Development and Implementation of the Industrial and Entrepreneurial Engineering Program at Western Michigan University

Dr. Azim Houshyar, Western Michigan University

Azim Houshyar has a PhD in Industrial and Systems Engineering from the University of Florida (1978). He is currently a Professor of Industrial and Entrepreneurial Engineering & Engineering Management at Western Michigan University. His interests include simulation methodology, reliability engineering, application of operations research to manufacturing processes, and production control.

Since 1987, Dr. Houshyar has been actively involved with consultation to local, national, and international manufacturing corporations. A few examples are: Whirlpool Corp., Humphrey Products, Eaton Corp., Checker Motors Inc., Steelcase, Ford Vehicle Operations, Ford Powertrains, Ford Stamping, Ford Electronics, Ford Framing, Ford Assembly, Verson, Automatic Feed, Pratt & Whitney, Prince Corporation, Herman Miller, and ABB Olofstrom. He has assisted corporations in the United States, Germany, Check Republic, Iran, Portugal, Canada, and Mexico.

From 1995 to 1997, Dr. Houshyar spent all of his spring and summer terms at Argonne National Laboratory (ANL) assisting them with the scheduling of the EBR-II nuclear reactor shutdown. Dr. Houshyar developed several mathematical and simulation models that helped plan for the reactor shutdown accordingly.

Dr. Houshyar has served as the Editor-in-Chief of the International Journal of Modelling and Simulation for over 20 years, and is very active in publication of scholarly articles. He has over 30 journal publications and 100 articles in conference proceedings. Some of Dr. Houshyar’s journal publications are in Computer and Industrial Engineering, Computers in Industry, The International Journal of Modelling and Simulation, Applied Ergonomics, The International Journal of Production Research, Industrial Management, Simulation, and The Institute of Industrial Engineering Transactions, to name a few. His professional affiliations include ORSA, TIMS, APICS, SME, and IIE.

Dr. Houshyar can be reach at houshyar@wmich.edu.

Dr. Bob White, Western Michigan University

Bob White has a Ph.D. in Engineering Valuation from Iowa State University (1980). He is currently a professor of Industrial and Entrepreneurial Engineering & Engineering Management at Western Michigan University. His interests include entrepreneurial engineering, engineering economy, capital budgeting, and operations control. Dr. White is actively involved as a consultant to industry having been involved with numerous companies. Dr. White has over 20 journal publications and more than 50 articles in conference proceedings. Some of Dr. White’s journal publications include The Engineering Economist, Computers and Industrial Engineering, The International Journal of Modelling and Simulation, and The International Journal of Production Research. His professional affiliations include IIE, ASEE, and SME.

Dr. Steven E. Butt, Western Michigan University

Dr. Steven Butt is Professor and Chair of the Department of Industrial and Entrepreneurial Engineering & Engineering Management at WMU. Dr. Butt has worked in the areas of operations research, product design, and engineering statistics for over 20 years. Projects with private, corporate, and government institutions have led to data sets with billions of elements for which Dr. Butt has written software to maintain, mine, and model. Recent results of his work include workforce scheduling models that take into consideration employee preferences, assignments, and physiological demands, and product design models based on input forces, contact pressures, biomechanics, and postures. Dr. Butt is an affiliate of WMU’s Human Performance Institute (HPI) and he has more than 50 peer-reviewed publications. His professional affiliations include ASEE, IIE, INFORMS, and ORSNZ.

Dr. Tycho K Fredericks, Western Michigan University
Dr. Tycho K. Fredericks is a Professor in the Department of Industrial and Entrepreneurial Engineering & Engineering Management at Western Michigan University. Dr. Fredericks has 18 years of experience working with healthcare professionals on product design and evaluation, and workload assessment. Additionally, he serves as Director of the Human Performance Institute and has been a gubernatorial appointee to various safety committees in the State of Michigan. He has been a member of the General Industry Safety Standards Commission, the Joint Ergonomics Standard Steering Committee and the Ergonomics Standard Advisory Committee. Dr. Fredericks has published over 100 scholarly articles and is currently responsible for the College of Engineering and Applied Sciences medical engineering initiative.
Introduction

The industrial engineering (IE) degree was first offered at Western Michigan University in 1959. It was the only engineering program at the university until mechanical engineering and electrical engineering were added in the mid 1970’s. The IE program obtained EAC accreditation in 1979 and has maintained continuous ABET accreditation to date.

Historically, the IE program was a traditional program, requiring the typical combination of math, science, engineering science, engineering design, and IE topics focusing on work design, production, economics, operations control, facilities design, and operations research. This traditional IE focus served students well in the economy of the 70’s and 80’s which was production-oriented. Students received good, well-paying jobs, and enrollment in the program remained at a healthy level between 110 and 130 students. Beginning in the late 1990’s and into the early 2000’s, economic developments at the national level, and especially in the State of Michigan, resulted in changes in the skills employers were looking for in our IE graduates. The emphasis shifted from a traditional IE to a “change agent” in today’s service and production sectors. Employers still wanted people with traditional IE knowledge, but they also were looking for employees that could create opportunities in a global economy.

During this period of the early to mid-2000’s, interest in the IE program was dropping and enrollment was declining. This phenomenon was not exclusive to Western Michigan University. Similar declines were seen at other universities located in manufacturing regions across the country. In some extreme cases IE programs were closed (e.g., University of Cincinnati, University of Toledo, and University of Alabama). Many students did not see a future in traditional IE. Enrollment at Western Michigan University dropped to below 50 students in 2006. The faculty realized that changes were necessary to once again have an attractive program. A core of senior faculty banded together to reinvent the IE program at Western Michigan University in an effort to prepare graduates for future careers -- including future positions which may not exist in the current workplace.

Review of programs at other schools

In 2005, it was unclear what direction the IE program at Western Michigan University should take. Some IE programs across the US had made changes to their programs, but these changes typically included making small content adjustments and placing terms such as “systems”, “operations”, “operations research”, or “manufacturing” in the program name. While these types of changes were considered, the Western Michigan University faculty also wished to focus on the strengths and needs of the local community. One key strength identified was the historical and vibrant culture of innovation and entrepreneurship in regional start-ups and established industries. This moved the investigation of current programs in a different direction and identified the unique changes that had occurred at the University of Illinois. The University of Illinois had recently
changed its IE department name to Industrial and Enterprise Systems Engineering (http://ise.illinois.edu/) and had developed a Master of Science degree in Systems and Entrepreneurial Engineering. Departments at schools such as Stanford, MIT, University of Pennsylvania, Marquette University, and Lehigh University had incorporated elements of entrepreneurship in their engineering programs. Additionally, the importance of entrepreneurial engineering was beginning to be realized and disseminated nationwide. In 2005, Polczynski and Jaskolski stated that, “In this rapidly evolving global business environment, an engineering role of increasingly critical importance is the generation of a continuous flow of front-end technology innovation to feed global suppliers and markets. While traditional engineering tasks, knowledge, and skills typically focus on the how-to-do-it activities associated with product and service design, manufacturing, and support, engineers are being called upon to a much greater extent to perform the what-to-do functions that drive technology innovation and fill the front-end of the design-product-service pipeline.”

Development of the new industrial and entrepreneurial engineering program

In 2006, the faculty initiated a complete review of the IE program. It was decided that no course or topic was off limits. The objective was to completely revise the IE program and put in place a curriculum that would meet the needs of future graduates. After several meetings and retreats, the faculty agreed that the new IE curriculum should have the following features:

1. Change the name of the program to reflect the change in emphasis of its content.
2. Keep a strong emphasis on traditional engineering topics including math, science, engineering science, and engineering design relevant to IE.
3. Incorporate a new three course sequence providing an emphasis in entrepreneurial engineering.
4. Build into the curriculum a minor that would require students to obtain a 15 credit hour minor in any program outside IE without extending graduation requirements.
5. Receive up to 6 hours of credit for courses taken as part of an international experience.
6. Receive up to 3 hours of credit for an internship experience.

To accomplish these objectives a complete course by course examination was required. Topics were reviewed by the faculty to determine their relevance in the new program and their relevance to IE. Topics and courses were deleted or combined when necessary. This was done within the requirement of keeping graduation credit hours at 128 while providing the available credit hours to meet features 2 through 6 above. To assist in this process, the IE program’s industrial advisory board (comprised of employers, alumni, and working IE professionals) was used extensively. This advisory board provided feedback on the proposed changes and also provided independent suggestions on how to best improve the curriculum to meet current and future needs. The input from this group proved invaluable in this process. Table 1 summarizes the changes that were needed to transform the industrial engineering program into industrial and entrepreneurial engineering (IEE) program.

Table 1 shows that the traditional IE program had 45 credit hours of engineering science and 25 credit hours of engineering design for a total of 70 credit hours of engineering science and design. The new IEE program has 32 credit hours of engineering science and 28 (=19 + 9) credit hours of
engineering design for a total of 60 credit hours of engineering science and design. The reduction of 10 credit hours of engineering science and design was accomplished by deleting courses identified by employers, students, alumni, and advisory board members as being the least important to the current practice of IE. While no longer required, students are still able to choose these courses as part of their approved elective courses in the new IEE program.

Table 1. Program requirements for Previous IE Program and New IEE Program

<table>
<thead>
<tr>
<th></th>
<th>Previous IE</th>
<th>New IEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math and Science</td>
<td>30 cr hrs</td>
<td>30 cr hrs</td>
</tr>
<tr>
<td>General Education</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Engineering Science outside IE</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Engineering Science inside IE</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Engineering Design</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>Entrepreneurial Engineering (Engr Design)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Minor</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>IE Electives</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Other - Technical Electives (Engr Science)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>127</td>
<td>128</td>
</tr>
</tbody>
</table>

By late 2006, the faculty had agreed on the necessary changes and curriculum change forms were submitted for review by the appropriate university committees. The new program was approved by the University Board of Trustees in June 2007 with the official program name:

**INDUSTRIAL AND ENTREPRENEURIAL ENGINEERING.**

The first students graduated from the IEE program in April 2009.

**Innovative and unique features of the program**

There are two major innovative and unique features of this curriculum redesign. The first is incorporating a new three-course sequence in entrepreneurial engineering designed specifically to help industrial engineers be successful in a diverse and rapidly changing economy. The incorporation of this sequence transformed the IE program from one reminiscent of the 60’s and 70’s to a program clearly looking into the 21st Century.

The second is the incorporation of a minor in any area of the student’s interest as part of the curricular requirements. This represents a significant change in undergraduate engineering education at Western Michigan University. We now have students graduating with minors in languages such as Chinese and Spanish, social sciences such as economics and psychology, as well as more conventional areas like supply chain management. The IEE program is the only engineering program at Western Michigan University that allows students to earn a minor (in addition to a math minor) as part of their curricular requirements. Faculty believe this gives our students a competitive advantage in today’s job market.
The development of the three-course sequence in entrepreneurial engineering presented faculty with the challenge of developing an experience that would allow students from their freshman to senior years the opportunity to learn what an entrepreneur (or intrapreneur) is and how to take an idea through product development, marketing, and production. Our primary focus is on effectively identifying, acquiring, developing, and transferring technology into viable new products, systems, and services. That is, teaching students to know “What-to-do” in the workplace, as well as “How-to-do” it\textsuperscript{1}. The three new courses are described below.

**Entrepreneurial Engineering I.** This course is taken by students in the second semester of their freshman year. Its purpose is to introduce students to traditional IE topics with an entrepreneurial engineering focus. In this course, students learn how conventional IE topics such as learning curve theory, forecasting, and basic accounting concepts are used by entrepreneurs to start new companies. Student teams are required to identify a product idea and prepare a basic business canvas for their idea. The business canvas requires students to determine things such as labor and material costs, overhead expenses, forecasted demand, and the preparation of financial statements. Student teams present their ideas during in-class presentation competitions.

**Entrepreneurial Engineering II.** This course is taken by students in the first semester of their junior year. This course requires students to develop and prototype a product. The product idea could come from Entrepreneurial Engineering I or from another source. The focus of this course is on the product development process from an entrepreneurial engineering perspective. This is a course that stresses hands-on development and application of good engineering design principles. About two-thirds of the course time is spent in labs developing and prototyping the working model. One of the final requirements of this course is a public presentation at an event called “Innovation Day” (see Figure 1). This has proved to be a very popular event with many outside groups attending, such as media representatives, business park partners, regional company representatives, high school and middle school students, and others. This event requires students to demonstrate and “sell” their product in a true entrepreneurial sense. The student teams are judged competitively with attendees given “innovation dollars” to allocate to the teams as they see fit. The team that ends the day with the most innovation dollars is awarded first place in the competition. This course also serves as a launch pad for our students to enter competitions such as: Accelerate Michigan Innovation Competition, Clean Energy Business Plan Competition, Great Lakes Entrepreneur’s Quest and the NCIIA’s Open Minds Competition.

**IME 4010, Entrepreneurial Engineering III.** This course is taken by students in the first semester of their senior year. This course continues with the student’s product developed in Entrepreneurial Engineering II and focuses on the logistics associated with producing the new product. This course incorporates coverage of traditional IE topics, such as design for manufacturing, robust design, facilities layout, facilities design, and supply chain management. By the end of this course, the students are required to develop a marketing, production, and logistics plan for their product.
Figure 1: IEE Students showing their product ideas at Innovation Day

**Impact of the changes on the industrial engineering program**

The practice of industrial engineering has changed dramatically over the last 30 years. IEs need skills to compete in a larger, more competitive global marketplace. The changes made to the IE program at Western Michigan University were substantial and aimed at providing students with the skills to be successful in the 21st Century. While not forgetting traditional engineering roots, the program has changed its focus to provide IEEs with a broader skillset that includes an entrepreneurial engineering focus and that allows students to obtain a minor in an area that they believe will provide them with the best opportunity to be successful. This means that each graduate of the IEE program will have the same set of engineering skills, a solid set of skills on how to be an entrepreneur (or intrapreneur), and a unique set of skills associated with their minor all designed to put each student in the best possible position for success.

**Effectiveness and benefits of the curriculum changes**

Response to the curricular changes has been overwhelming. In 2013 the Institute of Industrial Engineers recognized the changes made in this program with the 1st Place Award for Curriculum Innovation in an Industrial Engineering Program.

Since the official program start in Fall 2008, undergraduate IEE enrollment in Spring 2014 is up over 70% in comparison to Spring 2008 and over 90% in comparison to the Fall 2006 program low (Figure 2).
In the Fall of 2012, the program became the first in the nation to be accredited by ABET as Industrial and Entrepreneurial Engineering. Subsequent projections indicated that the IEE program enrollment could exceed the numbers achieved under the previous IE program (>130 students).

In the last three years, this program has produced two new Michigan-based companies (LLCs), several provisional patents, and one student team placing third ($10,000) out of more than 300 student teams in the Accelerate Michigan Innovation competition (see Figure 3). The Accelerate Michigan competition targets student concepts with longer-term business viability with potential to generate an immediate impact on Michigan’s economy. With more than $1 million in cash winnings, the Accelerate Michigan Innovation Competition is the world’s largest business plan competition.
Discussions are currently underway with the business college to include business majors in the entrepreneurial activities in the IE department. To date, Entrepreneurial Engineering II has been included as a required course in a new university-wide entrepreneurship minor and Entrepreneurial Engineering I has been included as an elective in this same minor.

The College of Engineering and Applied Sciences has established a new academic department to house the IEE program. This department will be named the Industrial and Entrepreneurial Engineering and Engineering Management Department and will also house the MSIE and PhD degrees in Industrial Engineering and the MS degree in Engineering Management.

Since 1998, all students in the industrial engineering program have been required to take the FE exam as part of their graduation requirements. Pass rates for the past 15 years have been above the national average for our IE’s each year, with our pass rate ranging from 75% to 93% (Figure 4). For the 11 years the traditional IE program was in place, the average pass rate was 81%. For the 5 years the new program has been in place, the pass rate has averaged 86%. Faculty were pleased to see that the changes in the engineering science and design content, which they believe adds strength and breadth to the program, have been validated with an increase in the average FE pass rate.

Figure 4: FE Pass Rate by Year

Feedback from employers has also been very positive. Employers have very impressed with the skill set of our graduates from both engineering and business perspectives. These employers have
also been very pleased with how our graduates have put to use the innovative and creative aspects of their undergraduate education into the real-world working environment.

**Providing a roadmap for others**

The process used in this curriculum innovation requires acknowledgement by faculty that change is required. It requires explicit recognition that the future of IE needs to be different from the past. With that recognition and a commitment from faculty, real change can be accomplished.

The following suggestions are offered:

- Confirm the commitment from faculty to do a comprehensive review of all courses and topics. This review should be revolutionary not evolutionary in nature. Nothing can be off limits in this review.
- Set objectives for the program that are forward looking and are independent of the past.
- Determine a focus area for the program and include this focus area in the program name.
- Do what is necessary to free up enough credits to allow students to choose a minor. This is liberating for students and greatly enhances the program.
- Build on the strengths of the community. Our community has a rich history of entrepreneurs, scientists, and engineers. Companies such as Gibson Guitars, Checker Cab, Bells Brewery, Upjohn, and Stryker have been founded in this community and the community has embraced our students.

**References**