. Software required for special applications was also included for particular courses. All Tablet PCs were connected to each other in face to face classrooms and to the Internet through an IEEE 802.11g Wireless Access Point. For online classes, the instructor alone had Tablet PC. Typical class sizes ranged from 10 to 20 students. Instructors, typically, could write, draw, and make personal notes as they offered instruction on a specific topic. In addition, special notes were made on instructor's charts and these were saved so that students could review them in the future. In addition, the students who had Tablet PCs with similar functions saved their own notes and annotations that they jotted down in each class. This methodology was used in several engineering undergraduate courses as listed below:

- Data Structures & Algorithms
- Linear Algebra & Matrix Computation
- Calculus for Computer Science
- Applied Probability and Statistics

The results of this two year-long use of Tablet PCs with DyKnow software in teaching engineering courses revealed that student learning dramatically improved [14]. Students gained a better understanding of the material taught. The results of students' surveys indicated that both the instructor and his/her students found that the inking approach for teaching complex engineering concepts has benefits [14].

Online Laboratories

One of the limitations of developing engineering degree programs online is the access to laboratories. Typical engineering degree programs have about a minimum of eight laboratory courses during the course of study. Hence, implementing laboratory exercises in the degree programs is a must. However, this process has posted a real challenge to instructors. There are several limitations including online access to laboratory equipment. There are currently two approaches followed in implementing online laboratories [15]. The first is the use of Web-based simulations, sometimes referred to as virtual labs. These virtual labs have been shown to be equivalent to physical labs for explaining and reinforcing concepts. However, they are viewed as limited since they do not permit a hands- on-approach (eg: circuit building). In addition, the simulations are viewed as limited in scope and accuracy. Also, simulations (e.g., for electronic design) used in industrial practice for verifying designs and checking faults are orders of magnitude more expensive than educational simulations [15]. The second approach involves using the Internet to allow students to manipulate and observe real equipment and instrumentation located at a distance. This approach is often referred to as remote labs. Remote labs deal with real phenomena and equipment and can be used to build skills as well as knowledge. At National University, we have used a combination of both approaches described here [16]. Implementation of tools such as ELVIS (Educational Laboratory Virtual Instrumentation Suite) and Emona DATEx (Digital Analog Telecommunications Experimenter) have enhanced laboratory activities. Qualitative and quantitative assessment data taken from the classes that used these tools showed that students not only liked it, but that it also improved their learning [16].

Games Development

Faculty members in higher education have been looking for innovative ways to engage and motivate students enrolled in STEM (Science, Technology, Engineering, and Mathematics) disciplines [17]. Games provide a vehicle for students to experiment and approach course concepts through a sandbox of play. Games have been shown to have a number of distinct benefits when applied to education including the following [18, 19]. They

- Are fault tolerant (iterate to solution/fail forward)
- Provide opportunity for continual feedback
- Have tools within the game that could serve many purposes
- Build on prior knowledge and allow for progressing to new levels
- Reward players for persistence
- Allow players to work at their own pace

These advantages allow players to build strategies or test boundaries in the game without the fear of failing [20]. Even if the student does not reach the desired objective, he/she can try again until he/she succeeds. Games often provide continual feedback, through the screen in video games or by indicating one’s status in physical games. This formative and summative assessment of player progress is helpful in correcting ideas and strategies in the game. The games can provide a visual representation of concepts and relationships between objects and topics [21]. Students learn to employ various tools within the game in the same way they would in the real world in order to solve problems and seek answers to challenges in the course and game. In one sense, it becomes a problem based learning environment.

The main objective of implementing game pedagogy in the engineering courses is to increase student innovation, motivation, and engagement in the topic taught. Here the games are designed and developed by the students under the direction of instructors. To develop these games, students are given a clear set of terms or concepts that are derived from the course learning outcomes and the students are expected to devise games that will facilitate the learning of these terms and concepts. This gives the student (or student team, if team project) the opportunity to study or research the topics ahead of time and start to conceive of possible ways of implementing these concepts into the game. Instructors, typically, field questions with examples of how the students might consider course concepts as game elements, since this leap will not, initially, seem obvious. Some instructors show example games of their own or components of games to quickly demonstrate the possibilities for game design. These game design approaches adopted in several courses have yielded positive results in learning engineering concepts [22].

Assessment Process

In general, the purpose of assessment at National University is to ensure that we are offering high quality programs, students are learning, and that we are producing high quality graduates. In addition, the assessment also helps to improve the program and provide necessary input for budget and other resources allocation within the school. Since assessment is handled at various levels, it is very critical to have a solid assessment plan that would effectively evaluate success and allow for the assessment to be completed within time. It should also provide input on how much learning students have accomplished in the program. As part of the program design, the PLOs, once they are finalized, are mapped to all of the required courses in the program. This course mapping also identifies whether a certain PLO is Introduced (I), Developed (D) or Mastered (M) in a certain course. Each PLO is expected to be mastered in one or more courses.

The assessment process for our programs is handled at various levels and by different group of people. As a starting point, the program lead takes on the responsibility to provide and upload all the information that is required for a Program Annual Report (PAR), or 5-year review. Next, each member of the School Assessment Committee (SAC) , takes on the role of a coach to lead in the preparation of the various components of their PARs for their programs. SAC coaches check the completeness of the PAR work done and enter their reviews on AMS. The PAR is then reviewed by the department chair and Dean of the school. The PAR is next submitted for approval to the Undergraduate or Graduate council. Each of these councils have its own Assessment Committees and members of these committees review PAR and add his/her comments and assign a score (Initial, Emerging, Developed or Highly Developed) based on the rubric for each section in the respective PAR. The chairs of these committees then present their report to the respective councils and seek their approval.

NU's Assessment process consists of PAR that is completed every year and a program review that is done after every five years. For each PAR 20% or more of the Program Learning

Outcomes (PLOs) is assessed. The idea is to assess all of the PLOs by the time a five year review is due. Each PLO that is assessed requires two direct and one indirect measure. It also states the "acceptable and ideal target" in terms of student performance. All of the supporting material is also required as evidence of student success. In addition, each PAR requires a "Multi-year Assessment Plan," which would specify which PLOs will be assessed in the coming years. "Assessment findings" is also a part of each PAR. It details findings for each outcome, "Overall Reflection," "Implementation of Changes from the Last Program Assessment," and "Implementation of Changes from the Last 5-year Review" (if applicable). The last section in a PAR is the "Overall Recommendations and Requests for Resources." The last two items are, basically, an attempt to close the loop for any change that might have to be implemented in the program. Figure #1 shows a typical time line when a PAR is processed through different levels.

Figure 1: PAR Review Cycle

A 5-year review process goes through the same level for review and approval as PAR. Figure #2 shows the time line for a typical 5-year program review cycle. A completed 5-year review would contain a section on "General Information" about the program with a timeline for the "Self-Study Plan." It includes information like responsibilities for collecting and entering data, target start and completion dates, as well as forming the self-study committee. The program lead is also supposed to identify external reviewers responsible for providing valuable input about the program after reviewing the self-study report. The 5-year self-study report consists of 12 sections in total. There is a section that provides detailed information about the program as well as sections about the relevancy of the program, the currency of the program, faculty qualifications, their preparedness and academic support, student achievement, academic success of students, program vitality, adequacy of resources, additional information, summary of recommendation, and the report from the external reviewers.

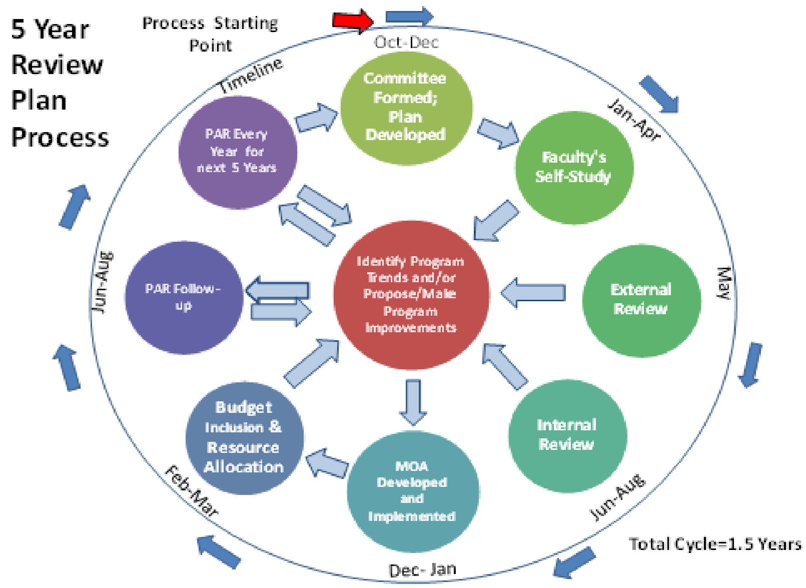

Figure 2: 5-Year Review Cycle

Unique Features

Students in our engineering program have access to a variety of online and physical resources. The course shell provided by eCollege environment has the capability for the easy sharing of links and documents. The webliography section provides a method for sharing links and the doc sharing function allows faculty to upload relevant documents. Each section of eCollege can be written in HTML, which provides the capability to add additional links. The course shell also includes a set of short webcasts for each of the four weeks. These webcasts are of about 10 minute duration covering important concepts for that particular week. In some cases the lecture slides also include audios.

Conclusion

This paper provides a summary of the step-by-step approach adopted by SETM from the design, development and implementation as well as assessment of online engineering degree courses/programs. Several features used such as, online laboratories, tablets with inking technology, serious game development, and synchronous discussion sessions, are explained. Continuous improvements are being made to all of these features for enhanced and effective student learning.

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