A Structure for Integration of Manufacturing and Mechanical Design Engineering Courses

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Abstract

Recent technological and industrial advancements have created a need for new initiatives in higher education programs. Graduating engineers today must be well versed and proficient in many disciplines other than their major fields. Not only do they need to be knowledgeable, but also be able to synthesize and apply their knowledge to the current product and/or system development tasks. As an initial phase in addressing this need, an integrated course structure was developed between Manufacturing Engineering course MFGG-490 Robotics and MECH-312 Design of Mechanical Components. Three inter-disciplinary student teams were formed with the objective for each team to design, analyze, fabricate, install and test a robot gripper to pick up injection molded parts from the molding machine. The students interacted and communicated both during common lab times and outside of the classroom. As a result, there were many simultaneous design and manufacturing process information changes. Students designed, redesigned, analyzed, machined gripper parts, assembled them, and tested the function of the grippers. A competition was held and the best optimal gripper was chosen based on the functionality and quality of work performed. The next iteration will include design of experiments to verify gripper functions.

The students were enthusiastic in the assessment survey given. Students felt that having to design under strict budget and time restraints, communicating and working with engineers from different disciplines would “greatly benefit their engineering careers.” Through this integrated learning experience, students gained interdisciplinary design experience to better their proficiency of the real world, multi-disciplinary design synthesis process.

Introduction and Background

Recent technological and industrial advancements have created a need for new initiatives in higher education programs. Graduating engineers today must be well versed and proficient in many disciplines other than their major fields. Not only do they need to be knowledgeable, but also be able to synthesize and apply their knowledge to the current product and/or system development tasks. Incorporating this type of knowledge into a class structure can be challenging. The development of interdisciplinary classes is beginning to be explored among a few universities. Common classes developed involve general engineering courses combined with math, physics, communication or graphic arts [Pearson, 1999][3] [Wood et. al., 2001][5] [Goff et. al. 2001][2]. Other approaches entail consecutive classes where one class of students utilize the reports of a previous class' work or team taught labs with instructors from different disciplines [Drake et. al., 2002][1].

At Kettering University, collaborative efforts have been tested involving a selected number of students in two non-concurrent courses or utilizing reports from previous course work to develop a project in another class [Scheller, 2000][4]. There has not been any attempt in conducting a truly interdisciplinary collaborative effort between two courses. The procedure outlined in this paper involves two concurrent courses from different programs of engineering forming teams with joint labs to complete a full spectrum design and manufacturing project.

Addressing Industry Needs

Due to the leaps and bounds in technology development especially those involving electronics and mechanical systems and appropriate manufacturing processes, industries need engineers who have working knowledge of multi-disciplinary topics. Due to keen competition, industries need to streamline design, planning, and manufacturing lead times. Thus they need strong team workers who can engage in processes producing the highest quality products, at the lowest cost, in the least amount of time.

In order to address industry's current needs, the administrators of Kettering University surveyed its Industrial Advisory Board to gain an understanding of the qualities necessary for successful graduating engineers. Graduating engineers not only need to understand technology developments involving electrical, computer and mechanical systems, and appropriate manufacturing processes, industries need ethical engineers who have working knowledge of multi-disciplinary topics and can communicate this knowledge effectively.

With this in mind, Kettering University embarked on a curriculum reform journey. The GOAL is to reduce redundancy and provide an effective but LEAN education for the students. The concept of integration is first established. The curriculum must avoid disjoint learning and isolated information. When students develop a product in its totality during a class project, they must synthesize different concepts into the product, and streamline upstream, current and downstream information. OBJECTIVES are to provide an environment for students to grasp basic concepts and synthesize them into a process or a product design and fabrication, communicate ideas during common lab hours over the network, plan and complete product realization, feedback and feed-forward information in the various stages of engineering, and collect data for quality control and continuous improvement.

Inception of Courses Integration Concept

A structure was developed to combine teams of multidisciplinary students to work concurrently on design projects. These teams take the designs from inception through analysis, redesign and fabrication to prototype evaluation. The developed procedure was implemented between two classes: one from the department of Mechanical Engineering, ME-312 Design of Mechanical

Components, and one from the program of Manufacturing Engineering, MFGG-490 Robotics. During the run of these classes, the teams of mechanical and manufacturing engineering students completed an original design of a gripper for a FANUC robot. The gripper was to be used in a robot cell that served an injection-molding machine. The task sequence for the robot was as follows: (1) grasp the part by the sprue and remove from the injection molding machine, (2) place

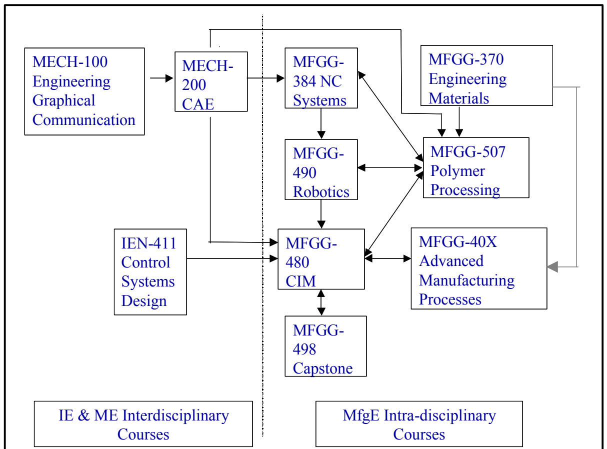


Figure 1. Vertical and Horizontal Integration in Manufacturing Engineering Curriculum

the part in a fixture and re-grasp to reorient, (3) insert the part in the cutter to be degated, (4) insert into the labeler to be labeled, and (5) place onto the holding tray.

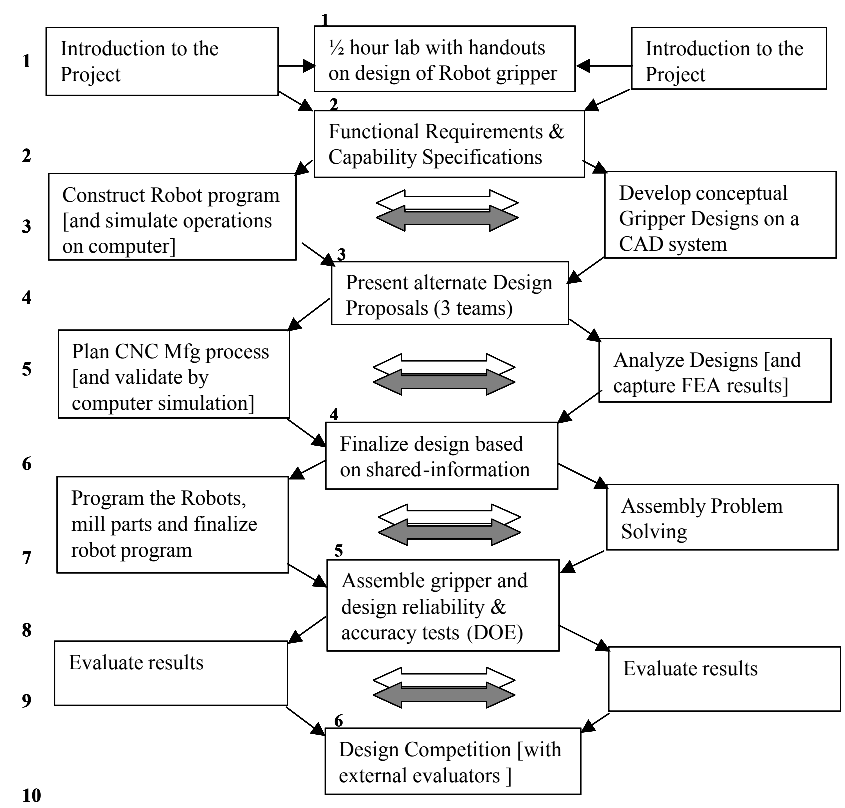
Structure for Integrating a Design and a Manufacturing Course

The structure of the course is formulated around simultaneous integration, sequential integration, intra-departmental, inter-departmental collaboration, interdisciplinary team product and process design, product realization and quality control. Figure 1 shows the flow of courses in the Manufacturing Engineering (MfgE) degreed program and courses from the ME (Mechanical Engineering) and IE (Industrial Engineering) programs that feed into the MfgE courses. In Figure 1, there are many intra- and inter-departmental pathways for integration. In this paper, only one path is discussed, namely, inter-departmental ME design and MfgE Robotics MFGG-490. Due to scheduling, a more advanced course in Design of Mechanical Components MECH-312 was used.

A Model for Inter-departmental Collaboration

Much like the corporate world, any successful project must have buy-in from top down. The two authors agreed upon teaching the courses with one common design and manufacturing class project. The department heads were briefed and they agreed to accommodate with common lab schedules. The collaboration not only spans the academic departments, but also administration offices for scheduling and room assignments, and information technology office to help set up Blackboard, an interactive learning software, to facilitate student / instructor communication. The authors drafted a sequence of combined class meetings where interdisciplinary teams of students can be formed, where teams can design their products (one product per team), do detailed drawings, generate a bill of materials, select material and tooling, acquire all necessary material through purchase orders, plan the sequence of operation for manufacturing the product and design experiments to test the functionality, accuracy, durability and reliability of the product. Figure 2 shows the activities of the two classes during common hour labs, throughout the term. Students are also assigned to hold outside-the-lab meetings to develop their project. These inside and outside the classroom meetings are indicated as white and black arrows in Figure 2. Each student team has to write and present a proposal, an interim progress report and a final report. Each team member has to be responsible for at least one section of the reports and speak at the presentations.

Figure 2: Flowchart for Horizontal Integration Model



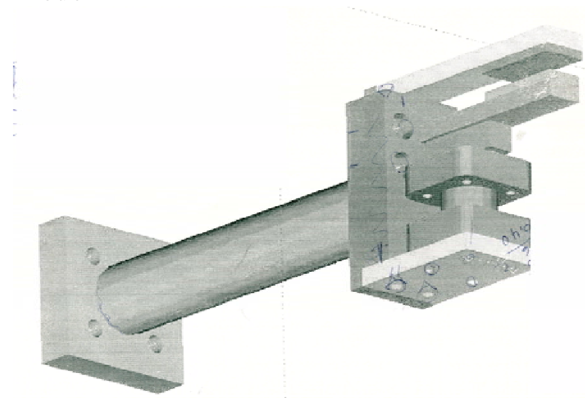
Integrated Student Project

Three inter-disciplinary student teams were formed with the objective for each team to design, analyze, fabricate, install, implement and test a robot gripper to pick up injection molded parts from the molding machine. Each team had a budget ceiling of $200. The students interacted and communicated both during common lab times and outside of the classroom. Manufacturing students provided the functional requirements to the design students since they learn the operations of the robot. Design students reciprocated with concept drawings of their perceived design. Together, they studied the functionality and revised the drawings whenever necessary. Each team then made detailed drawing of parts and assembly of the grippers. The Design students were responsible for the finite element analysis and hand calculations based on the failure theories learned in lecture. Figures 3 and 4 show the Fanuc robot used and a computer model of one of the group product. For the gripper to be functional, students had to extend the arm to attain the reach into a narrow channel to retrieve the injection molded part.

With the help of the MfgE students, materials and tooling were selected, Bills of Materials were generated, and purchase orders were submitted to the MfgE professor for immediate purchase of parts and tools. Most groups selected some type of pneumatic piston-cylinder actuators, and used aluminum for "fingers" for strength, ease with machining, and material availability. Students planned the fabrication operation sequence as well as the sequence of operations for the robot to pick up parts from the injection molding machine, to re-orient the part and to bring it to the cutter to degate the part. With some technician help, and with MfgE students taking the lead, all students were involved in fabricating and assembly of the gripper parts. Refer to Figures 5 and 6 for two of three grippers. Compare Figure 5 with the computer model in Figure 4.

Figure 3: Fanuc S-12 Robot with a parallel gripper

Figure 4: Group 1 Robot gripper Computer Model



The MfgE students were responsible for programming the robot, but the ME students cross-checked the robot activities to reduce cycle times. As a result, there were many simultaneous design and manufacturing process information exchanges and design changes prior to the fabrication of parts. Students designed, redesigned, analyzed, machined gripper parts, assembled

Figure 5: Group 1 Functional Gripper and the Gripping Mechanism with Fingers

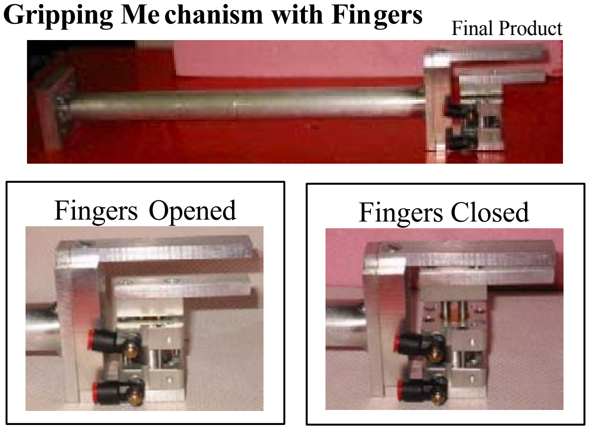
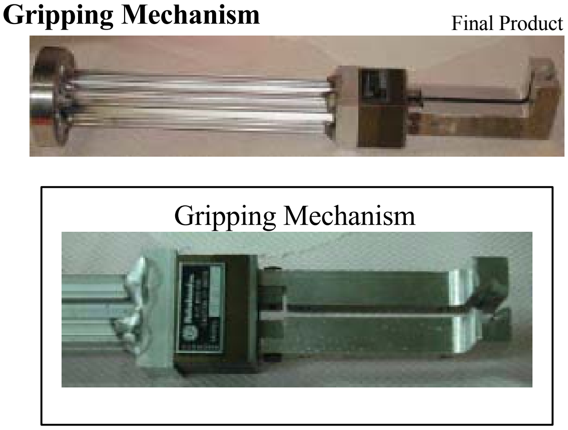


Figure 6: Group 2 Functional Gripper and the Gripping Mechanism



them, and tested the function of the grippers. These are the activities that industry needs from young engineers.

Student Competition

A competition was held among the 3 teams. During final presentation, each team's robot unloading, re-orienting and de-gating activities were timed. The accuracy and reliability were taken into account. The best optimal gripper was chosen based on the functionality and quality of work performed. The students were very serious about the competition. They also rated each other's design and functionality. There was a lot of excitement, a lot of cheering and a lot of rooting during the final presentation period. It was like going to a close ball game.

Assessment and Results with Students comments

The teams were managing the entire process and their designs were evaluated through a competition at the conclusion of the class. Professors as well as the student rated all three group projects. The criteria were design efficiency, fabrication process, tolerance of parts, functionality, and overall presentation. Professors also rated the students based on contents of the final report and knowledge, content, preparation, visual aids in the oral presentations. In both the assessment survey and the class evaluations, students rated the class extremely high. They were enthusiastic in their praise of the knowledge and uncommon experience gained from the class. The professors were satisfied with the level of engineering synthesis each group incorporated into their designs, while noting some improvements that could improve the general flow of the class.

Students were evaluated based on their 3 reports. They get a team grade as well as individual grade for each write-up and the presentation for content, knowledge, visual aids and preparation. A grade sheet was given to each student with the project assignment sheet. The students knew what they would be graded on. On the whole, 90% of the student knew exactly what to write or talk about. As a result, there were no surprises and the grades were fairly high. Each person is also rated for his/her participation during the term. In addition, peer grading was taken into account although the students were very generous with each other. The assessment surveys showed that students were enthusiastic about the project. Students felt that having to design under strict budget and time constraints, communicating and working with engineers from different disciplines would "greatly benefit their engineering careers." Seeing that the two professors worked well together, the students also felt that it was a strong contributing factor to their success and strengthened their interest. Some comments are: • a first in extensive design and fabrication experience at Kettering University • discussions with other engineers help understand knowledge learned • project help synthesize material learned from different classes • teamwork is tough, scheduling meetings is difficult, timing is SHORT • know what is involved at all stages of development, no more "pointing fingers".

Conclusion

With this interactive, hands-on learning experience, students were motivated to learn better and enhance their retention and ability to synthesize. The experience also enhanced project management and teamwork skills. Students were able to adopt multidisciplinary practice in a real project. Through this integrated learning experience, students gained interdisciplinary design and manufacturing experience to better their proficiency of the real world, multi-disciplinary design synthesis process. The professors were ensuring that the goal and objectives stated in the Introduction & Background section. They had fairly good success considering the structure was implemented for the first time.

Future

Encouraged by the students' positive reactions, their excitement and enthusiasm, the authors will continue to improve the collaborative effort and design a good assessment system. Many improvements are in order. One of them is to include design of experiments to verify gripper functions. The first term was too raw for the professors. Many logistics problems such as room availability were unexpected. The experience gained will allow the authors to draft a better common lab schedule, be more realistic about the rate of development of the project, provide network environment for communication of CAD and manufacturing information, and design a comprehensive assessment system.

Acknowledgment

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