Industrial-Related Projects in the Upper-Level Industrial Engineering Curriculum at Mercer University

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Abstract
Industrial-related projects are spread throughout the industrial engineering curriculum at Mercer University. Beginning with the introduction to industrial engineering course, and continuing through to the senior design course sequence, students enrolled in Mercer's industrial engineering program are exposed to a variety of courses that emphasize real world content. The four authors are responsible for teaching courses in the industrial engineering specialization. This paper presents an overview of the authors' efforts to include real world content in several upper-level industrial engineering courses. The activities include hands-on manufacturing, company interviews, the Ford/Firestone case study, work space design projects, and the use of commercially-available software tools. The paper concludes with a description of several successful industry-inspired senior design projects.

I. Introduction

It is essential to educate undergraduate engineering students both in theory and practice so that they are well prepared to meet the challenges in the job market especially in the manufacturing industries of the 21st century. With a goal to link industry more tightly to the engineering school, an undergraduate engineering program may identify two objectives: to improve U. S. technological competitiveness by creating a substantive, people-based technology transfer relationship between industry and engineering colleges; and to improve the industrial relevance of the undergraduate engineering experience without compromising the teaching of fundamental science and mathematics. These objectives can be achieved through curricula developed by a team of professors who have a strong industrial background, demonstrated teaching ability, significant management experience, good undergraduate and graduate academic records, and expertise in technology transfer, thereby bringing corporate know-how to the classroom [10]. To the extent that faculty develop industry-inspired or industry-sponsored projects as an integral part of the industrial engineering curriculum, the program's graduates are better qualified to meet the needs of future employers. The transformation of the undergraduate engineering curriculum may include an increased emphasis on cost, communications and continuous learning. Modifying faculty promotion guidelines to honor collaboration in teaching and research, as well as collaborating with industry would facilitate the transformation. Ideally, industry would be a full partner in the educational process [6].

At Mercer University, an emphasis on industrial-related projects is spread throughout the industrial engineering curriculum. Beginning with basic junior-level courses (ISE 370 and ISE 402), and continuing through to the senior design courses (ISE 487/488), students enrolled in Mercer's industrial engineering program are involved with course projects that have an industrial-related component. The four authors are responsible for teaching courses in the industrial engineering specialization. This paper includes an overview of the authors' efforts to include real world content in the following upper-level courses: ISE 402 (the use of commercially-available software tools), ISE 327 (company interviews and the Ford/Firestone case study), ISE 424 (hands-on manufacturing laboratory), ISE 412 (interface and work space design projects), and ISE 487/488 (industry-related senior design projects).

II. The Lower-Level Industrial Engineering Curriculum

Mercer University offers an ABET-accredited BSE degree, with specializations in electrical, mechanical, industrial, biomedical, environmental and computer engineering. During their first two years of college, all BSE students who follow the standard curriculum must complete college level math courses (Calculus, Differential Equations, and Engineering Statistics), Chemistry, and calculus-based Physics. Industrial engineering students must also complete a set of general engineering core courses (EGR prefix) as well as specialized industrial engineering courses (ISE prefix). At the freshman level, students enroll in EGR 107, in which they are introduced to problem identification, information gathering and development of alternative solutions, merit analysis, decision presentation, implementation, testing, and design. Also, the students enroll in EGR 108, in which they are exposed to engineering ethics, impact of engineering practice in the context of society, critical reading and thinking skills through extensive reading and discussion, preparing and presenting the results of teamwork both in written and oral format. Further details about EGR 107 and EGR 108 can be found in papers published previously [3,11,12].

Beginning with the summer after the freshman year, the students are eligible for the industrial experience program. Industrial engineers are encouraged to select summer intern programs in the local manufacturing industries where they get exposure to hands-on real world design and manufacturing related projects. At the sophomore level, industrial engineering students enroll in a one-credit survey course, ISE 288. The course text, <u>Introduction to Industrial and Systems Engineering</u> [17], provides a detailed overview of a wide variety of topics. We supplement the text with handouts of visualization and the interpretation of mechanical drawings in a manufacturing environment. The course includes at least one field trip to a local industrial facility so students may observe the use of state-of-the-art technologies in a manufacturing setting.

III. Examples From The Upper-Level Industrial Engineering Curriculum

<u>Junior Year</u>

ISE 370: Manufacturing Practices

At the junior level, students learn the basic concepts of manufacturing processes – casting, metal machining, plastics, electronic manufacturing, and introduction to automation and numerical control. In the manufacturing lab course, students are introduced to theory and application of metal working machinery, industrial safety, engineering and technological aspects of joining operation, interpretation of engineering drawings, design of simple jigs and fixtures, and hands-on experience.

In the computer assisted manufacturing course, fixed and flexible automation, computer aided process planning, computer control of manufacturing systems, group technology and cellular manufacturing, CAD/CAM integration, and programming on CNC machining center and numerically controlled devices are emphasized. They also work on term projects illustrating computer aided design and manufacturing concepts.

ISE 402 and 403: Exposure to Commercially-Available Software Tools
During the junior year, the students take a sequence of two operations research courses in which students are exposed to a variety of commercially available software tools. A major topic in the ISE 402 deterministic Operations Research course is Linear Programming (LP). Students are first exposed to problem formulation, followed by solving LPs using the graphic method, the Simplex method, using commercial software, and the interior point method. Students also receive exposure to sensitivity analysis and a brief discussion on duality. While the students receive a good foundation in the aforementioned topics, emphasis is primarily on problem formulation and secondarily on use of commercial software to solve the LPs. The students begin by using Microsoft Excel's Solver add-in. Sample spreadsheets / templates are provided to the students as a framework for solving the LPs. Students are encouraged to experiment with and develop templates with which they are comfortable. Additionally, students are given examples and perform assignments that demonstrate the ease with which sensitivity analysis can be performed by merely cutting and pasting and altering values within the spreadsheet. The students also learn how to formulate and solve LPs using Lindo 6.1 and Lingo 7.0 from Lindo Systems, Inc. The web site www.lindo.com/ supports the claim that the Lindo systems are commercially used by citing numerous testimonials by real-world users. Exposing the students to three software packages allows them to formulate their own conclusions on the comparative strengths and weaknesses of each package.

In the ISE 403 stochastic Operations Research and Simulation course, students are once again exposed to commercial software tools. In this course, students rely extensively on the use of the Rockwell Software's Arena 5.0 simulation environment. The Arena simulation software is used extensively in industry, as noted through numerous testimonials found on the www.arenasimulation.com/ web site. The course is taught as a series of combined lecture and in-class lab assignments so that the student is gaining the theory and applying the theory at the same time. The course culminates with a simulation project, where teams of students use Arena to simulate a real world manufacturing or service process. These examples demonstrate just two of many instances where students are exposed to commercially used software to help solve and analyze real world problems.

ISE 327: Quality Practices in Industry
All industrial engineering students are required to complete ISE 327, Statistical Process and Quality Control. The course prerequisite is EGR 252, Engineering Statistics. The ISE 327 course covers statistical process control methods for both products and services. While the course emphasizes the quantitative components of a quality assurance system, the students are exposed to issues related to the management of quality programs, including ISO 9000 and related standards. We discuss the history of quality, including the contributions of Deming and Taguchi. In order to introduce a real-world component into the course, we require the students to conduct a Company Interview. The

students are instructed to contact a professional who deals with quality in some capacity in a manufacturing or service industry.

The students are given the following set of interview questions as a guide.

Corporate Philosophy

- How important is quality to your organization?
- Do you have a quality mission statement? Does your company's mission statement mention quality?
- What methods do you use to ensure quality output?
- Do you have a quality department? Who heads the department? What is the educational background of this individual?
- In your organization, who is responsible for quality?
- How do you train your employees concerning quality issues?
- How do your customers influence your quality program?
- Has your company (or department) ever applied for a national quality award or international certification? (MBNQA, ISO 9000, Other?)

Quality Methodology

- Do you routinely collect data on the quality of your product or process? Do you use statistics to analyze the data collected?
- Do you use control charts?
- What kind of reporting techniques do you use? Who generates the reports? Who routinely sees the reports?
- What kind of quality control/process control software do you use? (Excel, generic SPC, customized or proprietary)
- How do you monitor incoming materials and/or your suppliers?
- Do you use acceptance sampling methods? If so, what standards are they based on? Who designs the sampling plan?
- What percentage of your product requires rework?

The students are instructed to add questions as needed. After the interview, each student submits a written report that includes the following: 1)Title page, 2) Introduction (Background about the organization, Name and position of contact person, Date and method of interview), 3) Interview (Specific questions asked, Responses to questions), 4) Discussion (Personal evaluation of status of quality at the selected organization), and 5) Appendix - (Supporting materials such as company brochures, on-site photos, award certificates, etc.). Thus, the Company Interview assignment is more than just a list of questions and answers. The students are encouraged to pay special attention to the Discussion section and compose a response to the interview in their own words. The inclusion of an Appendix allows students to individualize their efforts. Some students include samples of the company's product; others include copies of the company Web site in the Appendix.

The current industrial engineering students often contact former students in order to conduct the quality interview; sometimes they interview their employer from a previous co-op experience. Since many of our graduates are employed at the Warner Robins Air Force Base, Boeing, and

Milliken, these companies are represented almost every year. More recently, students have conducted quality interviews at educational institutions and hospital settings. As we discuss the reports, we see that many companies are very serious about quality; both Boeing and Milliken are Baldrige Award winners. Other companies, especially the small family-owned ones, have a more modest commitment to quality. Occasionally, there have been unintended consequences of the company interview assignment. For example, one student obtained an offer for a future co-op experience from one employer after conducting the quality interview with the employer's colleague. The Company Interview has been a part of the ISE 327 course for five years and gives students an opportunity to relate textbook learning to workplace reality.

ISE 327: The Ford Explorer / Firestone Tire Controversy

A basic assumption in the quality assurance field is that quality is judged by the customer [17]. Furthermore, Taguchi defines quality in terms of the way the product will be used in the field [4]. Therefore, engineers and manufacturers need to anticipate how the manufacture or use of a device will influence its performance in the field. Firestone reports [1] emphasize the company's belief that consumer use and repair were contributing factors in the deaths and injuries associated with tire separation. On the other hand, consumer watch-dog groups [14] assert that both Ford and Firestone had access to data that showed that the design and manufacture of certain tires mounted on Ford Explorers was associated with problems in the field.

More than two and a half years after the initial recall, many questions remain. What is the relationship between SUV rollovers and tire failure for specific brands of tires? Were proven design techniques such as failure modes effect analysis (FEMA) conducted? Does the National Highway and Traffic Safety Administration discover the existence of life-threatening problems in an efficient manner? Should it be more proactive? There are also concerns about the relevancy of QS-9000, the Big Three Automakers' common quality standard[18]. QS-9000 certification ensures that a company has met auto-specific requirements in addition to the general ISO 9000 requirements. The Ford/Firestone Controversy provides a rich case in which the complexity of problem identification, data collection, and data analysis is clearly shown.

This particular case has been used at Mercer University in the project management component of the engineering economy course that is a graduation requirement for all engineering specializations. It has also been used in the quality-related industrial engineering courses (ISE 327-statistical process and quality control and IDM 355-quality management) which are required of industrial engineering and industrial management graduates, respectively. Finally, the case study is adaptable to manufacturing courses taught by the industrial engineering faculty and design courses taught by mechanical engineering faculty.

The written case study materials include a summary of the events surrounding the August 2000 recall of certain models of Firestone tires, references to journal articles, and a list of related Web sites. Due to the tremendous public interest in the recall, numerous Web sites were constructed in response to Firestone's defense of the quality of their product. While some Web sites emphasize legal and ethical considerations, others emphasize details on the design and construction of automobile tires. The National Highway Traffic and Safety Administration's data on injuries and deaths associated with various SUV models brings up issues related to the interaction between automobile design and tire failures. In the past, students have been enthusiastic in their response to the case study materials. The in-class discussions have been very lively, perhaps because there have always been students in each class who drive Explorers or own Firestone tires. Further details about the case can be found in a paper presented at an earlier ASEE conference [2].

Senior Year

ISE 412: Interface / Work Space Design Project

Industrial engineering students are exposed to interface and work space design in the ISE 412 Human Factors Engineering course. Students are exposed to the tools necessary for evaluating man-machine interfaces and designing work spaces. These skills are then applied by the students in two ways; an individual project and a team project. In the individual project, students are required to evaluate an existing man-machine interface and analyze the strengths and weaknesses with particular emphasis on the cognitive engineering aspects of the interface. Students propose possible solutions for addressing the weakness and present their analysis in a formal oral presentation.

Work space design encompasses the total environment in which the human operates in addition to physical constraints [13]. To assist students in applying these skills more effectively in a real environment, students design various types of work spaces while learning how to avoid static loads and fixed work postures on the body; to reduce cumulative trauma disorders for the hand/wrist, shoulder/neck/elbow, back and legs; and where the optimum work height should be located [9]. They also learn that including users in design decisions is critical in final user acceptance [8] and ultimately the success of the work space design. One such project involved students designing the human-machine interface for several cells for a local wood working shop. Students worked in teams to develop two design alternatives for their station. As a wood working shop has many human-machine stations, each team was assigned a specific cell, e.g. lathe cell, table saw, etc. The groups would then need to work together to determine the placement of equipment for optimal space utilization, lighting required for each cell, storage, etc. to accommodate safe human machine interaction. This included those materials necessary to reduce stress, fatigue, and glare for the operator. Once they developed the alternatives for the work space, they performed merit, ergonomic, cost and safety analysis to determine the best alternative. The results of the analysis were then presented in the form of a written and oral presentation to the client and instructor.

ISE 424: A Sample Laboratory Experiment in Robotics

Manufacturing is strategic for United States global competitiveness, which directly relates to national health and wealth. American industry has awakened to the importance of the manufacturing enterprise and the need for engineering education. Although industry struggles to overcome tradition and organizational inertia in the product development enterprise, one must ask whether the same urgency has propagated to our educational systems that supply industry with engineers [16]. Students in ISE 424 (Computer Assisted Manufacturing Systems) participate in a number of industry-inspired laboratory exercises. A sample laboratory experiment is to write a program using the Robcomm3 software for the CRS-A255 robot arm (Figure 1) and the teach pendant. The robot has to pick up 22 dice of two different colors (red and green) and arrange them on a square board with 9 bins/circles. The dice are placed on a marked board as shown in Figure 2. A typical sequence in which the robot arm will pickup the dice from the marked board is indicated by arrows from the start location. The robot arm will actually move each die once into a specified circle/bin in the square board with 9 bins/circles (Figure 3), located in front of the robot. This laboratory experiment is carried out using the following steps: 1. Determine the initial and the final layout for each individual die. 2. Determine the number each die will display initially. 3. Setup points into the Robcomm3 software. 4. Write the program. 5. Run the program.

Fig. 1. CRS-A255 Robot Arm.

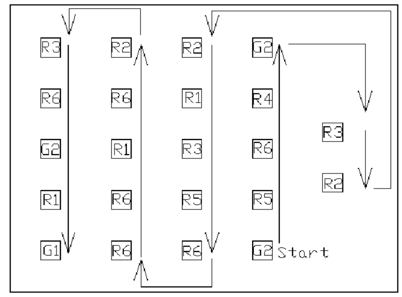

Fig. 2. The Board with Initial Locations Marked.

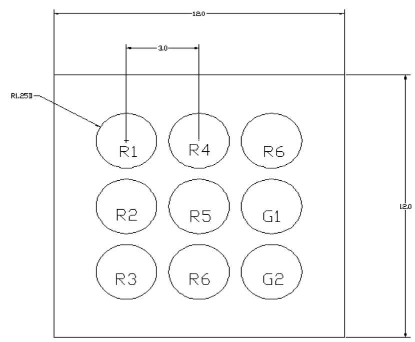

Fig. 3. The Square Board with Nine Circles/Bins

ISE 487/488: Typical Senior Design Projects

Engineering design converts an idea into a technical system that can be produced. The process is usually described as a sequence of phases, beginning with a perceived need, and can be broken down into four steps: task clarification, which defines the problem, resulting in a design specification; conceptual design, which generates, selects, and evaluates solutions; embodiment design, which develops the concept, resulting in a final layout; and detail design, which defines the shape and form of every component, resulting in manufacturing information. Management involvement is crucial to the development of high-quality, competitive product in the shortest time. Design team activities must be directed and monitored for performance. The design output must be continually assessed against specification requirements [7].

Students need to practice design to become competent. One experience at the end of a four-year program is not enough. The creation, implementation, and maintenance of a design curriculum are in fact a design problem. The faculty and industry partners of each school need to develop their own appropriate solution. Borrowing ideas and innovations is encouraged [15].

At the Mercer University School of Engineering, the design thread begins with the freshman design course and culminates in the senior design sequence. Senior design projects are multidisciplinary in nature with duration of two semesters. During the first semester, a team consisting of three students is expected to work on a project proposed by the client and come up with a preliminary design acceptable to the client. The students work closely with the client and the technical advisors to accomplish this task. Once the preliminary design is approved, during the second semester, the students' team will build, test, and install the design to the satisfaction of the client and the technical advisors. Under this system, it is possible for three students from three engineering disciplines to sign up for a single design project involving knowledge and skills from different engineering disciplines.

One such senior design project involved the development of a tracking system for a local aerospace company to quickly and efficiently compile and process production performance data. The system the students were to replace was completely manual and required 77 man-hours to obtain the desired results. The data tracking software this team developed was designed to take no more than eight actual hours to automatically/semi-automatically download the necessary labor and production data from the mainframe, format the data into a desired layout, and place the information into a database. The database tracked actual production hours, production rate, re-scheduling, non-conformance standards, management allocation, backlog recovery, work measurement standards, and budget. Once the database was loaded, the software calculated production performance percentage, budgeted hours, backlog, and manload/labor utilization. In addition the software was able to calculate these measures for plant, assembly and sub-assembly levels.

In another senior design project, a student used her successful co-op experience to develop an opportunity for a senior design project with Delta Airlines. Lisa B. Bollen, a cooperative education participant, was able to complete her senior design project while working as a co-op student for Delta Airlines in Atlanta, GA. After redesigning the placards for Delta's new fleet in 1996, her supervisors asked her to redesign their cooperative education program. She was to ensure that the new program incorporated proper orientation, training and career growth for co-op students. This included developing a mission statement, the objectives, the structure and implementation of the new program. As the School of Engineering requires all engineering students to complete a two - term senior design sequence involving the design or redesign of a real project, Ms. Bollen was able to use this assignment to complete her senior design requirement. Because of Ms. Bollen's ability to combine academics and work experience through senior design, she was named the 1997 State of Georgia Experiential Learning Student of the year in the engineering/technology category.

In a third project, a design team consisting of three students was asked to integrate a CRS-A255 robot arm with a Fadal VMC 15 CNC machining center [5]. The team was instructed to design an automatic clamping device to hold the part that is being machined. They also needed to design a control system to operate the automatic clamping device. They were expected to consider the safety issues while operating the system, as well as learn to program the robot arm and the CNC machining center.

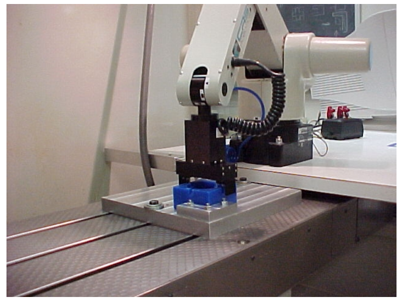

Fig. 4. Robot Preparing to Remove Part from Clamping Device.

During the first semester of senior design, the students developed several alternatives and conducted a merit analysis to select the best one. During the second semester, the students built the device and the interface. The clamping device and the control system were installed and tested together with the CRS-A255 robot and the CNC machining center for automatic loading and unloading of parts, as well as automatic opening and closing of the clamping device when the part is loaded/unloaded. The CRS-A255 robot preparing to remove the part from the clamping device is shown in Figure 4. At present, this set up forms an integral part of the client's CNC machining cell with robot interface for loading, unloading, and automatic actuation of the clamping device.

IV. Conclusion

The industrial engineering curriculum includes hands-on experiences, lab work in design and manufacturing, exposure to commercially-available software, required industry interviews, real-world case studies, and open-ended industry-related design projects. Combined with the availability of industry co-op and summer internship experiences, the curriculum brings knowledge of the real world into the industrial engineering classroom. As a consequence, our graduates are better qualified to meet the needs of future employers.

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