Using On-Line Education to Meet the Needs of Working Engineering Professionals

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Working engineering professionals and their employers understand the value of, and the need for continuing education; be it training courses, certificate programs, or advanced degrees. These consumers are looking for an efficient means to gain the required skills and knowledge to move their career, company, or project forward. These consumers demand well-written and well-presented material that matches their current need for knowledge. Often, the best approach to meeting these needs is a team consisting of university faculty members, highly respected industry professionals, and individuals trained in instructional design. The purpose of this paper is to show the method that was used to develop a successful on-line education program.

Introduction-

For most engineers it is a tough decision whether to continue on for a Master’s degree after graduating with a B.S., and for many because of family and financial responsibilities there is no choice but to take a full time position in industry. These working engineers see an increasing need for education beyond a B.S. but cannot afford to leave their jobs, move their families and attend university full time.

A distance degree program where the students can work on their degree part time while working, traveling, and holding family responsibilities fills the need of many working professional engineers. Group projects, live web-conferences, threaded discussions, and yearly one-week residencies provide students networking opportunities, and give the benefit of increased student interactions.

This paper outlines the method used to develop and implement the Master of Engineering degree, Engine Systems (MEES) program, a successful on-line degree program at the University of Wisconsin Madison.

Background-

Various education researchers provide supporting background for several elements of the MEES program.

Trevelyn\(^1\) showed that of the engineers that he surveyed, the most prominent aspect of the work they preformed was technical coordination. Technical coordination and group projects are key elements of the MEES program.

Baraket and Plouff\(^2\) indicate that professional skills such as Technical Communication and Project Management are best learned when the student is in a work environment, such as a co-op experience, and when they can be facilitated by using an on-line teaching environment. The MEES program includes courses in project management and technical communication.
Bhattacharya and Canizares show an increasing need for web-based graduate engineering education for engineers who are currently employed in industry. Strong enrollments in the MEES program have shown the need for this type of education.

Arias address the concern that students have regarding lack of collaboration in an on-line learning environment. Lawrence-Slater showed that virtual teams and on-line collaboration are essential components of web-based learning. In the MEES program much of the work is collaborative, and nearly every course has a group project as one of its key deliverables.

Aippersbach, Alley, and Garner showed that when students create assertion-evidence slides for a technical presentation they are able to better comprehend and recall the material than if they created topic-subtopic slides. The MEES program includes one credit hour of technical communication where the students learn the most effective ways of using slides and presentations to convey technical information.

Jones and Plemmons state “The need for project management education and training is not diminishing. Institutions who respond with educational programs that address the needs of their constituents will command an influential presence in their academic and business community. “ The MEES program offers a three credit course in Engine Project Management.

Tian and Abraham and Zueco discuss the application of using computer models for the teaching of principles of internal combustion engines. The MEES program utilizes Ricardo WAVE®, Matlab Simulink®, and Engineering Equation Solver in the courses.

Wang, Luo, and Li highlight the urgent need for engineers to have the ability to innovate. Innovation seminars are given to the MEES students during their time on campus for Summer Residency.

Feemster and Mohamidi et.al utilized MATLAB/SIMULINK in an educational setting. MATLAB/SIMULINK is utilized in the four credit hour Engine Systems and Controls course for the MEES program.

MEES Program design-

The design of this on-line master’s degree was based on several critical elements:

- An identified need
- A vision and mission statement
- A determination of the students’ skills and knowledge to be developed by the program
- A well thought out curriculum
- Course design incorporating instructional design methodologies and the strengths of the on-line learning environment
- A program and delivery method that meets the needs of the students
- Outstanding and competent IT (Information Technology) resources
- A financial and feasibility study
A feedback loop with input from university researchers, industry professionals, and alumni

Vision, mission and goal -

The vision of the MEES program is to move the internal combustion industry forward by producing knowledgeable and innovative industry leaders. The mission of the program is to provide top-notch graduate engineering education to working professionals in the internal combustion engine industry. The goal of the program is to provide the knowledge necessary to become a chief engineer on a new engine development project. Such knowledge emphasizes the ability to integrate expertise from many disciplines, as opposed to detailed technical knowledge in a single discipline.

The vision, mission, and goal of the MEES program are central to every decision that is made in the program.

Need and program scope-

A combined team of university professors and well-respected senior management professionals from industry designed the MEES program. The curriculum was developed starting with the idea “What does a person need to know to become a chief engineer for a new engine development project?” This information became the goal of the MEES program.

The mission and vision of MEES are primarily directed toward engineers working in the product development side of the industry. The relative size of the industry in comparison to the total need for graduate engineering education influenced the decision to keep the size of the program small and limited to a select number of participants each year.

With the relative need in mind, the MEES program was designed to accept a cohort of 15 new students each year. This allowed the program to have small classes during the first 1.5 years of the program, and allowed the program to put two cohorts into a single course, still keeping the enrollment in these courses at an average of 30 students during the last two years of the program.

Curriculum definition -

Once the vision, mission, and goal were established, the resulting objectives were used to define the curriculum. The first task was to identify the skills and knowledge needed to fulfill the stated goal, providing the students with the knowledge and skills required of a chief engineer on a new internal combustion engine development program.

The skills and knowledge identified were sorted into 5 general areas:

1) Teamwork, coordination and managerial
2) Design
3) Thermal sciences, fluids, combustion
4) Controls
5) Future trends

Teamwork, coordination, and managerial skills-

The skills identified in this category include:

The ability to:
- manage projects
- participate on local, remote, and global teams
- manage work load
- manage expectations
- effectively communicate thoughts, ideas, and concepts
- research and acquire needed information
- evaluate the information available
- make decisions based on available data

The two primary courses that focus directly on addressing these skills are Essential Skills for Engineering Productivity and Engine Project Management.

In the Essential Skills for Engineering Productivity course the students learn how to work in remote teams, coordinate technical projects, manage their time, manage the expectations of others, and how to present technical information. The portion of the course that receives the highest ratings from the students is the presenting technical information portion. The presenting technical information portion includes topics such as best practices for producing highly effective slides. This material has been so well received that the instructors for this portion of the class published a text book, *Slide Rules.*

While the MEES program is primarily technical rather than managerial in nature, project management was identified as an essential skill for becoming a chief engineer of an internal engine development project, and therefore included in the MEES curriculum.

While these two courses are the only courses that are strictly devoted to coordination and managerial skills, these skills are utilized and further developed in all of the MEES courses. All MEES courses require technical presentations, group work, and discussions. Most courses require a research project.

Although it is not the primary focus, the Engine Design series also teaches leadership, teamwork, decision making, and coordination. The students are required to work together in teams and design an engine with limited resources, information, and time. The Perspectives in Engine Modeling course, in addition to the technical content, further develops skills in technical communication and decision-making.

Thermal sciences, fluids, and combustion-
The MEES program includes three courses in these areas. The two major courses are Engine Fluid Dynamics and Engine Performance and Combustion. The Engine Fluid Dynamics course is the same course that is taught on-campus to the graduate students at the University of Wisconsin Madison. The Engine Fluid Dynamics course is the only course in the MEES program that was not developed specifically for the program. The MEES on-line students typically do as well, and often better than the on-campus students in this course.

The other major course is Engine Performance and Combustion. This course covers application of thermodynamics, combustion kinetics, and fuel chemistry to the development of combustion and aftertreatment systems.

The third thermal/fluids course in the MEES program is specifically intended to provide the required pre-requisite skills for the above-mentioned two courses.

Engine Systems and Controls, and Engine Noise and Vibration courses-

The area of Engine Controls has been one of the largest areas of advancement of engines in recent times. Therefore the number of credits and amount of material for the Engine Systems and Controls course has increased.

Engine Noise and Vibration is a new course starting in 2015. Previously, a significantly smaller amount of material on noise and vibration was presented as part of the engine design series.

Engine design series-

The content that is most central to the program is that presented in the Engine Design series of courses. In this course sequence the students form team of two to four students, and design an engine beginning from market identification and customer requirements. By actually designing an engine, the students demonstrate the highest learning objective from an instructional design point of view. The instructors from this course have extensive industry experience designing and developing engines, and have written the textbook on engine design\(^\text{14}\).

A couple of examples of the engines created during this course\(^\text{15,16}\) are shown in Figures 1 and 2:
The Perspectives in Engine Modeling class provides information on how to use modeling to make design decisions. Students were also taught aspects of innovation which could be applied to their engine design models.
Future directions-

The Analysis of Trends in Engines course looks at the factors that are influencing the internal combustion engine industry, and how the industry is likely to change in the future. It is necessary for the students to be able to anticipate industry changes and know where to go to find information about how the industry is likely to change in the future. This course sequence covers manufacturing constraints, legislative drivers, alternative fuels, and powertrain technologies.

MEES program design and delivery–

Once it was determined what knowledge and skills were needed, the curriculum was set and the delivery method was determined.

As the MEES program is for professionals working across the nation and around the world, it requires that the majority of the coursework be done at a distance. The design and delivery method was modeled after a very successful distance degree program at the University of Wisconsin. The availability of a student services director to help with issues such as admissions, enrollment, and other aspects of the education system was required. Because the students are remote and working professionals, they are not able to come to campus to perform many of these functions themselves.

Surveys and discussions with students resulted in the course load being designed around the students’ needs. Many of the students required financial aid, which requires a minimum enrollment of four credit hours each semester. Since all of the participants are working adults, and many of the participants have young children, taking more than four credit hours of such a highly technical program would create additional difficulties in completing the degree. Four credit hours per semester is manageable for most students, as evidenced by an on-time graduation rate above 90 percent.

A key consideration in the design of the MEES program was networking and interaction with the other students. Since all of the students are working professionals in the industry, the students themselves bring a great deal of knowledge and experience to the program. Having the students work in teams and share technical information greatly increases the value of the program. Having a time each year for the students to interact face-to-face with other students and instructors was considered very important to the program goal. The students come to campus one week each year for Residency. Here the students network, form teams that will be used throughout the coming semesters, attend live lectures, and get training on the software used in the MEES program. The lectures during residency include preparation for their courses for the coming year, lectures on innovation, software training including WAVE, MATLAB/Simulink, and EES (Engineering Equation Solver) as well as hands-on Engine Noise and Vibration educational opportunities.

Prior to starting the program, many incoming students were reluctant to take the time away from their jobs and families to attend the residency program. In discussions with those same students
at the end of the program, they state that residency was in fact the most prized part of the program.

The MEES program is set up as a cohort, with students taking every class with the same group of students that started the program with them. This works well as the students are able to maintain their groups from course to course and are able to encourage one another. Additionally, having a cohort program is necessary to make it possible to operate a program with only 15 students admitted each year.

The MEES program is designed to have a great deal of interaction between the students, and with the instructor. In addition to recorded lectures, the students are expected to attend weekly web-conferences. The students are required to participate in threaded discussions throughout the course, with the other students and faculty members.

The combination of live lectures during residency, live web conferences, discussion forums, and group projects make the MEES program feel anything but distant.

Instructors-

The MEES program utilizes instructors both with impressive careers in academia as well as those with equally impressive careers in industry. The use of industry professionals teaching alongside university researchers allows the courses to have a rigorous academic foundation as well as practical application to the students’ current and future job responsibilities.

Feasibility-

A feasibility study was done to determine if the MEES program would be sustainable. The feasibility study included current and future projected enrollments, and a budget including course development costs, and projected availability of faculty and support staff. The feasibility study showed that the program would be sustainable with an average enrollment of 13 to 16 students yearly given the current tuition rate and salary structure.

Students-

There have been 99 graduates of the MEES program since it’s beginning in 2003. The students and graduates are from all over the United States (
(Figure 3), with four students living and working outside of the United States during their degree program.

Figure 3: Geographical location of U.S. MEES Students and Alumni
The majority of new MEES students learn about the program from a current student or alumni.

At the end of each course the students are asked to evaluate how useful that course was to their current and future job position and responsibilities.

![Usefulness to Current Job Responsibilities](image)

Figure 4 and Figure 5, compiled from the data from the end of course surveys for the time period from 2010 to 2015, show that the majority of students felt that their courses were useful for both their present position and future positions.

The weighted average (based on program credits) for the entire MEES program is as follows:

- When asked if the course content was useful for the students current job responsibilities and position, the responses were (weighted average based on course credit hours) 80 percent useful, 16 percent undecided and, 4 percent not useful
- When asked if the course content was useful for the students’ future job responsibilities and position, the responses were (weighted average based on course credit hours): 91 percent useful, 8 percent undecided and, 1 percent not useful.
Figure 4: Usefulness of Course Content to Student's Current Position and Job Responsibilities

Figure 5: Usefulness of Course Content to Student's Future Position and Job Responsibilities
Conclusion-

The following steps were followed in the development of the MEES program.

- The need for the program was identified; The MEES program is to provide top-tier graduate education for engineers currently working in the internal combustion engine industry, seeking to gain skills required to become a chief engineer of a new engine program.
- The vision and mission of the program were defined. The mission of the MEES program is to provide the highest quality graduate education for engineers currently working in the internal combustion engine industry. This sets the direction for the program, defines the group of applicants, and determines the direction of the program.
- The curriculum was defined based on the need, vision, mission, and objectives of the program.
- The delivery method for the program was determined. This included determining the course load, residency, the course structure, and the cohort model.
- A feasibility study was conducted to determine if the program would be sustainable based on projected enrollments.
- Courses were developed specifically for on-line delivery, utilizing course developers in conjunction with the instructors.
- A student support director was made available to work with students.
- The IT (Information Technology) department was staffed to meet the needs of the on-line programs.
- Continual feedback on the program is received from students, alumni, university professors, and industry leaders.

The result is that the MEES program has had 99 graduates to date, and student responses overwhelmingly indicate that the courses are useful for the students’ current and future job responsibilities.

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Wang, Peijun1, Dabing1 Luo, Lin1 Li, and Yongyan1 Cao. (2013) "Cultivation of the ability to innovate through the construction of an experiment platform for virtual design and manufacture." International Journal Of Mechanical Engineering Education 41, no. 4: 354-359.


