Design and Manufacturing Curriculum in Industrial Engineering at Mercer University

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Abstract

This paper presents an overview of design and manufacturing curriculum in effect at Mercer School of Engineering for the undergraduate students in Industrial Engineering. There is a need to incorporate changes in the design and manufacturing curriculum to meet the ABET requirements of EC 2000 ("a" through "k"). The work in progress, the future plan for changes, a sample lab experiment in robotics, and a typical senior design project in progress involving design and fabrication are presented and discussed.

Introduction

The curriculum change is a continuous process in engineering education to incorporate emerging technologies, tools, and techniques so that the students before graduation are well prepared to meet the challenges waiting for them in the job market. Due to world-wide competition, the survival of the manufacturing industries and service organizations depends on faster delivery of better products with high quality and low cost to global customers. The industries/organizations are looking for well-trained graduates to meet the above challenges.

The ABET's EC 2000 is composed of eight criteria that emphasize quality and professional preparation maintaining the traditional core of engineering, math, and science requirements, but also placing importance on a set of new skills that includes teamwork as well as global, economic, social, and environmental awareness [4]. Hence, there is a need to make changes in the overall curriculum to meet the EC 2000.

With respect to design, visualization skills are extremely important to engineering students. The ability to visualize is an important tool required of engineers in order to function effectively. In addition to the traditional visualization tasks associated with engineering design, enhanced visualization skills are necessary to function in the modern age of computer-aided design [5].

Computer-based teaching is changing engineering education. It is observed from the published results that students prefer computer-based teaching and learning methods compared to that of traditional ones because of ease of use. Published research data indicate that there are no negative outcomes when computer-based teaching is used, in the place of, or in conjunction with, a traditional laboratory [3].

The quality of education will not be met until a quality culture is developed. Success can only be achieved when everyone involved in engineering education has the commitment, the motivation, and the means to incorporate the culture of quality in every lecture, every laboratory work that is supervised, … , or every paper that is written. Self-assessment of quality in classroom processes and systems is essential to promote continuous improvement and customer satisfaction [1].

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One of the most serious challenges facing engineering education is the lack of financial resources. The educational system, in general, is made up of a collection of teachers, each responsible for a small group of students, along with administrators, counselors, and other support staff to assist in the process. Most of these educators believe that improvement in education is blocked by the need for constantly increasing funds and the lack of resources to support the need. At present, education is faced with new challenges and increased opportunities because of social, economical, environmental, and political changes. Educators are encouraged to use quality and productivity principles from business and industry, and competency-based curricula for meeting the challenges [6].

Design and Manufacturing Curriculum

Design and manufacturing courses are integral parts of industrial engineering education at Mercer University. In this section, an overview of the design and manufacturing curriculum starting from freshman design through senior design, and introduction to manufacturing processes through automation and systems integration are presented and discussed along with ABET's EC 2000 requirements.

The ABET's EC 2000 requirements, Mercer University School of Engineering (MUSE) requirements, and the Mercer University Common Learning Outcomes (MUCLO) are presented in Table 1. The MUSE outcomes 2 and 3 correspond to outcomes "c, e, and k" of EC 2000. Both outcomes (2 and 3) also require "a, b, d, and g" of EC 2000. The common learning objectives corresponding to these two outcomes are: critical thinking, application of technology, knowledge integration, knowledge application, judgment in ambiguous situations, and problem solving.

The industrial engineering curriculum is designed to meet the EC 2000 requirements ("a" through "k"). At the freshman level, students are introduced to problem identification, information gathering and development of alternative solutions, merit analysis, decision presentation, implementation, testing, and design. Also, the students learn 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.

At the sophomore level, visualization and the interpretation of mechanical drawings in a manufacturing environment is emphasized. The ASME and ISO standards for geometric dimensioning and tolerancing, 2-D, and 3-D drawing of simple objects are also introduced to the students.

At the junior level, in the fall semester, students learn the basic concepts of manufacturing systems and management applications in manufacturing such as manufacturing processes – casting, metal machining, plastics, electronic manufacturing, introduction to automation and numerical control as well as forecasting, inventory control, and project management. 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 spring semester of the junior year, students are introduced to computer assisted manufacturing, 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. They also work on term projects illustrating computer aided design and manufacturing concepts.

At the senior level, they are introduced to synthesis and integration of the common techniques and methods of industrial engineering to solve "real" world or "quasi-real" world problems. Emphasis is also given on team solutions and communications. In the senior design exhibit, small groups of students design, build, and test realistic engineering system under faculty supervision. These projects include safety, economic, environmental, and ethical considerations and require a written report and oral presentation.

Table 1: Outcomes Mapping of EC 2000/MUSE

Mercer University School of Engineering	*ABET Engineering Criteria 2000*	*Mercer University Common Learning Outcomes*
1. Apply mathematics and science principles to the solution of engineering problems.	a) Ability to apply knowledge of mathematics, science, and engineering	Knowledge Problem Solving
2. Apply appropriate breadth and depth of skills in engineering design and analysis of engineering problems.	c) Ability to design a system, component, or process to meet desired needs e) Ability to identify, formulate, and solve engineering problems k) Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Critical Thinking Application of Technology Knowledge Integration Knowledge Application Judgment in Ambiguous Situations Problem Solving
3. Apply appropriate breadth and depth of skills in identification and analysis of engineering problems.	c) Ability to design a system, component, or process to meet desired needs k) Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Critical Thinking Application of Technology Knowledge Integration Knowledge Application Judgment in Ambiguous Situations Problem Solving
4. Design and conduct experiments and analyze data.	b) Ability to design and conduct experiments as well as to analyze and interpret data k) Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Knowledge Advancement Application of Technology
5. Function effectively on interdisciplinary teams.	d) Ability to function on multi-disciplinary teams	Interpersonal Skills
6. Communicate effectively to both specialized and public audiences in a variety of modes.	g) Ability to communicate effectively	Written and Oral Communication Application of Technology
7. Relate the practice of engineering to global contemporary issues, to professional ethics, and to the need for lifelong learning.	f) Understanding of professional and ethical responsibility h) Broad education necessary to understand the impact of engineering solutions in a global and societal context i) Understanding of the need for and ability to engage in lifelong learning j) Knowledge of contemporary issues	Judgment in Ambiguous Situations Moral and Ethical Growth Global Awareness Critical Thinking
8. Provide leadership to and contribute to sustaining and improving community.	h) Broad education necessary to understand the impact of engineering solutions in a global and societal context j) Knowledge of contemporary issues	Tolerance Compassion Responsibility Moral and Ethical Growth

Source: Mercer University School of Engineering (MUSE) outcomes mapping, Fall 2000.

Proposed Changes in the Curriculum

There is a need to introduce a primary course in engineering graphics with hands-on construction activities, paper and pencil activities, and computer activities. The topics and activities need to be arranged in a logical order for the development of 3-D spatial skills. The proposed course outline includes: Visualization skills in engineering and science; isometric and orthographic sketching; pattern development; two and three dimensional drawing; translation and scaling; rotation of objects; and computer exercises in visualization. Recommended software packages include I-DEAS and AutoCAD [5].

With respect to the enhancement of manufacturing laboratory facilities for hands-on experiences, the School of Engineering recently purchased a 3-axis CNC machining center, and a five-axis CRS-A255 robot arm. In the manufacturing processes course, students design 2-D and 3-D parts and use the CNC machining center to make these parts. Typical design and fabrication of parts made by the students include: ashtray, star, heart, waffle, spider web, smiley/sad face, yin-yang, etc. The students learn to program, using G-code, linear, circular, elliptical, and parabolic motions of tool path on the CNC machining center. They also use rectangular/circular pocket commands for machining 3-D parts. In the computer assisted manufacturing course, the students learn to program the robot, using programming languages and interface the robot with numerically controlled devices and conveyor systems. Students are also allowed to use the manufacturing lab facilities for designing and fabricating parts for their senior design projects.

In addition to the existing facilities in the manufacturing lab, it is being proposed to acquire a tabletop injection molding machine, a rapid prototyping facility, and a coordinate measuring machine. With the injection molding machine, it is expected to introduce the concept of plastic manufacturing as well as conduct experiments using design of experiments and Taguchi methods by varying the operating parameters of the molding machine. The rapid prototyping facility will help to introduce the concept of CAD/CAM integration, and virtual concept of 3-D parts making. The coordinate measuring machine will help to demonstrate the metrology and measurement aspects of manufacturing.

A Sample Laboratory Experiment in Robotics

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.

Figure 1: CRS-A255 robot arm

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.

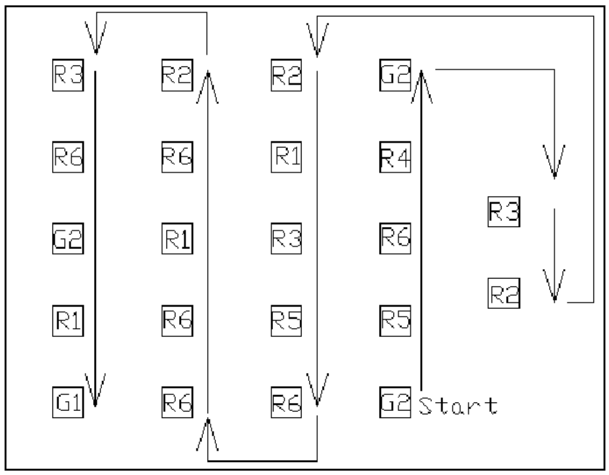

Figure 2. The board with initial locations marked

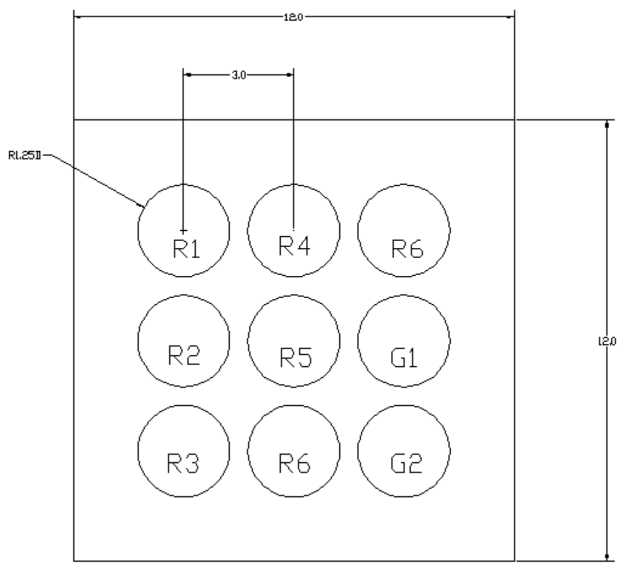

Figure 3. The square board with nine circles/bins

A Typical Senior Design Project

At Mercer University School of Engineering, 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. They 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. It is very common that three students from three engineering disciplines sign up for a design project involving knowledge and skills from different engineering disciplines.

One such project is given to a design team consisting of three students. The task is to integrate a CRS-A255 robot arm with a Fadal VMC 15 CNC machining center [2]. The team should design an automatic clamping device to hold the part that is being machined. They also should design a control system to operate the automatic clamping device. They are expected to consider the safety issues while operating the system, as well as learn to program the robot arm and the CNC machining center. The summary of the work accomplished by the team is presented and discussed below.

The Clamping Device:

Three different alternatives proposed for the clamping device are: 1. Use a pneumatic vise. 2. Use two air cylinders and a permanently mounted piece of L-shaped metal. 3. Use one air cylinder and a permanently mounted piece of V-shaped metal. The feasibility criteria considered for the clamping device are: to produce a clamping force from 10 to 150 psi; to fit onto a 16"x 29" CNC machining center table; capable of opening and closing automatically; and to hold a 3"x 3" part. The merit criteria considered for the clamping device are: cost, centering ability, and safety.

Based on the feasibility criteria, merit criteria, cycle time analysis, force analysis, robot work envelop, robot control program capability, and sensitivity analysis, the third design alternative has been chosen. This includes an air cylinder with a V-block attached to the end of the shaft, and a V-block that will be mounted on the CNC machining center table.

Control System Design:

Three different alternatives proposed for the control system design are: 1. Write a computer program for the CRS-A255 robot arm to control the air solenoid. This will be accomplished through an integrated relay switch in the robot's general-purpose input/output port on the back of the C500C robot control unit. The relay switch will be normally open and supply the 120-volt AC to the solenoid so that it will stay closed thereby keeping the clamping device open. When the computer activates the relay switch, the switch will open removing the 120-volt AC from the solenoid so that the solenoid will open. This will allow the air pressure through to close the clamping device. 2. Use the manual approach, in which the human user will flip a switch and the clamping device will either open or close. Similar to the design alternative 1, when the switch is flipped, the current will flow through the solenoid and close it thereby opening the clamping device. When the current is cut off, the solenoid will open and allow the air pressure to close the clamping device. 3. Use the combination of alternatives 1 and 2. In this, the user will select whether the clamping device should operate in automatic or manual control mode.

The feasibility criteria considered for the control system design are that it should fit on or around the table to which the robot arm is attached to, the table should fit securely inside the CNC machining center opening, and the robot arm should not make contact with the CNC machining center while loading or unloading a part. The merit criteria considered for the control system are: cost, easy use, safety, constructability, and client preference.

The third alternative with a dual control system in which the user may select either automatic (computer control) or manual (user control) mode has been selected. The overall project cost is estimated to be $150 considering only the material cost for building the clamping device and the control system.

During the second semester, the students' team will build, test, and install the clamping device and the control system. This set up will form an integral part of the CNC machining cell with robot interface for loading, unloading, and automatic actuation of the clamping device.

Conclusions

The existing curriculum, the proposed changes, and the assessment work in progress at Mercer University School of Engineering will not only meet the ABET's EC 2000 requirements but also provide the students the state of the art learning experience through course work, and hands-on lab experience both in the areas of design and manufacturing. They will be well prepared to meet the challenges in the job market.

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