122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society

Paper ID #12662

Development of an Online Master's Degree Program in Manufacturing Systems Engineering

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Development of an Online Master's Degree Program in Manufacturing Systems Engineering

Abstract:

This paper reports on a newly developed online master's degree program in Manufacturing Systems Engineering at the University of Kentucky for which classes were launched in spring 2015. With increased emphasis on manufacturing in recent years, including the establishment of four national institutes for manufacturing innovation, a resurgence of demand for manufacturing engineers with the required knowledge is expected. Because this program will be entirely online, it will increase accessibility and provide an opportunity for career enhancement and advancement for practicing engineers who may not otherwise have access to a graduate degree in manufacturing engineering.

This paper primarily focuses on online program development including the goals and objectives to be achieved, selection of a learning management system, faculty training in required teaching technology and online teaching techniques, as well as methods of assessment to be used. Being a manufacturing systems engineering degree, a number of courses in the program involve laboratory experiments or hands-on simulations. The challenges involved and approach used to transition these activities to the virtual environment for use in online courses will also be covered.

While fully online courses were launched in spring 2015, faculty in the program taught courses in a blended format during the fall 2014 semester, with considerable portions of course content provided online and utilizing the Echo 360 technology for lecture recording. Results from surveys conducted during the fall 2014 semester and, how the findings are to be incorporated into future courses will be presented. In addition, challenges to successfully developing and launching an engineering graduate degree and the infrastructural support required are also discussed.

Introduction

Traditionally, engineering educators pay careful attention to the needs of the industries that hire their graduating students. As industry problems grow more complex, industries seek engineers with broader multidisciplinary skill sets to effectively address them. As one CEO said recently at a national summit on educating engineers for the 21st century: "Boeing needs engineers who are more than just technically competent; Boeing needs engineers who are creative, who can work in teams, who will pursue new knowledge throughout their careers." (NAE, 2013). Educators must also monitor relevant trends in the U.S. economy, such as the recent White House initiative to ramp up America's manufacturing base to world-class advanced and sustainable manufacturing status. Both of these developments indicate the timeliness and potential impact of creating an online version of the University of Kentucky's Master of Science (MS) in Manufacturing

Systems Engineering (MFS) degree. Established in 1992 and aimed at working professionals as well as full-time students, the MFS has been dedicated to 'preparing students for successful careers and professional development in manufacturing processes and systems' and to producing graduates with 'the knowledge, skills and attitude required for value creation…' (http://www.engr.uky.edu/mfs/).

One aspect of the program that makes it more innovative than just another online program is the transformation of features unique to MFS from a face-to-face format to a virtual format for effective and successful online delivery. A high level of faculty-student interactions, laboratory work and interactive simulations are hallmarks of MFS coursework. The program also benefits from instruction by the very successful lean manufacturing systems group established at the University of Ketnucky to teach the practices of the Toyota Production System for continuous improvement. Lastly, the MFS boasts faculty with internationally recognized expertise in sustainable manufacturing. The challenge for MFS online lies in successfully reproducing the learning experiences that arise during face-to-face teamwork activities and interactive projects. This means moving the MFS online involves creating online equivalents for significant interactive team work and activities ranging from laboratory experiments on different manufacturing processes, team-based product design with physical products/in software platforms and their assessment to simulating manufacturing system and supply chain operations. To help students master the complex technical concepts and skills and to give them a foundation in creativity and teamwork, these interactive aspects of the coursework are critical.

The goal of the MFS degree program at the University of Kentucky is to respond to the national, and internationally emerging, demand for our university's brand of sustainable manufacturing engineering education by increasing accessibility through an online degree. Such an offering is expected to significantly increase enrollment of, in particular, professionals who experience difficulty attending classes on-campus (MFS has had frequent inquiries about online offerings).

The program has traditionally helped provide continuing education for engineers from a number of companies including Toyota, Lexmark, Parker Seals and Semicon Associates. The program has always received numerous inquiries from working professionals around the state, from other states and internationally about availability of online offerings. Therefore, expanding the MFS degree program for online delivery is long overdue and will immediately boost enrollment.

The Online MFS project will serve manufacturing, a bulwark of the state's economy, at a critical point. The state has been attempting since 2000 to make the transition to a high-skill high-wage knowledge economy based in part on developing a strong advanced manufacturing sector. The effort has been energized recently by signs of a manufacturing resurgence in the state: large investments in new production by GE Appliances, Ford and Toyota (Mangas, 2013). This transition is critical for a state where almost 20% of the economy is manufacturing (Crawford, 2013). What makes the state's manufacturing sector unique: a high proportion of small and mid-sized (SME) manufacturing firms, many working as suppliers in automotive manufacturing supply chains for OEMs in the region: Ford, Toyota, GM in Kentucky, Nissan in Tennessee, and Honda in Indiana. This means that the sector is populated by many firms without the resources or in-house engineering to pursue productivity gains through new technologies and new product design. Thus, our state ranks lower than the national average in productivity increases. At the same time, to raise productivity for SMEs via technology innovation, through increased value-added attributes in product design and product quality, not through the traditional advantage of low cost labor, means addressing the challenges of better access to workforce education (Mangas, 2013). The state's traditional competitive advantage in low cost low skill labor turns into a disadvantage in what's been called the knowledge economy. That's one reason why our state ranks very low in R&D investment, in STEM degrees, in science and engineering workers as a proportion of workforce (NSF, 2013). A recent report on advanced manufacturing in the South directly ties low educational levels for a workforce to a sizeable deficit in innovation activity (Waldman and Murray, 2013). Thus, enhancing access to graduate level manufacturing engineering education through the MFS online degree program in the state and the region will have a significant economic impact.

This paper presents:

- An overview of the online MFS program, including the curriculum, enrollment requirements, and graduation requirements. Also discussed is some historical background on face-to-face MFS education at the university.
- A faculty training program offered by the university for online delivery of courses.
- A discussion of hybrid, or blended, course delivery of two of the program's courses in Fall 2014 as part of the process of converting them to an online format.
- Assessment data from the course blended course delivery in Fall 2014, and assessment plans for future fully online courses.
- Discussion of the first two fully online program course offerings in Spring 2015.
- A summary, including lessons learned to date, and plans for the future.

Program Overview

The Master's degree program in Manufacturing Systems Engineering received approval from the university and the state oversight body, after an extensive review of similar programs around the country. The emphasis on manufacturing was initiated by the location of the Toyota plant in

Georgetown, KY and the state initiatives in manufacturing at that time, including the funding of the Center for Robotics and Manufacturing. Key features of this program include:

- A multidisciplinary program, housed in the College of Engineering, drawing on specific faculty and departments for its coursework; faculty appointments were in their home department.
- Administration of the program by a Director of Graduate Studies, with a staff assistant
- Overall coordination by an Advisory Committee appointed by the Dean of Engineering, responsible for curriculum and related issues.
- Thesis and non-thesis options, based on coursework primarily in engineering, with at least one course in organizational behavior from the Business School (see Table 1). Courses include those specifically developed for the Manufacturing Systems program, as well as electives from several departmental programs.
- As originally envisioned, the program was to appeal to engineers employed in local manufacturing firms, as well as traditional full-time graduate students.

Table 1: MFS Degree Program Requirements

	Thesis Option	Non-thesis Option
Total Credits from Courses	24 (8 courses)	30 (10 courses)
Credits from Thesis/Project	6	3
Total Credit Hrs Required	30	33

University of Kentucky is accredited by The Southern Association of Colleges and Schools (SACS), and student outcomes and performance assessment related to satisfying that accreditation requirements are documented by the program. The student outcomes related to the MFS program are outlined as:

- Students will understand design of products, processes and systems and will be able to evaluate the use of resources for manufacturing.
- Students will be able to use engineering/laboratory experience that will enable them to formulate valid observations about manufacturing processes and systems to formulate novel hypotheses and apply methodologies to verify these hypotheses.
- Students will have the ability to apply knowledge of mathematics, physical sciences and manufacturing engineering to critically analyze technical literature and write technical reports related to manufacturing systems, processes and products and interrelations between these and their social, economic and environmental context.
- Students will understand the need for and have the ability to engage in life-long learning and will be able to educate others about principles of manufacturing for sustainable development.
- Students will have an ability to use the technical and advanced engineering tools necessary for improvements of engineering practice.

- Students will have an ability to function in a team, understand what effective management and leadership and are able to demonstrate both abilities.

To be admitted to the program, applicants are required to have a BS degree in Engineering or equivalent with a GPA of at least 3.0. Applicants with a BS degree in physical science or related area are considered but may require additional coursework before they can pursue the MFS degree. A satisfactory GRE score has been considered as one of the requirements for admission to the MFS program. However, over the years, no strong correlation has been found between the pre-admission GRE score and student performance once in the MFS program. Given this situation, continuing to impose the GRE score as an admission requirement was thought to be a potential deterrent to many applicants, particularly the full-time employed professionals who are one of the target audiences for the proposed online MFS degree. In addition, many benchmark universities that are currently offering online degrees in Manufacturing Systems Engineering and related areas have waived GRE as an admission requirement. A review of programs offering degrees similar MFS, summarized in Table 2, reveal this. This was particularly the case with manufacturing-related degrees offered in the online/distance mode. Thus, effective from Fall 2015, the requirement to submit Graduate Record Examination (GRE) scores when applying to the program has been removed. However, applicants are required to submit GRE scores if they are interested in being considered for any graduate fellowships offered by University of Kentucky.

The program has graduated more than 120 students since its inception. As the program was implemented, graduates grew to a peak of 23 in 2006. In addition to providing coursework for students in the manufacturing program, several of the MFS classes have significant enrollment as electives for students in other disciplines, as many as 30 to 50 per offering. There was significant interest in lean manufacturing during the peak years. More recently, interest has shifted to sustainable manufacturing, manufacturing processes, design for manufacture, and supply chain. While the enrollment in the program has dropped significantly in the last several years, due to economic and other reasons, inquiries from full-time employed engineers interested in pursuing graduate studies in the distance mode and in the online format have increased.

One of the main features and attractions of the MFS program courses is the hands-on approach used; many courses include a variety of interactive exercises. A variety of activities such as laboratory exercise, mini factories and table-top production lines as well as industry projects are included in a number of MFS courses. Such activities are critical to provide the interaction and engagement sought by students and help them better understand the application of the tools and techniques learned in the classroom. Students engaged in some of these interactive, hands-on activities in the face-to-face classes are shown in Figure 1.

Figure 1: Example Interactive, Hands-on Activities in MFS Courses

Goals and Objectives for Online Transformation

The success of an MFS online degree will depend on innovatively transforming coursework to offer the same level of faculty-student interactions and experience to online students. The task requires creating the 'feel' of the physical environment, developing simulators to replicate variable human behaviors that produce the unpredictable system variability inherent to manufacturing systems to provide an experiential scenario similar to, for example, those shown in Figure 1 for some MFS courses. If this is a demanding task, the potential rewards are great.

A number of programs offering degrees similar (manufacturing technology degrees not included) to the MFS degree were reviewed to learn the scope of those programs including the number of credit hours offered, availability of thesis or project alternatives and also to ascertain whether they are offered in the online or distance modes. This information is summarized in Table 2 below. While a few of the MFS program's benchmark institutions already offer somewhat similar manufacturing programs online (for example, NC State and U Wisconsin-Stout), these programs offer at best a limited amount of what could be called interactive learning. Therefore, successful offerings in this area would make University of Kentucky's program unique, providing significant competitive advantage in the ability to attract potential students nationally and internationally. As opposed to a cautious approach that would merely put current lecture content online it is anticipated that this bolder approach to creating an experiential learning-based MFS online degree program would help University of Kentucky become a new leader in online manufacturing engineering education.

Table 2: Comparison of Similar Programs

Institution	Degree (MS)	Credit Hours	Thesis/ Project	Online/ Distance	GRE Reqd.
North Carolina State University (NC State)	Integrated Manufacturing Systems Engineering	33	Project	Online	Yes/Exceptions allowed
University of Wisconsin - Stout (UW-S)	Manufacturing Engineering	30	None	Online	No
Rochester Institute of Technology	MS in Manufacturing and Mechanical Systems Integration	36	Thesis/project	No	Not clear
Rochester Institute of Technology	Manufacturing Leadership	30	Project	Online	No
University of Michigan	Master of Engineering (M. Eng.) in Manufacturing	30	Project	Online	No
The University of Texas-Pan American	MS in Manufacturing: Manufacturing Engineering	36	Project	No	No
Boston University	Manufacturing Engineering	32	Project	Distance	Not clear
Lehigh University	Manufacturing Systems Engineering	30	Thesis	Online/ Distance	Not clear
NYU Polytechnic	Manufacturing Engineering	30	Not clear	Online	Not clear
Missouri University of Science and Technology	Manufacturing Engineering	30	Thesis/ Project	Distance	Yes
California State University-Northridge	Manufacturing Systems Engineering	33	Comp. Exam	No	Required for international students
Bradley University	Manufacturing Engineering	33	Thesis/ Project	No	Not clear
The University of Texas at San Antonio		30/33	Thesis/ Project	No	No
University of Southern California	Manufacturing Engineering	30	Not clear	No	Yes
University of St. Thomas in Minnesota	Manufacturing Systems Engineering	39	Project	No	No. May be, if GPA less than 3.0

In keeping with this vision, the goals of this project are ensuring effectiveness of online MFS course transformation and delivery, increasing student enrollment in the MFS online courses and degree program for long-term sustainment; and faculty engagement, training and development to deliver the courses effectively. The project intends to use a number of metrics to assess each of these goals, as summarized in the Table 3 below. The assessment will be carried out throughout the project and after to make certain the overall goals of the MFS online degree program are achieved.

Table 3: Goals and Metrics

Goals		Metrics
Course-/Program-related	Converting planned number of courses for online delivery	# courses ready for delivery, # of courses delivered online
	Effectiveness of converting interactive content for online delivery	Student learning product assessment (see E), student perception measures (see E) , % students responding satisfied/very satisfied
	General online delivery effectiveness of all course contents	Quality Matters rubric score (internal evaluation) with subsequent QM certification
	Student learning	Artifact assessment in comparison to learning outcomes
	Teaching effectiveness	TCE with additional questions
Outreach/Enrollment/ Retention	Increasing enrollment in MFS courses and degree program	# of students enrolled in MFS program
		# of MFS student credit hours offered
		# students retained from previous year
		# students graduating from the online MFS
		# of inquiries received by prospective students, # of applications received
		# of students with tuition underwritten by employer
Faculty engagement, trainin and development	Increase faculty willingness to teach online courses	# faculty prepared to teach online
		# of online education workshops/training sessions attended by faculty
	Increase faculty trained in online delivery	# of faculty delivering online courses
		# of online education workshops/training sessions attended by faculty
		% faculty responding: satisfied or very satisfied
	Dissemination of teaching practices	# of presentations made in the college, university, at conferences

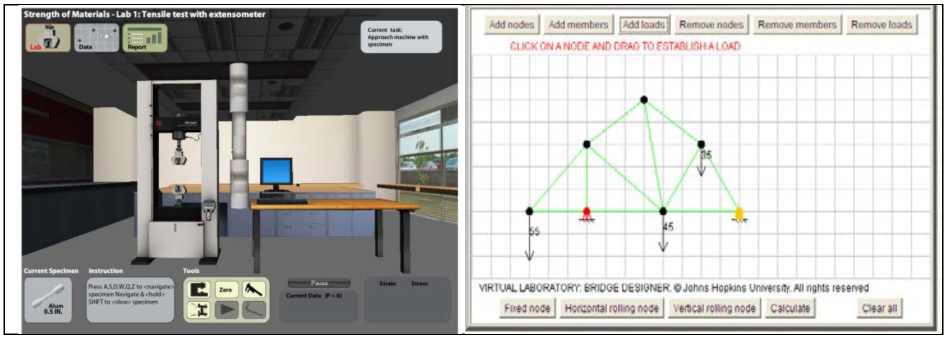
The tentative course development plan, through 2017, for the MFS online degree program is summarized in Table 4. As discussed previously, a number of these courses involve a variety of hands-on activities that must be maintained to provide online students with a similar experience to what was available to the face-to-face students of the MFS program.

Many innovative techniques such as immersive gaming software and other evolving technologies are now creating avenues to make online problem-based learning much better than before (James Gee, quoted in Waldrop, 2013). Researchers are exploring many novel ideas for online interactivity. These include: the use of remotely controlled instruments at centralized labs to give students in virtual lab data to conduct experiments; the use of ‘labs in a pocket’, in the form of camera-equipped phones, to capture data on real-life scenarios for analysis in virtual labs; using the ‘lab as a video game’, building on the approach used in online games like World of Warcraft to promote enquiry-based learning are some innovative approaches being explored (Waldrop, 2013). While these present exciting alternatives to create remote & virtual labs, many concerns exist about how effective these approaches really are and whether they can substitute for the ‘real’ experience. Also, none of these are yet used in manufacturing engineering courses. One of the goals of this project is to explore these emerging ideas to study how these approaches can be incorporated in MFS online courses. Other alternatives through custom, in-house software platforms are being used by some schools to present fundamental engineering concepts online (e.g.: Virtual Engineering Lab at Southern Polytechnic State University (SPSU) and Johns Hopkins; Figure 2). Developing such Adobe Flash Player-based modules using the external expert will also be explored.

Table 4: Plan for Online Course Development for MFS Degree Program

Seminar/Independent Study		Product Area		Process Area		Systems Area	
MFS 606: Global Issues in Manufacturing	S 2015	MFS 501: Mechanical Design w/Finite Elements	S 2015	MFS 505: Modeling of Mfg.Procees & Machines	F 2015	MFS 503: Lean Manufacturing	F 2015
MFS 780: Independent Study	F 2015	MFS 507: Design for Manufacturing	S 2016	EGR 599: Energy Assessment	S 2016	MFS 605: Factory Automation & Control	F 2016
		MSE 556: Introduction to Composite Materials	S 2016	MFS 699: Sustainable Manufacturing: Product, Process, Systems	F 2017	MFS 613: TBD	F 2016
			S 2016			ME 647: Systems Optimization	F 2017

One of the courses heavy on hands-on activities is the MFS/ME 503 Lean Manufacturing Principles & Practices course that teaches students the various tools required to implement continuous improvement practices. In addition to a number of activities conducted in the classroom, the course also involves students operating the Cylinder Factory housed in the College of Engineering. This factory uses real materials and machines where students work to measure, cut and process the raw materials to fabricate components that are subsequently assembled into finished piston-cylinder assemblies. This simulation is the capstone experience to apply a majority of the tools and techniques covered in the MFS/ME 503 course. In order to translate these activities to the online course environment, different possibilities are being explored. These include the development of virtual laboratories to conduct some of the in-class simulations in a web platform, and the possibility of requiring online students to have a one-time, on-campus weekend to participate in the laboratory exercises.



SPSU (Barham et al.2011) Johns Hopkins University (Karweit, 2013)

Figure 2: Virtual Lab Examples to Illustrate Simple Concepts

Faculty Preparation & Training

In 2013, the university developed the eLII program (Enhanced Learning Innovation Initiative). The Office of the Provost, Analytics and Technologies (AT) and the Center for the Enhancement of Learning and Teaching (CELT) invited colleges and departments to apply for funding to support the development of innovative, technology-rich pedagogy and learning strategies to address needs in a constantly changing learning environment via new online degree programs. The MFS program was one of three funded in the initial round (Cohort 1).

The eLII program offered significant funding for the course development of the first four courses to be offered online. The faculty were expected to apply for faculty development training grants, which provided a small amount of additional funding for computers and other hardware required for online delivery. These faculty attended a three to five-day workshop, covering a range of technologies and approaches for online delivery. In addition, the faculty participants were expected to complete a series of online course segments, which amplified and applied the technologies. This was followed by participation in one of a number of Faculty Learning Communities, where the group identified one or more focus areas related to online delivery, and met on a monthly basis. The eLII office also offers periodic workshops or seminars on topics of interest for online or blended delivery. The College of Engineering has subsequently committed to provide funds for faculty to develop another eight courses for online delivery.

In addition to the formal university-wide training, the MFS faculty were able to draw from online teaching experience within the College of Engineering. The College of Engineering at the University of Kentucky has a long history of offering courses through ITV (Interactive Video). The ITV technology allows synchronous delivery to distance classrooms with the ability to interact live with students. Some of the MFS faculty already had experience in ITV delivery. In addition to the ITV experience, a sophomore level Statics course has been taught in a fully online, primarily asynchronous, format since the spring of 2012. Experience from the process of developing, implementing, and modifying that online course was shared with the MFS faculty.

Features of the Statics course design were used to develop a template for the MFS courses. Some of those features include:

- Use of an LMS (Learning Management System) to house all content.
- Organization of content into weekly modules that clearly define expectations.
- Short, 10-20 minute, lecture videos.
- Use of Camtasia and Echo 360 recording technologies to create asynchronous content.
- Use of Adobe Connect Pro to facilitate synchronous web meetings and virtual office hours.

An invaluable part of the development process for the MFS faculty has been the sharing of experiences, both good and bad, in the use of various distance learning formats.

Blended/Hybrid Course Trials

In preparation for transitioning to fully online course delivery, faculty involved in the program undertook the conversion of some courses into the blended format in the Fall 2014 semester. Two courses that were experimented with are: MFS/ME 501 and MFS/ME 503.

The MFS/ME 501 course, titled Mechanical Design with the Finite Element Method is a blend of basic finite element theory and application with a commercial finite element package. It is required in the Mechanical Engineering undergraduate program, and is an elective for other programs. Since it is dual–level, it can be taken for graduate credit.

All course content for ME-501 in Fall 2014 was made available to students in the course learning management system (LMS), Blackboard. While the decision has been made to use Canvas as the LMS for online courses in the MFS program, the university still had Blackboard as its primary LMS in Fall 2014, so that system was used for this course. Lecture notes, all assignments, and tutorials and videos on use of the ANSYS finite element software package, were all posted in Blackboard. The lectures were delivered synchronously using Interactive Television (ITV) technology, with students attending in two locations. However, all lectures were recorded using ECHO 360, and links to all lectures were posted in Blackboard. So, actually, a student could take the course essentially as an on-line course offering in Fall 2014, except assignments were typically submitted at class time in hard copy form, and exams were offered only in the traditional way, with student taking them in the physical course classroom.

The second course that was delivered as a blended course in Fall 2014 was MFS/ME 503, titled Lean Manufacturing Principles & Practices which introduces students to a variety of tools and concepts such as standardized work, problem solving, 5S, pull production, setup reduction, etc., that can be used to continuously improve processes to eliminate waste. In addition to the MFS graduate students, the course regularly has a large percentage of undergraduate students who take it as a technical elective with total enrollment nearing 40 each semester.

During the Fall 2014 semester, Canvas was used as the LMS for this course and all materials—including handouts, lecture videos, reading material and homework assignments—were shared using this platform. Approximately 35% of the course content was delivered in the online format, with previously recorded lectures delivered asynchronously using Canvas (screen shot of an example module shown in Figure 3). In-class discussions were held to address student questions and clarify content for the material delivered online. In addition, 30% of the quizzes (students had quizzes for each module) were also conducted online, using the 'Quiz' feature in Canvas. All assignments were submitted in hard copy and all exams were offered in the traditional format. This course has a number of hands-on simulations and all those were conducted in the face-to-face mode during Fall 2014.

Students were surveyed on various aspects of the blended offering of these courses, and some preliminary assessment data is provided in the following section.

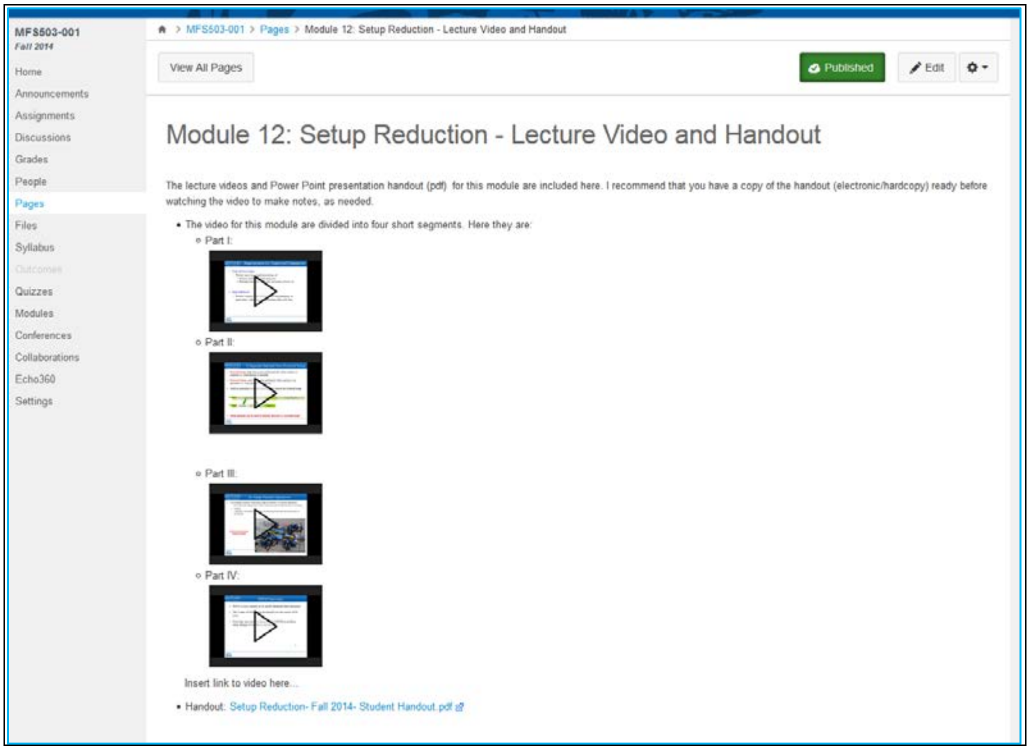
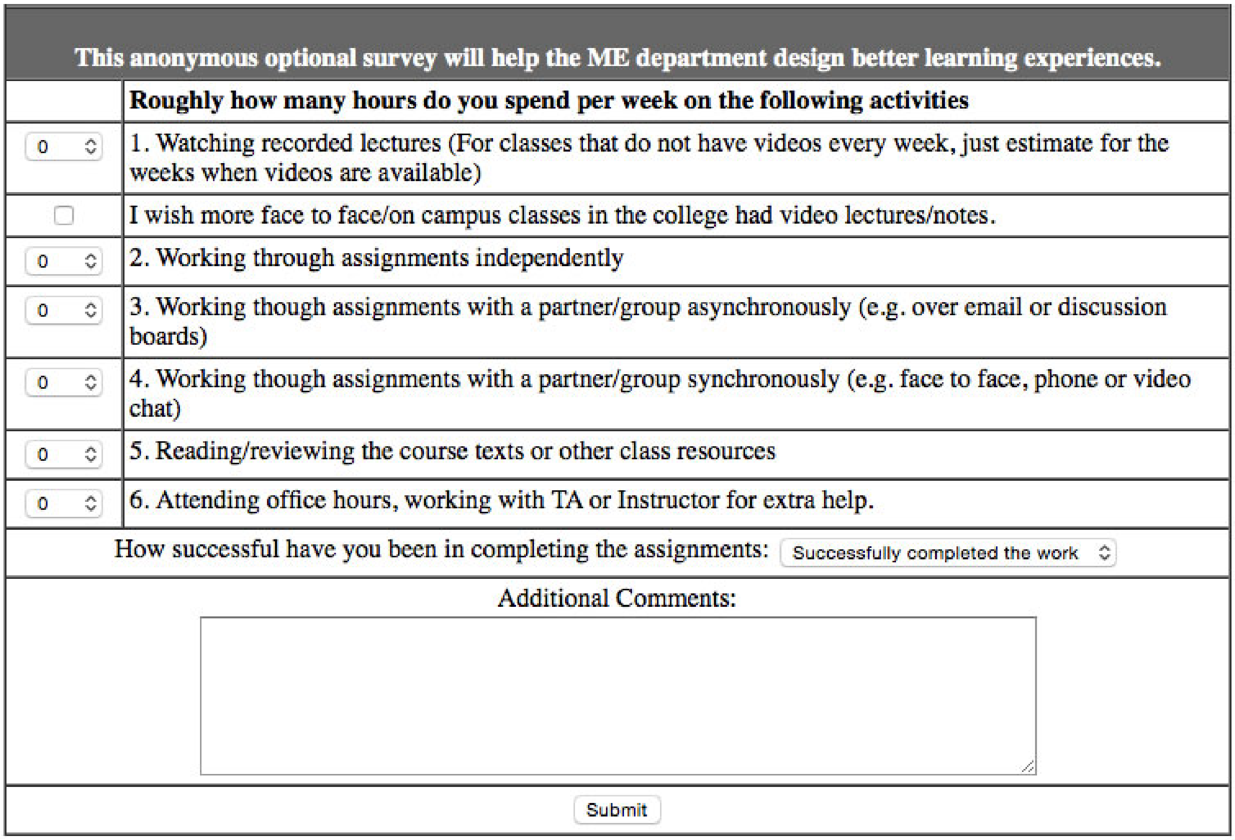


Figure 3: Interface for Online Lecture Video Material Sharing on Canvas – An Example

Preliminary Survey Results

The University of Kentucky requires an IRB (Institutional Review Board) review for research involving human subjects. The scope of our project involves use of both student academic data and student satisfaction surveys. IRB exemptions are allowed for normal educational practices in commonly accepted educational settings including the use of surveys. An IRB Exemption requires submission of a research plan which must include details such as how data will be handled and survey questions that will be used. Student consent to participate in the research must also be obtained. A plan detailing the requirements for the project were submitted to the university IRB and the exemption was approved.

As a preliminary step in the launch of the online program, faculty have begun integrating video captured lectures and notes as part of the on-campus/face-to-face courses. A survey was sent to students in two courses (n=55). The survey consisted of 9 items. Six of the items asked students to estimate how much time they spent each week on various out of class activities, including the use of the video lecture and notes. Of the remaining three questions one was an open response where students could make comments, one asked the students if they would like to see more use of video lecture and notes in other face to face courses, while the third asked them to rate their success in completing weekly assignments. The response rate for the survey was 26 students (47%). A screen shot of the survey is provided in Figure 4. A discussion of the results follows.



This anonymous optional survey will help the ME department design better learning experiences.

	Roughly how many hours do you spend per week on the following activities
0	1. Watching recorded lectures (For classes that do not have videos every week, just estimate for the weeks when videos are available)
☐	I wish more face to face/on campus classes in the college had video lectures/notes.
0	2. Working through assignments independently
0	3. Working though assignments with a partner/group asynchronously (e.g. over email or discussion boards)
0	4. Working though assignments with a partner/group synchronously (e.g. face to face, phone or video chat)
0	5. Reading/reviewing the course texts or other class resources
0	6. Attending office hours, working with TA or Instructor for extra help.

How successful have you been in completing the assignments: Successfully completed the work

Additional Comments:

Submit

Figure 4: Survey of extra-class activity.

Of the 26 students who responded, 62% of them selected the, “I wish more face to face/on campus classes in the college had video lectures/notes” option on the survey. This result was encouraging for the faculty design team, since the majority of survey responders viewed the materials being developed in a positive light. The response to this item was used to split the data file into two groups for means comparison. While the mean for the “success on assignments” question was higher for the pro-video lecture group (3.88), the difference from the video-agnostic group (3.60) was not statistically significant. The total time spent on extra-class activities was higher for the pro-video group (13.03 hrs vs. 9 hrs) with the difference being statistically significant ($p < 0.05$). In each of the six extra-class activities students were asked about, the time reported by the pro-video group was higher, with all but two being statistically significant. The two activities where the differences were not statistically significant were watching recorded lectures and working with groups asynchronously, which interestingly are often cornerstones of an online course. Perhaps the most interesting result from the survey was the greater amount of total time spent by the pro-video group. Several of the team found felt it seemed counter intuitive. A potential hypothesis is that the students who indicated a like of the video lectures needed the extra support while those who saw less utility in them did not. From a course design standpoint this would make sense and dovetail with past work in areas such as mastery learning. For example, in the Handbook of Formative Assessment (2010) Guskey notes "to attain better results and *reduce* variation in student achievement, Bloom reasoned that teachers would have to *increase* variation in their teaching" (p. 109). The results for the survey are summarized in Table 5 below.

Table 5: Survey Results by Item and Group

	All	Pro-video group	Video agnostic
Wish more f2f classes had video lectures	26	16	10
Watch Recorded Lectures	1.31	1.50	0.94
Working Independently*	2.19	2.53	1.61
Working w/ Group Asynchronously	1.37	1.47	1.00
Working w/ Group Synchronously*	1.21	1.50	0.61
Reviewing Course Texts/Materials*	1.38	1.78	0.72
Office Hours w/ TA or Instructor*	0.25	0.38	0.06
Total Time*	11.48	13.03	9.00
Success w/ Assignments	3.77	3.88	3.56

* = Differences were statistically significant at the 0.05 level.

The design team plans to conduct the survey with more on-campus courses at the University that employ video lectures and notes as well as with the on-line courses that will be launched in the Spring semester of 2015. Moving forward with the design process it is of interest to monitor how students in both the online courses and face-to-face courses spend their time and how that matched up with their success in the different course formats.

Spring 2015 Course Offerings and Status

Two courses were scheduled for online delivery in the Spring 2015 semester: MFS/ME 501 and MFS/ME 606. A discussion of the current status with these two course offerings is presented here.

MFS/ME 501 was initially offered as a fully online course in Spring 2015. The course is organized in modular form, using the Canvas Learning Management System (www.instructure.com). The modules consist of the week's course material, and each (typically) contains the lecture slides in printed form, several lecture videos, one or more videos on ANSYS Workbench (www.ansys.com) finite element software usage, a short quiz, and an assignment.

An initial assignment required the students to post a self-introduction in Canvas. This serves to verify that all students are able to access the course Canvas shell, and adds some perception of human interaction to this purely online course. The modular approach was used to organize material as it is an effective way of keeping the students focused on a specific topic during the week, which is important since initiative is required to view and digest the material. The material is released a module/week at a time; for flexibility, students can progress a week ahead of the planned schedule. A screenshot is provided below, in Figure 5, of the initial modules as implemented in Canvas.

One of the institutional requirements prior to delivering a course entirely online is getting the course approved for this mode of dissemination. This requires the submission of a 'Course Change Form' that is reviewed and approved at the Department, College, Graduate School and University Senate levels. Since the approval process was not completed on time for the MFS/ME 606 course, plans for its delivery as an entirely online course in Spring 2015 had to be modified. Instead, the course is now being offered as a hybrid course, with the lectures presented in class (and available for students to watch online).

MFS/ME 606 is a seminar course with presentations from invited speakers from industry, academia and the government discussing various issues related to manufacturing. Just as the other course offered this semester, students were required to post self-introductions using a Padlet© wall. The course is organized in a modular format with one presentation per week. An online, synchronous discussion is held each week, via Adobe Connect, to discuss questions related to the discussion topic with the guest speaker, too, connecting remotely.

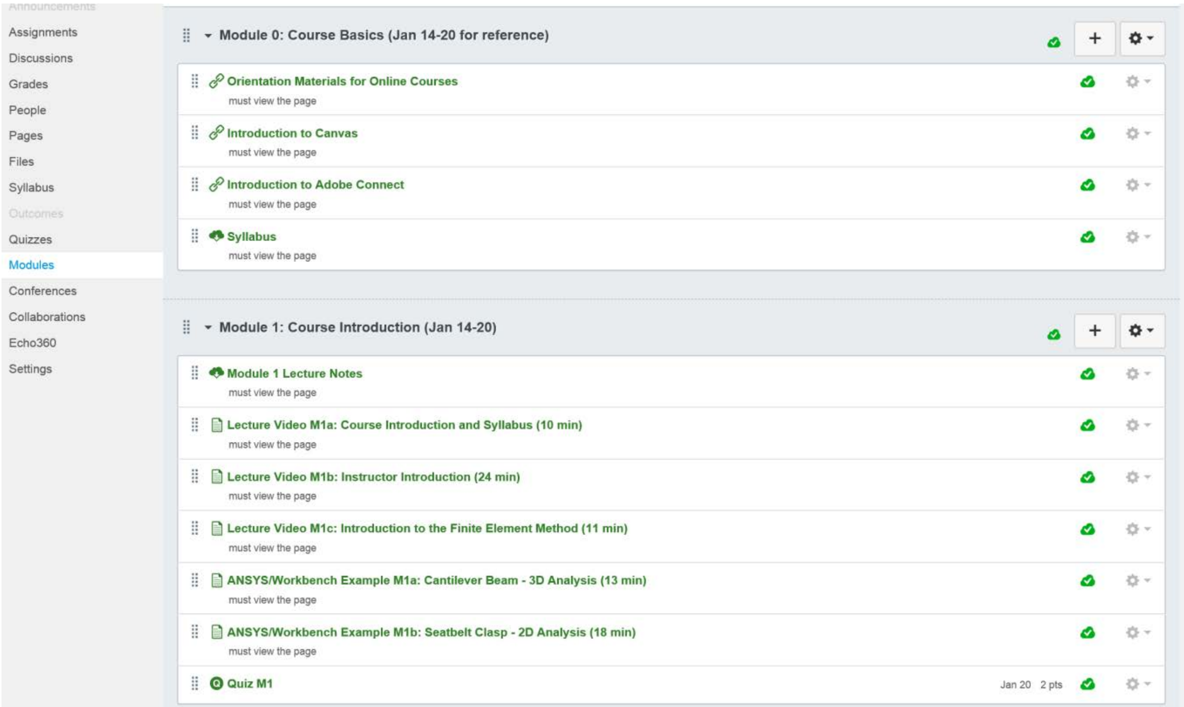


Figure 5: Initial modules implemented in Canvas for MFS/ME-501.

Preparation for these preliminary courses has revealed that transitioning to the online mode requires a very organized course structure; lecture videos and all course material must be gathered and the course shell on LMS ideally completed before the beginning of the semester. Attention span studies have repeatedly shown that student attention and learning decrease after about 20 minutes (Frederick, 1986). Therefore, when possible, lecture videos for the online courses were created in shorter segments of 10 – 20 minutes each, to make it easier for students to concentrate on the material and increase learning.

While this course delivery has moved smoothly, one of the difficulties encountered initially has been with getting the synchronous meetings (conducted using Adobe Connect) to run without any disruptions. Issues related to audio, freezing of video streams, noise, etc., were encountered and had to be resolved.

Conclusions and Future Work

Limitations of the traditional classroom approach have kept the current MFS program from reaching its real potential: its primary audience, working professionals in need of continuing education to add to their professional knowledge, is constrained by the requirements to attend classes on campus at fixed times while continuing to work full-time and attend to family responsibilities. The effort outlined in this paper is an effort initiated through funding from the eLII Program at the university ideal for reaching this audience.

Launching the initial set of online courses for this program in the Spring semester of 2015 has taught the team of faculty important lessons with regards to technologies available for online course development, online course structuring on LMS and effective course delivery to ensure learning objectives are met. These, however, account for less than 20% of the courses slated for online delivery for the program; the majority of the courses remain to be developed for online delivery in the future semesters. A number of challenges will have to be addressed before all the remaining courses can successfully be delivered online and the MFS program becoming a fully online degree.

One of the tasks facing the team in relation to courses heavy with hands-on learning content is identifying what portion of that content can be effectively converted for online delivery through suitable platforms and technologies to decide if there will be a need to retain some hands-on activities/laboratory experiments as fully face-to-face activities which require students to come on campus. If this is to be done, a careful evaluation of such activities for each course as well as how to coordinate and co-organize them to optimally utilize student visits to campus must be undertaken.

Another difficulty facing the team involves marketing the program to increase awareness and interest in the online MFS program with the ultimate objective of increasing enrollment. All the tasks, including marketing the online program, is currently coordinated by the Director of Graduate Studies with support from the faculty team who have very minimal expertise about the best channels to promote an online degree and reach the intended population. The team intends to seek help from other groups within the college as well as the university-level to address challenges in this area.

The initial plan of the program was to convert as many courses for online delivery to allow online students to have access to the same variety of courses that would be available for students coming on campus. The MFS program administration has since learned that international students, who have historically been the largest constituents of the student population, are only permitted to take one course online, per semester, in order to maintain their full-time status offered through the F1 visa. This restriction introduces additional complexity with course offerings as the program will be required to ensure a sufficient number of face-to-face courses will be available each semester to meet the needs of this student population. Therefore, one of the issues that must be addressed moving forward is, determining how such offerings could be made available, given the limited faculty resources available.

The team also intends to continue assessment to monitor how students in both the online courses and face-to-face courses spend their time and compare performance in the different course formats to provide insights for future course design.

Acknowledgements

This research was funded through a grant from the eLearning Innovation Initiative (eLII), sponsored by the Office of the Provost, Analytics and Technologies (AT) and the Center for the Enhancement of Learning and Teaching (CELT) at the University of Kentucky.

References

Barham, W. et al., (2011), A Game-based Virtual Engineering Laboratory for Online Teaching, presentation at Sloan-C International Conference on Online Learning, Nov. 9-11, 2011, Lake Buena Vista, FL.

Crawford, M. (2013), The States Leading the U.S. Manufacturing Resurgence Area Development, http://www.areadevelopment.com/RegionalReports/Q1-2013/states-leading-US-manufacturing-resurgence-2665542.shtml?Page=1
https://www.mapi.net/system/files/Advanced_Manufacturing_American_South_0.pdf

Frederick, P., (1986), The lively lecture – 8 variations, College Teaching, Vol., 34, pp. 43-50.

Guskey, T. R. (2010). Formative assessment: The contribution of Benjamin S. Bloom (pp. 106-124). In H. L. Andrade & G. J. Cizek (Eds.), *Handbook of Formative Assesment*.

Karweit, J., (2013), A Virtual Engineering/Science Laboratory Course, Johns Hopkins University, http://www.jhu.edu/virtlab/virtlab.html, accessed: Nov. 3, 2013.

Mangas, P. 2013. The Health of Manufacturing in Kentucky. Business Lexington.
http://bizlex.com/2013/02/the-health-of-manufacturing-in-kentucky/#sthash.t5rd4lYv.dpuf

National Academy of Engineering (NAE), 2013. Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning. Washington D.C.: National Academies Press.

National Science Foundation. Science and Engineering State Profiles. "Kentucky." Last updated: August 2013. http://www.nsf.gov/statistics/states/

Waldman, C. and Murray, M.N., (2013), *Advanced Manufacturing in the American South*, Howard H. Baker Jr. Center for Public Policy, University of Tennessee, Knoxville
https://www.mapi.net/system/files/Advanced_Manufacturing_American_South_0.pdf

Waldrop, M.M., (2013), Education online: The virtual lab, Nature – News Feature, July 17, 2013, available at: http://www.nature.com/news/education-online-the-virtual-lab-1.13383.