Transforming the Industrial Engineering Technology Curriculum through a Graduate Level Management of Systems Engineering Course

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Abstract

The purpose of this study is to identify Industrial Engineering Technology (IET) curriculum requirements through the application of systems engineering design tools and methods in a graduate-level engineering management course. Four teams of students in a Management of Systems Engineering graduate course defined IET course requirements by applying systems engineering design tools and methods. The teams applied Voice of Customer and Quality Function Deployment methods to define requirements of four main stakeholder groups, including: current students, faculty and administration, employers, and alumni. The team goals are to: benchmark existing ABET accredited IET and Industrial Engineering programs; identify IET students' skills required for the future engineering challenges; incorporate interconnected experiences throughout the curriculum; enhance courses to include the university's Common Academic Program (CAP) requirements; and identify growing industries where IET skills can be applied. This is a work in progress, and constitutes the first step in transforming the university's Industrial Engineering Technology curriculum. The results of this study will serve as a basis for the integration of experiences and courses to enhance the success of our Industrial Engineering Technology graduates. The proposed curriculum will enhance the analytical and technical skills required for an Industrial Engineering Technology undergraduate to excel in the future engineering world.

Background

In a constantly changing world, technology is a part of society that will continue to improve and change. The university offers degrees in many different engineering disciplines, but the focus of this project is to transform the Industrial Engineering Technology bachelor's degree. The University is a Catholic, Marianist University that is committed to serving the common good. The word community is well known and cherished by faculty, students, and alumni of the university. The curriculum at our University focuses on the education of the whole person and creating the awareness in students that they should want to help serve their communities. The university at the highest levels, stresses the importance of teaching, learning and agility to adopt to new models. The president of the university, in his recent inaugural address said, "We also proclaim our foundational support for excellent teaching and learning and the agility needed to adopt new models. We renew our commitment to teaching that engages students and prepares them for servant-leadership roles." [1]. The University's Industrial Engineering Technology (IET) program is one of only 11 Industrial Engineering Technology bachelor's ABET (Accreditation Board for Engineering and Technology) accredited programs [2]

This study attempts to identify the skills and abilities that industrial engineering companies look for when hiring undergraduate industrial engineering technology students. The study used a systems engineering approach in solving the problem. The students in a master's level course titled "Management of Engineering Systems" helped to address the problem. A graduate assistant that took the course the previous semester mentored the student teams. This project included sixteen students in total, who were divided into four teams. The study focused on the curriculum, the ABET accreditation, future skills, and future industries for Industrial Engineering Technology students. This paper details the results of this study which serve as a first-step towards the overall project goal of transforming the IET curriculum to better prepare Industrial Engineering Technology undergraduates for the engineering challenges of the future.

Literature Review

An ABET article on curriculum reform discussed the need for STEM programs to continually adapt to changes in industry as well as the need for ever increasing numbers of engineers. The article emphasized the importance of higher learning institutions to be proactive and innovative in designing and delivering curriculum that is "… outcome-based, informed by real-world business needs that give students core discipline knowledge while retaining a student's ability to explore individual interests." [3]

The literature review includes a review of the current literature in curriculum reform in both industrial engineering and industrial engineering technology programs. Next, different methods incorporating systems engineering approaches will be discussed. Then studies by the National Academy of Engineers related to the Engineer of 2020, and the Grand Challenges will be highlighted as a basis for understanding the challenges that engineers face, and how engineering programs must adapt and change to meet these rapidly changing needs.

Curriculum Reform in Industrial Engineering and Industrial Engineering Technology Programs:

One focus of the project was to see what other institutions have done recently to revise and transform their Industrial Engineering Technology curriculum. We searched on scholarly articles in engineering education, educational and curriculum reform in both industrial engineering and industrial engineering technology. There were no recent articles for curriculum reform for industrial engineering technology curricula. The authors did find articles discussing curriculum redesign for industrial engineering programs. Researchers at a medium-sized private university in the northeast United States applied a systems engineering approach to develop a new industrial engineering curriculum. They designed a "flexible" program with accelerated graduate programs, a second major, various minor options, study-abroad programs, and practical hands-on education [4]. Another article investigated how industrial engineering education in South Africa is embracing Industry 4.0. The study found that technical universities are more positively disposed to embracing Industry 4.0 [5]. Researchers in a Peru university investigated how their industrial engineering curriculum needed to change based on the changes that

American and European universities were facing. They found that there was a common move into service industries away from the traditional industrial sectors. Their study also found that engineering should continue to respond to social, business and environmental requirements; engineers will need to be able to adapt to rapid change; engineers will be asked to receive instruction differently from a traditional classroom, through distance learning; and engineers must be able to adapt to changing technology [6]

Another article addressed the development of a Minor in Engineering Leadership & Management for the purposes of integrating leadership and management students within an engineering curriculum. The minor, offered to engineering and computer science majors at the University of Central Florida (UCF), is an 18-credit hour program focusing on project engineering, engineering administration, team effectiveness and financial engineering. The minor also included a laboratory-based capstone experience and was integrated with UCFs Leadership & Management Institute [7].

Systems Engineering Methods for Curriculum Reform:

A 2006 article developed a systems model to identify the difficulties to innovate higher educational curriculum within higher educational research institutions due to not having a natural "pull" of the customer to encourage innovation, unlike industry-based research oriented institutions. The researchers proposed that a consumer pull for better teaching and learning could make a difference to encourage research oriented universities to reform their curriculums [8].

Another article presented a model for re-engineering an undergraduate industrial engineering curriculum. The model used a five phase approach which included planning and assessment, identification of emerging topics, curriculum redesign, recruitment strategies, and a measurement and continuous improvement plan. A voice of customer (VoC), including both industry and academics, was used to identify emerging topics and desired characteristics for industrial engineering graduates. The results from the VoC were used to create knowledge clusters which served as the basis for generating future curriculum requirements. Quality Function Deployment was used to verify that curriculum requirements meet customer requirements and accreditation standards. An initial curriculum model was presented, and the team identified opportunities for future work which included training faculty on enhanced instructional strategies [9], [10].

Another paper summarized the results of the same research study just discussed, that aimed at identifying the desired professional characteristics of an industrial engineering undergraduate and the emergent topics areas needed to prepare those undergraduates for the future workforce. The researchers used a modified Delphi technique to obtain consensus and an importance ranking of the emerging topics from both industry professionals and academics. These emerging topics and desirable characteristics would then serve as the basis for a

reengineering of the existing industrial engineering undergraduate curriculum at the University of Central Florida [11].

Challenges that Engineers Face:

The National Academy of Engineering produced a study of what topics and attributes would be needed from engineers in the year 2020 [12]. This article focused on what engineering jobs and positions would be available in engineering industries in the future. The article suggests biotechnology as a future line of work. This includes tissue engineering, surgical techniques, biological weapons, and water treatment. Nanotechnology was another discipline listed that is a viable area for industrial engineers. The study suggests logistics as a future industry in engineering work. This includes efficiently moving goods and services and an understanding of "just in time" manufacturing. Environmental issues such as deforestation and sustainability are discussed as a future challenge the world will face. "The Engineer of 2020" also forecasts future issues of aging citizens maintaining independent and healthy lifestyles. The final subject predicted in the study emphasizes an industry directly related to industrial engineering. The study suggests future work on the aging infrastructure particularly in the United States. This field includes water treatment, waste disposal, and transportation. "The Engineer of 2020" report not only suggested future lines of work for engineers but also proposed important attributes that engineers of the future should have. Leadership, communication, and management principles were the attributes that stuck out as non-traditional engineering traits. Other, more traditional engineering traits were listed as well, such as analytical skills, practical ingenuity, and creativity. "The Engineer of 2020" study was helpful in predicting future lines of work for engineers and also pointing out that globalization is rapidly changing the world and work environment and the future engineers need to be prepared for change.

"The 14 Grand Engineering Challenges" were also considered as input to the curriculum design [13]. These include a list of challenges that can be studied through engineering within the next century. The problems are worldwide problems that would affect everyone. The challenges go well with our university's mission of serving the common good. Of the fourteen challenges, some seem more practical to address in an undergraduate course. Making solar energy affordable, providing better access to clean water, enhancing virtual reality, and creating better medicines are some of the challenges that can be implemented into the IET curriculum. The fourteen challenges are generated from suggestions from hundreds of engineers and scientists. Success in any of the challenges could drastically change the standard of living across the world.

Methodology

A systems engineering approach was used to evaluate the problem. Four teams of students in a Management of Systems Engineering graduate course used design tools and methods to create the system and stakeholder requirements. The professor of the class and a graduate assistant mentored the student teams. For this project, we utilized the Vee systems design methodology. A representation of the Vee model can be seen in Figure 1.

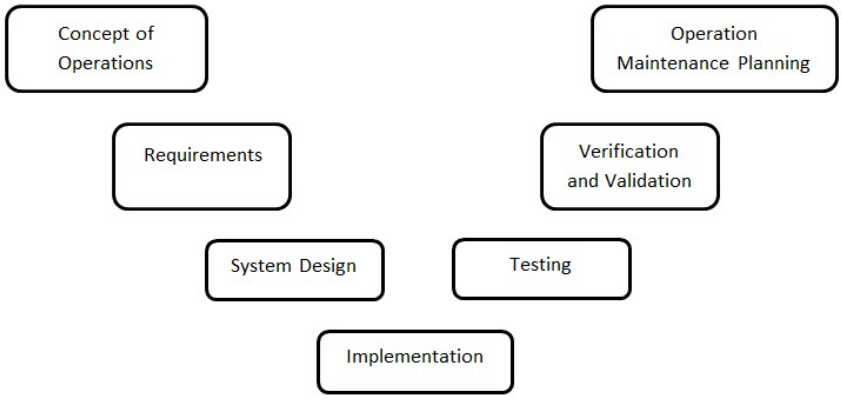

Figure 1. Representation of the Systems Engineering Vee Model

The Vee model begins from a very general phase called the "concept of operations", which is a big picture of the Industrial Engineering Technology curriculum system. The goal of this phase was to better understand the system itself. In this phase, the students studied the current system and what the scope of the project includes. The student teams created Critical to Satisfaction (CTS) characteristics, which are basic elements to the system that significantly affect the outcome of the process. The risks to the project, along with the risk handling approach, for each identified risk, were predicted and ranked based on the impact of the risk. The result of this phase of the project, were clearly identified stakeholder groups and goals along with the CTS characteristics and a project risk assessment as shown in Tables 1-3 below.

Table 1: Summary of Stakeholders and Goals by Student Team

Team	Stakeholder	Goal
A	IET Faculty	IET skills for future engineering
B	IET Alumni	Interconnected learning throughout curriculum
C	Industry partners	Growing industries in IET
D	Current IET Students	Include CAP requirements in IET

Table 2: CTS Characteristics

Title	Description
Meet ABET requirements	Requirements must be set so the program remains accredited
Improve students hands-on learning	More hands on learning and use of equipment students learn about
Student Satisfaction	Student satisfaction measured by how ready they are for industry
Balanced workload	Make sure students have enough time for theory and lab classes each semester
Student Schedule Flexibility	Students have the chance to adjust their study plan
Incorporate CAP requirements into classes	Adding CAP requirements to applicable industrial engineering technology classes
Multiple CAP completing paths	Various ways to complete CAP requirements that keep flexibility and interest for students
Identify key skills	Ensure that students have technical skills and non-technical skills to succeed in the work place

Table 3: Risk Identification

Potential Risk to Successful Project	Occurrence of Risk	Impact of Risk	Risk Mitigation Strategy
Need to have qualified professors	Very Low	Moderate	Hire qualified, well rounded professors from other universities
Chance of not meeting CAP standards	Low	Moderate	Monitor all changes in curriculum to ensure CAP requirements are met
Lack of student engagement	Moderate	High	Communication with professor on importance of project
Not meeting ABET accreditation	Very Low	Very High	Consistent review of courses in comparison to requirements
Lack of communication with stakeholders	Moderate	High	Seek other resources and professors from the department for contacts

The next phase in the Vee methodology is to identify and define system requirements. The goal of this stage was for the students to identify both the high level, and the detailed requirements necessary for the curriculum reform. In this stage, the Voice of Customer is very important, so teams were expected to reach out to their stakeholder groups to directly understand and document the system requirements. In this phase of the project, some teams were more successful at engaging with their stakeholder groups than others. The size and extent of the data collection varied from team to team. The teams all collected their data primarily through interviews with faculty and students. Team A and team D received data from the voice of faculty and students that were readily on campus. Teams C and B were given contacts for alumni in the area that met the requirements. One of the shortcomings of this study is with the quality and depth of the stakeholder engagement. Future work will focus more heavily in this area and include surveys, focus groups, and interviews.

The third phase in the Vee methodology is System Design. In this phase of the project, the teams will use Quality Function Deployment (QFD) to translate customer requirements into specific plans and products to meet those requirements. For example, consider the QFD created in the UCF study and shown below in Figure 2. This approach was used to connect customer requirements and knowledge competencies with curriculum strategies, instructional methods, and support technologies [9]. Once our team has more clearly and completely defined the customer requirements, a similar QFD approach will be used for the System Design.

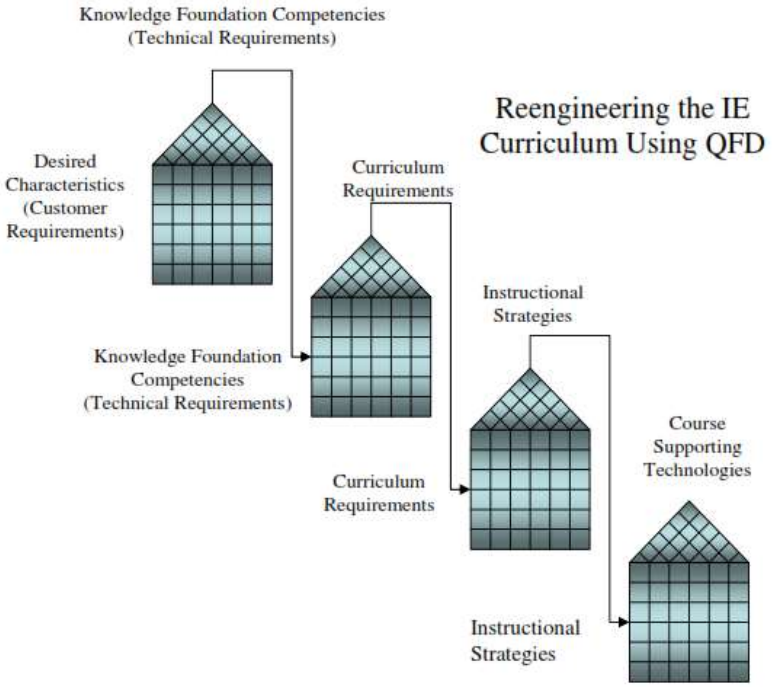

Figure 2: QFD Used in UCF Reformation

Preliminary Results

One of the key challenges identified by both the IET Faculty and Student stakeholder groups (Team A and D) was academic advising with regards to the university's Common Academic Program (CAP). This program is required for all undergraduate students and encompasses the university's institutional learning goals of scholarship, faith traditions, diversity, community, practical wisdom, critical evaluation of our times, and vocation.

Team D's goal was to explore possible ways to incorporate requirements from the university's CAP into existing IET courses. This would provide students more flexibility in selecting both CAP and technical elective courses. In this study the teams were able to find CAP (Common Academic Program) requirements and tools for professors to use in getting courses to be CAP approved. From surveying students who are currently in the IET program, one very common complaint was the lack of flexibility when scheduling. The degree requires 133 credit hours to graduate, and that is with students taking approximately 17 hours per semester. The study found that the engineering department would be able to apply a simplified template and checklist for the students to use while completing the engineering requirements. This will be very beneficial for the students when planning their academic schedule and the template created will help professors receive certification for the CAP courses.

Throughout the semester the teams primarily worked separately. They each had their own stakeholder groups and subsystems to be concerned about. Toward the end of the project, the teams of students united together and shared ideas and solutions with one another. It was found that when the teams went their separate ways to solve the problem and then came together and integrated the work, the teams produced the best work.

As mentioned earlier, one of the primary shortcomings in the design of this study was with the Voice of the Customer. Teams A and D were able to meet and talk with professors and students on campus. Their stakeholders were more available and convenient to meet. On the other hand, Teams B and C were responsible for stakeholders not directly associated with the university. There was very little interaction with the actual assigned stakeholders for these teams. Communication outside of the university did not take place as the professor and graduate student had anticipated. A more robust and complete assessment needs to be completed to receive their inputs.

Students learned many things about teaching and motivating other students throughout this process. The graduate assistant noticed that students often did not perform the adequate research necessary to generate a solution. To resolve this issue the professors and mentors of the project need to stress and create requirements for the students to research and collect data. From the educational standpoint of this study, students need to focus more on the Voice of the Customer. The point of this is to have the students constantly interacting with the stakeholder

groups. This will motivate students to consider the situation as a real problem rather than as a textbook problem with a black and white answer.

Future Work

In the future, a new curriculum will be implemented into the IET program. The current state of the project is at the end of the requirement phase and close to moving into the design phase. Stakeholder groups will be reevaluated and focused on understanding what topics need to be introduced into the curriculum. The stakeholder groups will be current students, alumni from the IET program, and professors teaching in the IET program. Because the IET alumni are inherently tied to industry, they will also serve as the Voice of Customer in identifying the emerging trends and topics within Industrial Engineering. The goal going forward will be for the graduate assistant to perform the voice of the customer with the three remaining stakeholder groups. In April of 2019 a focus group meeting will be held. Four different scenarios will be exposed to a mixture of twenty alumni, students, and faculty. A brainstorming exercise will be performed to extract the information from the focus groups. After further evaluating the results of the focus group session, the stakeholder requirements and system requirements will be updated. From this new information, the curriculum team will generate topics and requirements that need to be added to the new curriculum to reform the IET program. The QFD will be used to map the stakeholder requirements and emerging topics to the updated curriculum and experiential learning activities.

References:

[1] Spina, E., (2017). Inauguration Address. Available at https://udayton.edu/president/inauguration/, accessed October 23, 2018.

[2] ABET-Accredited Programs, ABET.org, http://main.abet.org/aps/Accreditedprogramsearch.aspx, accessed 1/30/2019

[3] No author, Engineering Change: Lessons from Leaders on Modernizing Higher Education Engineering Curriculum, An ABET Fall Issue Brief, 10/17/17.

[4] Buyurgan N, Kiassat C. Developing a New Industrial Engineering Curriculum Using a Systems Engineering Approach. European Journal of Engineering Education. 2017;42(6):1263-1276.

[5] Sackey SM, Bester A, Adams D. Industry 4.0 learning factory didactic design parameters for industrial engineering education in South Africa. South African Journal of Industrial Engineering, Vol 28, Iss 1, Pp 114-124 (2017). 2017;(1):114. doi:10.7166/28-1-1584.

[6] Palma M, Ríos I de los, Guerrero D. Higher Education in Industrial Engineering in Peru: Towards a New Model Based on Skills. Procedia - Social and Behavioral Sciences. 2012;46:1570-1580. doi:10.1016/j.sbspro.2012.05.342.

[7] Ferraras, A., Crumpton-Young, L., Rabelo, L., Williams, K., and Furterer, S., (2006) "Work in Progress: Developing a Curriculum that Teaches Engineering Leadership & Management Principles to High Performing Students," Proceedings of the 2006 Frontiers in Education Conference, San Diego, CA.

[8] Porter, A., Roessner, J.D., Oliver, S. and Johnson D. (2006), A Systems Model of Innovation Processes in University STEM Education, Journal of Engineering Education. January 2006.

[9] Furterer, S., Sharawi, A., Crumpton-Young, L. Rabelo, L., Williams, K. and St. John, H.G. (2007) "A Departmental Reform Strategy and the Resulting National Model for Undergraduate Industrial Engineering Curriculum, Proceedings of the 2007 American Society for Engineering Educational Annual Conference

[10] Ferraras, A., Crumpton-Young, L., Furterer, S., Rabelo, L, Williams, K., McCauley-Bell, P., and E. Hampton (2006) "The Development of a Curriculum to Instill Engineering Leadership & Management Skills in Undergraduate Students," Proceedings of the 2006 American Society for Engineering Education Annual Conference

[11] Eskandari, H., Sala-Dakanda, S., Furterer, S., Rabelo, L, Crumpton-Young, L., and Williams, K. (2007) "Enhancing the Undergraduate Industrial Engineering Curriculum: Defining Desired Characteristics and Emerging Topics," Education and Training, Vol. 49, No. 1, pp. 45-55.

[12] No author, The Engineering of 2020, Visions of Engineering in the New Century, National Academy of Engineering of the National Academies, The National Academies Press, Washington, D.C., 2004.

[13] No author, NAE Grand Challenges for Engineering, National Academy of Engineering, 2017. https://www.nae.edu/File.aspx?id=187214, Accessed January 27, 2019.