AC 2009-1888: THE DEVELOPMENT OF AN ON-LINE SYSTEMS ENGINEERING PROGRAM: LESSONS LEARNED

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DEVELOPMENT OF AN ONLINE SYSTEMS ENGINEERING PROGRAM –LESSONS LEARNED

Introduction

A survey by the Sloan consortium[1] has shown that enrollments in online programs are growing at rates that far surpass the rate of growth for the broader student population. The vast majority of these students, however, are taking undergraduate courses and this is the area experiencing the highest rate of growth. Engineering programs have the lowest penetration rates with only 16% of institutions with engineering programs reporting having a fully online program, compared to 33 percent for business, although penetration rates for doctoral/research institutions is somewhat higher. Expanding the geographic reach to students is the primary reason for institutions to enter online education, although the Sloan study reports that 85 percent of students come from within 50 miles of campus, which they classify as local or from the state or surrounding states which they classify as regional.

Given that backdrop, what makes a master's program in systems engineering a good candidate to be developed as an online program? First, it should be noted that systems engineering is a relatively young discipline compared to the other engineering disciplines and one that might be considered a 'niche' discipline, with appeal primarily to those in the aerospace and defense industries. According to Fabrycky[2] there are 27 so called 'systems-engineering centric' master's programs in the United States, meaning systems engineering alone rather than systems and industrial engineering or systems and electrical engineering, etc. That number represents a small fraction of master's programs in the more traditional engineering fields. An even smaller fraction of those programs are available in a fully online mode of delivery. Given those statistics, it seems there should be a significant opportunity to expand the geographic reach of a master's program in systems engineering well beyond what was found for the typical program in the Sloan study. As a professional discipline, students interested in pursuing a master's in systems engineering tend to be working full-time and interested in pursuing a degree part-time. Many have worked for a number of years, assuming positions of responsibility within their organization which may require significant travel. Also, these students tend to be older, having reached an age where many have family responsibilities. These factors all make a fully online program an appealing alternative to traditional, blended, or hybrid programs. With this background, a decision was made in early 2007 to complement Penn State University's resident Master of Engineering in Systems Engineering program with one that is fully online. Reaching such a decision was only possible due to Penn State University's strong institutional commitment to distance education and successful record in delivering it. This paper describes key decision points along the way and provides an assessment of lessons learned to date.

Program Format

A critical early decision point in the development of the systems engineering master's program was to determine the format that would be implemented, particularly whether to use a cohort approach or an open enrollment approach. In the open enrollment approach, which is implemented within the existing resident program, students take a set number of required courses and a set number of elective courses to complete the degree. While there may be pre-requisites for some courses to be respected, students are essentially free to choose and schedule courses as they prefer and often must only complete all degree requirements within a specified time period. The approach has the advantage of providing a large degree of flexibility to the student as they can schedule as few or as many courses as they like or even 'stop-out' for a period when other commitments make it difficult to attend classes.

A cohort is defined as a group of students who begin a program together and proceed through a series of courses in a specified curriculum in a 'lock-step' fashion. The cohort approach obviously provides a minimum degree of flexibility for students and they must be able to commit to a fairly intense period of study. In addition, taking six courses a year often results in tuition costs that exceed an employer's annual tuition reimbursement cap, which will mean out-of-pocket expenses for the student that often can be an impediment to enrollment. The cohort approach, however, has many pragmatic as well as pedagogical advantages. By specifying a fixed set of courses and a fixed sequence, courses can build upon one another to a much more significant degree than in the open enrollment model, where not all students would necessarily have the same background unless pre-requisite courses are specified. There are other pedagogical advantages of the cohort model for graduate engineering programs as noted by Schuver, et al[3]. Considering the cohort as a 'learning community' promotes collaborative learning and knowledge creation by drawing upon the expertise of students, who for the most part, are experienced professionals themselves. Schuver, et al.[3] also note that the cohort provides a culture with unity of purpose or collective purpose, a more supportive learning environment, where students are more comfortable to consider alternative perspectives, and immersion-type experiences for students to work closely and develop a strong sense of camaraderie. From a pragmatic standpoint, a cohort approach allows a program to be launched after just several courses have been transitioned to an online environment, with course development taking place while the cohort proceeds, in contrast to an open enrollment program where it would be expected that a larger selection of courses would be available to students at the start of the program. The advantages, both from the pragmatic and pedagogical perspectives, seem to favor the cohort approach, which was selected for this program.

A decision to implement a cohort model then requires a decision to be made of which of the program's elective courses will be specified for the program. Such a decision naturally involves many factors, including appropriateness to the program, faculty resources and faculty preferences. Ideally the program should incorporate as many of the faculty teaching in the program as practical in order to spread the developmental tasks widely and avoid overwhelming one or two faculty members. In addition, faculty buy-in is essential for successful implementation of an online program, as described by the Sloan study[1]. Thus, faculty involvement from the earliest planning stages is essential. The final curriculum selection, as selected by program faculty, is shown in Table 1.

Online learning can be either synchronous or asynchronous or some combination of the two. In asynchronous delivery students are separated by time and location, whereas in synchronous delivery students are separated only by location. Midkiff and DaSilva[4] have detailed the differences between these two formats from their experiences with graduate engineering and information technology programs at Virginia Tech. Synchronous delivery typically follows a lecture-centered format similar to face-to-face courses. In fact, online students may be in the same ‘classroom’ as those in a resident program. Videoconferencing equipment augments the traditional classroom to allow the lectures to be broadcast to either a remote location or to a student’s computer. Two-way communication capability allows for students to fully participate in a way very similar to the traditional classroom. In this format of delivery, the traditional lecture is still the centerpiece of the learning experience.

Asynchronous delivery can also be focused on the traditional lecture, by simply allowing students to view it as their schedule permits, but increasingly asynchronous delivery is different pedagogically as well. Rather than having a primary role of lecturing, the instructor’s role is changed to one of being a facilitator to guide the student through the learning process. Lectures, if present at all, may be in the form of short audio or video clips. The role of the student changes as well: from being a passive receptor of information to one of being actively engaged and more responsible for learning. Students who choose an asynchronous program must be disciplined, motivated, and capable of a high degree of self-learning. As noted by Midkiff and DaSilva[4] this may present a challenge, as students are not necessarily able to self-select for these criteria.

This form of asynchronous delivery in no way diminishes the role of the instructor, but simply changes it. However, the impact of this shifting role should not be underestimated as its degree of acceptance by faculty varies and occurs over a period of time. The primary distinction between this form of asynchronous delivery and correspondence courses of the past is the interaction between faculty and students and between students themselves, both of which are critical for success of the course. Students separated not only by location, but also in time, can feel quite isolated, so techniques to foster interaction, including discussion boards, live chats, email, audio and video messages and even an occasional phone conversation must be encouraged.

Table 1 Courses in the Master of Engineering in Systems Engineering Curriculum

YEAR 1	YEAR 2
Engineering Analysis I	Deterministic Models and Simulation
Creativity and Problem Solving I	Systems Engineering
Technical Project Management	Requirements Engineering
Probability Models and Simulation	Software Architecture
Creativity and Problem Solving II	Decision and Risk Analysis in Engineering
Systems Optimization	Master’s Paper Research

A choice between asynchronous and synchronous delivery, therefore, depends on many factors. With an overarching goal of expanding our geographic reach to the largest extent possible and our target audience of predominately working professionals, asynchronous delivery was chosen. To help alleviate some of that isolation in asynchronous programs, a decision was also made to have students participate in a one week online orientation session prior to starting their first course. The orientation was intended primarily to have students get to know each other through various activities, but also to familiarize them with the various tools available in the course management system, such as posting, working on shared documents and submitting assignments to a drop box.

Faculty Support

Clearly the development of an online course or transitioning an existing course to an online environment requires effort and skills that go beyond the development of a course in a face-to-face environment, even the development of a new course. Thus, issues of faculty compensation and instructional resources to assist faculty had to be addressed early in the program planning stages. Faculty compensation may take the form of course release time or direct monetary compensation. The study by Burke[5] had indicated that compensation varied from nothing up to $10,000 per course, with the amount dictated by simple economics. However, the study warned that lack of a commitment from the administration for additional remuneration may lead faculty to question the effort to be placed on course development, resulting in a lower quality program.

As most faculty involved in the development of a new online program may have little or no experience in developing courses for a completely different mode of delivery, it is essential that resources and guidance be planned and provided. A study funded by the Alfred P. Sloan Foundation, 'Effective Workload Management Strategies for the Online Environment'[5], considers various phases of online program development including the authoring phase. Several of these effective strategies from the authoring phase and ways which they were implemented for this online program are addressed below.

<u>Adopt a Course Development Model</u> - Initial decisions discussed previously, namely a decision to use a cohort approach and one to utilize asynchronous delivery, were important milestones. Other questions such as the extent to which various forms of media were to be utilized were also important. The use of long recorded video lectures, essentially the same as those delivered in the traditional classroom, was considered and dismissed, because of the technology involved in producing production quality video, but also because that mode of delivery seemed ineffective for reaching our target audience. A development model utilizing an existing course management system for delivery of a range of media including text, short video clips, links to relevant websites, and discussion boards was adopted. Identification of available resources to be used by students rather than writing text heavy sections was encouraged. As discussed previously, emphasis was placed on a high degree of faculty – student interaction.

Provide Author with a Sample Online Course - This turned out to be one of the most important steps in the program development phase. Few faculty in the program had been exposed to online courses. Some had seen examples of award-winning, slick, multimedia presentations that served only to set unrealistic expectations. Others had seen examples of undergraduate courses that were designed for a much different target audience and some had seen examples outside of engineering and science, which were of little assistance. Particular concern was raised on how to deliver mathematically intensive courses online, such as the Engineering Analysis I course, which is the first course in the program, as shown in Table 1. An opportunity to view a graduate level statistics course provided a number of useful ideas from which the course development model could be structured, including ways to deliver a mathematically intensive course. The structure of the Engineering Analysis I course was developed to provide students the tools required to learn important mathematical techniques in a manner similar to that which they would use in a face-to-face course. Topics are first introduced using a web-based format supplemented with readings from the text. Self quizzes are used to ensure the material is understood before progressing to problems or a following topic. Solutions to sample problems are worked out using short audio-visual clips that students can readily follow. These solutions are supplemented by other examples presented in a web format as well as those in the text. As in face-to-face mathematics courses, much of the learning takes place by students tackling related problems given in weekly assignments. In face-to-face courses, students typically tackle such assignments working in small groups. For the online course, a discussion board was developed for students to post questions about problems to which other students readily reply with tips. The board is closely monitored by the instructor to ensure the group remains on track. Finally, prompt instructor feedback is integrated into the course design.

Establish a Course Development Team – One of the most important resources in the authoring phase was the inclusion of an instructional designer to work closely with faculty during course development. The instructional designer provided pedagogical assistance as well as the needed technical expertise in web design and multimedia effects. A team consisting of the program head, the instructional designer, and four faculty members responsible for the development of the first four courses in the curriculum sequence was formed as the key group to lead the development effort. The group met regularly and faculty were encouraged to share their thoughts on course design and early work on course development. Keeping this team relatively small turned out to be quite effective.

Finalize One Module Before Developing the Rest of the Course - This was one of the ways the course development team functioned most effectively. Course modules were developed and circulated for comment and discussion. The feedback led to some modifications that could be implemented early in the development process, minimizing the amount of rework required. Having the course development team review modules as they were developed also helped established a common look and approach to be used for all courses in the curriculum. Obviously with the range of courses in the program as shown in Table 1, content was quite different, but mode of delivery and pedagogical approach are consistent, so students have a good idea of what to expect as they proceed from course to course.

Apply Project Planning and Management Methods to Course Development – The development of the online program was viewed from a systems engineering context including the development of a statement of need, identification of stakeholders (potential students, faculty, and the University) establishment of requirements, including constraints and performance parameters and viewing the developed courses in terms of their overall lifecycle, i.e. considering the need for updating. Course completion schedules, including intermediate milestones were established with reviews conducted to go over progress. This is not to suggest that the project went entirely as planned, but certainly utilization of this approach helped the development process.

Timeline

Key activities in the development of the online program and their duration are depicted in Figure 1. The time from concept inception to program launch was approximately 18 months, although course development continued well beyond the initial launch. Critical early decisions made in the first two months were focused on the specific courses to be included in the curriculum and the use of a cohort model. A business plan was developed to estimate development costs and expected revenues. The business plan also included a market analysis to attempt to gauge demand and evaluate competitive programs. Approval of the business plan cleared the way for the formation of the development team, which included bringing on the instructional designer as well as a graduate student assistant to work with the first group of faculty. An intern student had also spent three months reviewing the literature related to online graduate engineering programs. Penn State University has a fairly rigorous consultation and approval process to extend programs to online delivery even for existing programs. Based on previous experience this process was estimated to take approximately 6 months.

A significantly greater amount of time was spent in the development of a course model than originally anticipated. Early ideas focused on how to duplicate the traditional lecture for the online environment. Consideration was given to recording face to face lectures and archiving these for the online students or recording lectures in a recording studio environment to deliver production quality lectures. The use of recorded lectures, though, was contrary to what students, our primary stakeholders, preferred, as determined from a review of available literature on online learning as well as discussions with students currently taking online courses, and the idea was eventually abandoned. As a result, the time required for development of a course model was underestimated, resulting in a delay of the full scale course development. Fortunately, the use of the cohort approach allows for course development to continue beyond the program launch, which made it possible to meet the scheduled launch date.

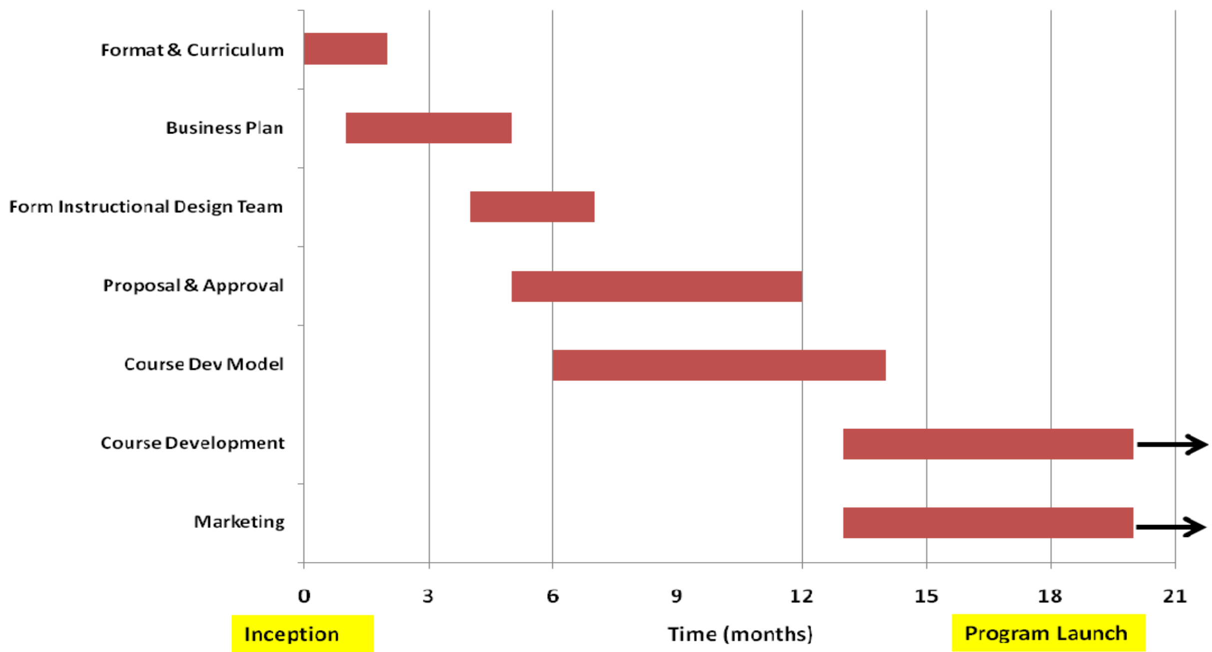

Figure 1 Timeline identifying principal activities for development of the online systems engineering program.

Assessment

While it is too early judge overall success of the program, it is possible to make some preliminary assessments. Although the course development schedule did not meet the preliminary targets, the impact was minor and the program was launched as scheduled. There have been two cohorts thus far, with each meeting the enrollment projection. The cost of program development has been in line with the original budget for the most part, although it became apparent that instructional design support would be required longer than originally anticipated, as discussed later.

As stated earlier, the principal 'need' for developing the online program was to extend its geographic reach beyond what was possible through traditional or hybrid delivery. A geographic distribution of applicants to the first two cohorts is given in Figure 2. As expected, a fairly high percentage of applicants are from within Pennsylvania, although less than half of those are from within 50 miles of the campus, which the Sloan[1] study had classified as local. Further evaluation shows that the geographic distribution is more a reflection of the location of industries where systems engineering is a well recognized discipline, i.e., the locations of major aerospace and defense contractors, which accounted for approximately half of the applicants.

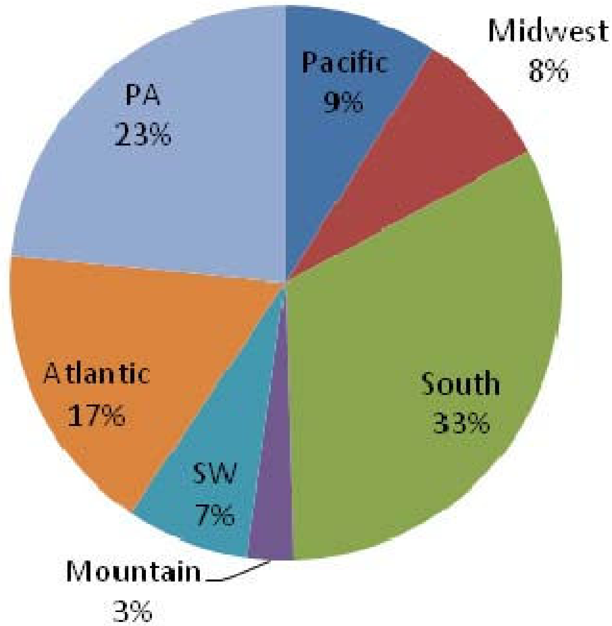

Figure 2 Geographic[1] distribution of applicants for the first two cohorts of the systems engineering online program.

In launching this online systems engineering program there were a number of valuable lessons learned. While strong institutional commitment was obviously essential to develop and deliver an online program, commitment on the part of the faculty was perhaps the most important issue leading to its success thus far. Involvement of the faculty in all key decisions along the way helped develop a sense of common purpose that was invaluable. The formation of a course development team, including an instructional designer dedicated solely to the systems engineering program was also essential. Faculty with little or no experience in the development of online courses or with working with students at a distance required additional dedicated support. The need for instructional design support was underestimated in the early program plans. Original plans had considered instructional design support only through the course authoring phase. It became clear that instructional design support will be required beyond the authoring phase to cover modifications and updates during the program lifecycle.

The length of time required for development of a course model was also underestimated. This resulted in a delay in development of some courses beyond the program launch,

[1] Pacific – AK,CA,HI,OR,WA; Midwest – IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI; SW – AZ, NM, OK, TX South – AL, AR, FL, GA, KY, LA, MD, MS, NC, SC, TN, VA, WV; Mountain – CO, ID, MT, NV, UT, WY; Atlantic – CT, DE, ME, MA, NH, NJ, NY, RI, VT

although the program was launched on time. Nevertheless, devoting the time upfront to develop a well-defined course model that would be adopted by all faculty and courses had significant benefits. The asynchronous model has been well-received by students thus far for its flexibility. The use of short video and audio clips rather than long recorded lectures has also proven to be very popular, and the emphasis on student-student and student-faculty interaction as well as timely feedback from instructors has also received positive student evaluations.

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