Impact on the Local Industry and Student's Success from Integration of Internship and Senior Design

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Dr. Khaled Zbeeb received his PhD and Master's degree in Mechanical Engineering from the Florida Atlantic University (FAU) in 2011 and 2009 respectively. He also received his Bachelor degree in Aerospace Engineering from the University of Kansas in 1992. While pursuing his graduate degrees at FAU, Dr. Zbeeb taught various mechanical engineering classes including Dynamics, Thermodynamics, Fluid Mechanics and Engineering Graphics. In 2012, he joined Western Illinois University as an assistant professor, and he has been teaching there the following courses: • Thermodynamics • Heat Transfer • Thermo-Fluids • Dynamics • Engineering Graphics • Computational Methods in Fluid Dynamics (CFD) • Fluid Mechanics. • Finite Element Method

Dr. Zbeeb's research devotes itself to the theoretical and computational modeling of thermo fluid and energy systems. His interests span both low and high speed fluid mechanics, multiphase flows, hydrodynamic and acoustic instabilities, engine internal flow fields, vorticity dynamics, combustion, alternative fuels and CFD. His research activities since 2008 have materialized in over twenty publications in first-rate journals, book chapters, and conference proceedings. His work on flow modeling for two after-bodies trapped vortex combustion has led to the establishment for new design correlations for the TVC technology. His research interests focus on CFD, thermal fluids, heat transfer, energy and alternative fuel.

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Abstract

The School of Engineering at Western Illinois University-Quad Cities in Moline, IL offers a general B.S. in Engineering that recently received ABET accreditation. This young program has experienced explosive early growth in enrollment from the previous years and achieved an 84% retention rate. It is the only four-year engineering degree offered at a public institution within 60 miles of the local metropolitan area. The heart of our partnership with industry for student success is the Engineering Senior Design and Internship. A one-semester internship and the two-semester design project requirement provide the program a reason to engage and involve industry partners. Students typically complete their internship with an engineering firm prior to their senior year. During the internship, they often identify a Senior Design project. When this occurs, the company's project manager oversees project progress and the obtaining of the company's objectives. On the academic side, a project advisor coordinates with the company to ensure that the project meets all of the engineering programs Student Outcomes and Learning Objectives. The collaboration between the School of Engineering and the local community has been positive and very successful. In this paper, several Senior Design projects are discussed. The assessment and evaluation of ABET Student Outcomes using the Senior Design course is presented and discussed as a means of directly measuring curriculum success. Engineering's Senior Design course has had a direct impact on the local community, often with a significant return on investment for industrial partners. The significance of this community engagement has resulted not only in the employment of all of our seniors at graduation, but also in the program's rapid growth.

1. Introduction

Western Illinois University in Macomb, Illinois was granted permission to create a new School of Engineering in 2009 in the Quad Cities metropolitan area 80 miles from the main campus. The engineering program was initiated in the Fall semester as the sole program in the School of Engineering, offering a Bachelor of Science degree in Engineering. The School of Engineering is a unit of the College of Business and Technology in Moline, Illinois.

To jumpstart the program with limited resources, it started as a 2+2 multidisciplinary engineering program that offered only junior and senior year engineering courses. The typical freshman and sophomore classes in Math, Science, and General Education and lower division engineering courses were taken by students at area community colleges and the university's main campus. Since most students were classified as transfer students, the curriculum was tuned to facilitate a smooth transition for these students.

This General Engineering program offers electives for "tracks" in the areas of Mechanical, Civil, Electrical & Computer (focused on Robotics and Automation), Quality & Manufacturing, Engineering Management, and Materials Engineering to develop depth and understanding in discipline areas to fulfill the specific needs for local industry and the community. The program requires students to complete Internship-Senior Design sequence in their junior-senior years and provides opportunities to work on the real-world problems with local engineering companies. The two-credit, paid Internship is taken in one semester (or summer) during the junior year and four-credit (two credits per semester), paid Senior Design is completed over two semesters in the senior year. The first graduates received their Bachelor of Science in Engineering degrees in May 2011. An accreditation visit was conducted the following fall semester and the program's ABET EAC accreditation was announced in September 2012. In 2009, the initial program enrollment was eight students. In the Fall 2014 semester, the School of Engineering had grown to over 154 students and achieved an 84% retention rate in the previous year.

2. Concept of Internship-Senior Design Sequence

Some of the key elements of the program's growth and success have been the enthusiastic partnership and effective collaboration between the School of Engineering and local industry from the birth of the program. The university, local industry, and community united to establish the only four-year engineering degree offered at a public institution within 60 miles of the Quad Cities metropolitan area. The Engineering program was specifically designed to satisfy the expectation of the program's constituencies, which included students and a variety of potential employers.

A WIU Engineering Advisory Committee made up of owners, principals and managers from engineering firms and manufacturing companies in the metropolitan region was formed and consulted from the very beginning of this program. The emphasis on "innovative designs that are based on sound engineering principles and that consider functionality, cost effectiveness, sustainability, safety, aesthetics, and satisfy the requirements of a customer" is what local companies are seeking in new graduates from our engineering program. Furthermore, a universal requirement of all companies in the region for new engineers is that they should be able to use modern design tools, write and present ideas to solve problems and effectively lead in team work.

It is anticipated that a significant percentage of WIU graduates will ultimately work in the companies participating on the School of Engineering's Advisory Committee. To fulfill the specific needs of local industry and improve the readiness of the graduates, the engineering program is designed such that students are required to complete a one-semester, two-credit, paid Internship and two-semester, two-credit per semester (total of four), paid Senior Design, sponsored by industry.

The requirement of Internship is the total of 80 hours of engineering or engineering related work. They typically complete their internship prior to their senior year. The students are supervised by both faculty and industry mentors and required to report to both with weekly progress reports and the final report. During the internship, they often identify a Senior Design project. When this occurs, the project managers at the companies and the engineering faculty collaborate to define the project, set the expected outcomes, and agree on the deliverables. Once the project is approved, the company's project manager oversees the project progress and accomplishment of the company's objectives. On the academic side, a project advisor coordinates with the company to ensure that the project meets all of the engineering program's Student Outcomes and Learning Objectives. In addition, faculty advisor ensure that students work no more than 20 hours per week during the regular semester and help student focus on the academic performance in classes. The requirements for Senior Design are weekly progress reports and presentations, preliminary design review, and the final report and presentation to the sponsors and the engineering faculty.

Almost all of the capstone design projects have been done with technical professionals and staffs in industry rather than in a classroom setting. The local companies provide real world problems and vital issues important to them and are customers for the Senior Design students, similar to the concept found in Lamancusa's The Learning Factory[1]. The only two exceptions were made for seniors to build testing equipment to be used for instructional purposes at the School of Engineering and the school sponsored the projects, as discussed in the next section.

Students use theoretical and practical problem solving skills to begin the process of component synthesis and system design in the context of real-world constraints. These design projects also provide students real world experience and in-depth understanding in engineering management in multidisciplinary working environments[2]. All students in the WIU School of Engineering are required to take engineering management courses to learn how to select, manage, and close out projects. Under supervision, they determine choice of material, cost, manufacturability, and performance characteristics. They are trained to provide team leadership, develop presentations, manage project, and organize efficient production systems[3].

3. Senior Design Project Examples

A few examples of the Senior Design projects are discussed below. For each project, the background and outcomes are presented, followed by the accomplishment and impact made to the sponsoring companies, local community, and students' successes.

Transit Project for a Steel Corporation, Fall, 2010 – Spring, 2011

Background

Sivyer Steel, a 107-year-old steel casting company in Bettendorf, Iowa, was facing the challenging task of transitioning from traditional mass production to a much more lean and efficient form of production. Sivyer Steel is a key technology company in the area. To modernize the factory, a number of ideas on how to eliminate waste and improve overall production were discussed. These discussions lead to the development of the Transit Project, as it was identified as the primary bottleneck in the production process. A team of two senior and one junior engineering students and one junior technology student worked on a major redesign effort.

Outcomes

The primary goals of this project were to increase overall throughput by eliminating bottlenecks, incorporating new technology or equipment to modernize the manufacturing process, and model the finishing department using simulation software. The major functional changes in how the finishing department operated included (1) large castings being routed to a new magnaflux unit in the casting department, (2) moving castings with a new overhead crane system through the department, (3) quenching large castings in the department instead of elsewhere, (4) routing more large castings through the department during processing (weld and grind station), and (5) tempering and preheating castings at new ovens in the department.

Accomplishment and Impact

The annual savings of Sivyer Steel in handling costs for movement alone was only $43,000. However, the most significant benefit from this project was that the company could double the throughput annually. This change will add more than $1.7 million to their annual profit and the company should realize a $12.7 million return on investment (ROI) over the next five years. As a measure of their confidence in the performance of the senior design team, the company hired the graduating senior team leader, placed him in charge of a new Manufacturing Engineering department, and has given him responsibility to complete a $5.5 million redesign of the factory. Only the senior students got academic credit for Senior Design but the juniors had a significant learning experience.

105mm Soft-Recoil Howitzer Elevation System, Fall, 2011 – Spring, 2012

Background

This project focused on the design of an electro-mechanical motion system for a 105mm howitzer weapon system developed by Mandus Group in Rock Island, Illinois. The 105mm howitzer utilizes a "soft recoil" system to reduce the recoiling forces as much as 70 percent, which results in weight reduction of the weapon system by 15 percent. The reduced recoil forces also allow the weapon system to be fired from the bed of a 1/2-ton military truck without using spades or outriggers. The electro-mechanical (rather than hand-mechanical) motion and fire control system streamline the aiming process and eliminate the need for a survey crew to establish the location and firing coordinates of the weapon. This truck-mounted howitzer system requires no site preparation and can be brought into and out of action very quickly, making it ideal for a mobile artillery application.

Outcomes

The goal was to design an electro-mechanical motion system to be installed on the first prototype of the 105-mm howitzer. A military surplus M102 telescoping ballscrew was reconditioned and modified to provide the 40" of travel, with a compressed length of 36" and extended length of 76". The maximum load of 4750lbs occurred at full depression, and a 1/2-hp motor was required to provide enough torque to lift the gun by rotating the ballscrew at 120rpm. A circular ring gear was used for the traversing system that required significantly less torque, and could be traversed in a full circle in approximately 20 seconds using a 1/8 hp motor. The howitzer's electrical distribution box housed the motor controller, connected to the joystick, and provided power to the digital fire control system. With the joystick and gunner's display unit, the crew was capable of navigating on a map, aiming the weapon, and communicating within an armed force's digital communication network. The prototype was tested with 25 simulated rounds, 25 sand rounds, and 25 live rounds. After further modification, the howitzer entered the extensive reliability and performance testing required by customers.

Accomplishment and Impact

The electronic motion system adds to the soft recoil howitzer's mobility by providing a 360° field of fire, and adds to survivability by allowing the crew to quickly fire and move before the enemy can establish counter-fire. These features are what international artillery customers are looking for, and what makes the system such a valuable product. The international market for light and self-propelled artillery is estimated at 3000 artillery systems, worth approximately $5.4 billion by 2020. The company could potentially satisfy 30% of this market with this weapon system, leading to potential sales of $1.6 billion. The howitzer's electronic motion system provides approximately 15% of the value added to the weapon system, leading to a direct economic impact of $240 million. The student responsible for this project was hired full time as a design engineer before he graduated.

Local City Trail Study, Spring, 2012 – Fall, 2012

Background

The city of Bettendorf in Iowa was facing a problem that many cities and towns are facing. The increasing population and rising gas prices required more flexible ways to travel within the city. The city requested that Shive Hattery, a local civil engineering company, to conduct a study of major roadways in the city and evaluate them for suitability for bike lanes and/or recreation trails. The company worked with the WIU School of Engineering and a senior student to fulfill the city's request to devise a master plan for a trail network within the city.

Outcomes

The final plan of the trail network incorporated existing trails connecting the city to the surrounding areas. The plan tied together many of the existing trails surrounding the downtown district to the planned trails connecting the rapidly developing areas in the north within the city. The planned trails are expected to provide better connectivity for commuting and recreational use. Two very well connected new trails will connect the southwest area to the northeast. A separated trail was under construction in a city's segment. Once that corridor is completed there will be a strong connection from south to north, also connecting to the existing trail and a recreational trail through the valley to the local high schools and community colleges.

Accomplishment and Impact

Prior to this study, a contractor was hired to study approximately 8,000 linear feet of city roads to determine what type of trail to construct and the best location for a trail segment. It cost the city $80,000 for the study. Projecting that onto the 65 miles of corridor involved in this study, it would have cost the city over $3.4 million for this trail study using a similar contractual process. Instead, the work was assigned in the form of a senior design project through collaboration between Shive Hattery and the WIU School of Engineering. As a result, the city was able to save $3.3 million. In addition to the financial savings, the health and safety aspects of planning and construction of bike lanes and trails were considered to make it safer to ride a bicycle for commuting, fitness, or recreational purposes. A dedicated bike lane or a wider recreation trail helps keep pedestrians safer. Other benefits include a cohesive trail network that can help the city become healthier, by encouraging people to be more active and attracting people and businesses to the community. The company was so eager to hire this engineer that two offices within the company ended up in a bidding war over who would hire her.

Other Senior Design Projects

The senior design projects completed at WIU School of Engineering, including three introduced above, are presented in Table 1. As a young engineering program, the school has not had many seniors from semester to semester. Many projects were completed by one senior although he or she worked in a group setting with many technical professionals at the companies and the engineering faculty as shown in the table. There were two academic years without any project since the program had no seniors. Two projects were sponsored by the School of Engineering to build a material testing load frame and a consolidometer loading frame to be used for instructional purposes in classes for the school. There were a few projects that involved non-seniors. Their participation and contribution to the projects were meant for a significant learning experience not for the academic credits.

Table 1 Senior Design Projects Completed at WIU School of Engineering

Semester	Senior Design Projects	Number of Senior Design Projects	Number of Students in Project Team	Number of Experts Involved in Project	Sponsors
S'10 - F'10	Lincoln Electric Welder	1	1	8	John Deere
F'10 - S'11	Transit Project	1	4	4	Sivyer Steel Corp.
S'11 - F'11	None				
F'11 - S'12	Howitzer Elevation Sys.	4	2	5	Mandus Group
	Material Testing Load Frame		3	3	WIU Engineering
	Harvester Works Energy Usage		1	6	John Deere
	Spark Plasma Sintering Model		1	6	QC Manufacturing Lab.
S'12 - F'12	Bettendor City Trail	1	1	6	Shive Hattery Inc.
F'12 - S'13	Howitzer Traverse System	5	1	8	Mandus Group
	Steel Production Redesign		1	5	Sivyer Steel Corp.
	Open Source CFD		2	3	John Deere
	Workflow Redesign		1	5	Sivyer Steel Corp.
	Sewer Nozzle Analysis		1	2	Sewer Equipment Co.
S'13 - F'13	None				
F'13 - S'14	Aluminum Welding for Harvester	1	1	4	John Deere
S'14 - F'14	Computer Vision for Manufacturing	4	3	3	QC Manufacturing Lab.
	Harvester Vibration Analysis		1	8	John Deere
	Construction of Metal 3D Printer		3	3	QC Manufacturing Lab.
	15 Kip Tensile Test Machine		2	3	QC Manufacturing Lab.
F'14 - S'15	Consolidometer Loading Frame	1	3	3	WIU Engineering
Total		**18**	**32**	**85**	

4. Discussion on Assessments and Challenges

One of the assessments on the performance of the students in the WIU Engineering program was done in their Internship course. Each student was visited by the Director or faculty several times. The weekly activity and progress reports were submitted by students and a final report in the company's format was submitted to show what was accomplished. However, in general terms, the best measure of assessment of student outcomes has been Senior Design since it is the "capstone" course of all engineering courses taken at the School of Engineering.

The Student Outcomes selected by the School of Engineering are the ones recommended by the Engineering Accreditation Committee of ABET. The standard ABET requirements of (a)-(k) are used to define what an engineer should be able to do upon graduation, which is considered the best indicator of learning and student success. For each ABET requirement, student performance is evaluated by the professional judgment of the faculty and company mentors of the senior design project. The School of Engineering Student Outcomes Scoring Rubric, derived from the ABET requirement, was used to measure student outcomes. The assessment of Senior Design in each of the ABET requirements from (a) to (k) scored 4.3 or higher and the majority of requirements was evaluated at 4.8, well over the goal of 4.0 out of 5.0, set forth in the WIU School of Engineering Criteria. The faculty concluded unanimously that the student outcomes for the Senior Design projects had been accomplished. The project groups and mentors in the sponsoring companies were invited to the project presentations and provide their comments, suggestions, and qualitative assessments in form of questionnaire.

The collaboration between the WIU School of Engineering and the local community has been positive and very successful. As reported in the previous section, the Engineering Senior Design Project course has had a direct impact on the local community, often with a significant return on investment for industrial partners. One hundred percent of the graduates so far have been hired for engineering related positions. Many of them were hired even before they graduated by the companies that sponsored the Senior Design projects. Their first projects upon graduation at the companies were a continuation of the senior designs or similar projects. The feedback received from the companies helps improve not only the engineering program and curriculum but also cooperation and a long term relationship between the School of Engineering and local industry.

One of the challenges was to keep students focused on their studies during the junior and senior years while working for the sponsoring companies. Students were expected to balance their time between academic performance and work load at the companies. Their enthusiasm in working on real-world problems and/or the pressure to meet the sponsors' expectation often resulted in exceeding the maximum of 20 hours per week work load during regular semester, set by the School of Engineering. Making noticeable progress with the projects often required significant time, which negatively impacted their academic performance in other classes.

The biggest challenge this young engineering program is facing is to keep up with our rapid growth with limited resources. Although the School of Engineering, as one of the signature programs at Western Illinois University, is doing exceptionally well across the board, the program is reaching its maximum capacity for its effectiveness. The student to faculty ratio is about 36:1 and increasing. As the number of juniors and seniors increase, it becomes increasingly important to free up the faculty's time to sustain the effective collaboration and team work with local industries in the Internship-Senior Design structure. Hiring new faculty and faculty assistants, who can serve as project managers to oversee the Internship and Senior Design, has been requested but budget cuts imposed by the State on the university has hindered the effort. One positive development is that the university has secured funding to plan a new engineering and science facility to increase instructional and laboratory spaces.

5. Concluding Remarks

The Quad Cities metropolitan area has an economy based around heavy manufacturing and a strong historical tie to engineering firms. The School of Engineering has become a valuable resource for providing education and new ideas to the community. In addition, the school provides solutions to particular problems local companies are facing through collaboration and cooperation in the form of Internship and Senior Design projects. The collaboration and cooperation have been positive and very successful. Engineering's Senior Design Project course has had a direct impact on the local community with a significant return on investment for industrial partners. One hundred percent of the graduates have been hired for engineering related positions upon graduation. Many of them were hired even before they graduated by the companies that sponsored the Senior Design projects and some of their first projects at the companies are a continuation of the senior designs.

Employers expect to teach new engineers the company's unique way of doing things and seek new ideas from the new talent even before they are available for full time positions. The internships and senior design projects offer students the real-world experience of putting their education to practical use, and provide local businesses the ability to utilize the knowledge and research capabilities of the university while collectively molding the next generation of engineers and technical workers. The Internship-Senior Design structure has been serving the School of Engineering and local industries well not only in improving the engineering program and curriculum but also in developing a long-term cooperation and strong professional network for mutual growth and success.

References

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