A Complete Approach to the Capstone Experience

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Abstract

University of Wisconsin-Stout is founded on the educational principle that people learn best by doing. This principle is expressed in Stout's philosophy of a "Hands On-Minds On" education. This philosophy works well with the "Art to Part" concept of the Manufacturing Engineering capstone course sequence. This concept of having engineering students actually design, build parts and fabricate machines in an undergraduate program is not new; in fact it is an old idea.

The capstone experience in the Manufacturing Engineering program at UW-Stout is a two-semester course sequence. In the first course students experience the engineering design process by designing realistic products for manufacture. Design projects are managed by teams of students, industry contacts and faculty advisors. The final detailed design is used in the second course, where an automated manufacturing system is developed to produce the product.

Introduction

University of Wisconsin-Stout was founded on the educational principle that people learn best by doing. In 1891 James H. Stout, a wealthy lumber baron, established the Stout Manual Training School to provide training and education "through which young people of both sexes may secure such instruction and training in industrial and related lines of educational effort as will enable them to become efficient industrial, social, and economic units within their environment." UW-Stout has transformed over the years from a vocational training and teachers college into a university that provides many specialized professional degrees for careers in business, industry and education. The principle of 'learning by doing' is expressed in UW-Stout's philosophy of a 'hands-on, minds-on' education and has been an integral part of undergraduate and graduate education since the school's inception. This 'hands-on, minds-on' philosophy has been incorporated wholly into the curriculum of Stout's recently ABET accredited Manufacturing Engineering program.

Almost all engineering programs prior to the 1960s required students to work with machines and materials in testing laboratories, metalworking, mechanical and electrical shops. Those experiences, gained from the various laboratory exercises, developed in the students an intuitive feel for the way in which the mechanical world operated. Sadly, by the 1980s many universities had disassembled their laboratories and had come to rely upon analytical skills and computer generated models using lecture and demonstration as their principal mode of instruction. This change occurred for many reasons, some of which were the cost of upkeep on laboratories and the lack of support given to instructors who focused upon the basics of practical engineering. Also, there had been an ongoing change in faculty where instructors of design and applied topics were replaced with those who were more focused upon basic research of cutting-edge technologies while the basic engineering technologies were neglected[1]. Luckily, UW-Stout was able to avoid the trend of eliminating laboratories, so we continue to have a strong history of applied knowledge in education. With our laboratories intact we have been able to incorporate laboratory activities into the manufacturing engineering courses to a degree that most schools cannot approach, while still providing the necessary courses in engineering science. If there is anything that we know about the business of education it is that teaching methods tend to go in and out of fashion. Things have now nearly come full circle with accrediting agencies, universities and employers recognizing that there is a need for the application of knowledge in learning basic engineering principles. Engineering programs are required to not only test students' analytical skills, but also to have students demonstrate in practical applications that they understand principles, can work in teams and show that they can make good engineering decisions.

Manufacturing Engineering at UW-Stout

The manufacturing engineering curriculum at Stout is based on the premise of developing pragmatic manufacturing engineers who can "respond aggressively to the changing needs of the global marketplace, apply research and theory in the development of marketable products and efficient processes, and design with an awareness of the realities of manufacturing and the needs of society"[2]. The program began admitting students in the fall of 1994 with its first accredited class graduating in May of 1998. Most of the courses in the professional studies area of the curriculum incorporate a hands-on application of engineering science and theory using lab based instruction and experimentation. In teaching manufacturing engineering principles, the Stout faculty believe that it is important that students learn the techniques of manufacturing processes so they may more fully understand the complexities of how things are made and know the limitations of production methods.

The curriculum at UW-Stout allows students to build a 'technical toolbox' which emphasizes engineering practice in industrial applications. This practical knowledge of shop floor operation allows graduates to 'hit the floor running'. As stated by one of the advisory committee members, Bob Cervenka, CEO of Phillips Plastics,

> "These graduates will be able to step on the (plant) floor and be productive immediately. But in the long run, we expect these people will help our entire company become more productive, through their knowledge of every step of the manufacturing process."

Using the four areas of professional studies required in the undergraduate manufacturing engineering ABET accreditation the following list shows the individual courses in each area and the associated credit hours.

Materials and Manufacturing Processes
Material Removal Processes (3)
Polymer Processes (3)
Casting, Ceramics, & Powder Metal Processes (3)
Bulk/Sheet Forming Processes (3)
Joining and Fastening (4)
Coating, Finishing, and Packaging (3)

Manufacturing Competitiveness
Production & Operations Management (3)
Engineering Economy (2)
Quality Engineering (3)
Facilities & Material Handling Systems Design (2)
Principles of Occupational Safety & Loss (2)

Process, Assembly, and Product Engineering
Engineering Drawing (5)
Design of Jigs, Fixtures, & Tooling (3)
Capstone I: Product Design (3)

Manufacturing Integration Methods and System Design
Computer Aided Manufacturing (3)
Controls & Instrumentation (4)
Fluid Mechanics (2)
Flexible Manufacturing Systems (4)
Design & Simulation of Manufacturing Systems (3)
Capstone II: Manufacturing System Design (3)

The culmination of the curriculum is the senior design experience of Capstone I and II.

Capstone at UW-Stout

The faculty at UW-Stout defines manufacturing engineering as the design of processes and systems used to produce products. So naturally, the capstone experience is focused more heavily upon the manufacturing processes and systems used to produce a product rather than upon the product itself. This focal point of manufacturing allows the capstone experience to extend beyond the design of components into the design of special machines for the production of items. These "flexible" automated systems are designed by the students to produce items as varied as dominoes, pancakes, welded parts and dental floss.

The capstone experience in the Manufacturing Engineering program at UW-Stout is a two-semester course sequence. Design projects are managed by teams of students, industry contacts and faculty advisors. In the first course, Capstone I, students experience the engineering design process by designing realistic products for manufacture. The final detailed design is used in Capstone II, where students design and build an automated manufacturing system to produce the product.

The overall learning objective for the capstone sequence is to immerse the student in a real life professional problem solving experience that allows them to use all the 'tools' they have gathered from their education. Obviously, there are limitations on how closely we can duplicate a real-life experience, so it is specified that: the product be no larger than a bread box and consist of a family of parts; it must be capable of being produced in our facilities; a non-industrial sponsored project must stay within our cost limitations; and the project must be able to be completed within the timeframe of the course. Although the classroom setting imposes constraints as to material, equipment or expense, these are very similar to constraints imposed in actual practice in any industry. The inventiveness and resourcefulness of the individual is more highly prized than the simple ability to propose a workable solution, especially if the solution requires too great an expense. We very much like to enforce the KIS principle (keep it simple) and give high recognition to the creative and effective solution to problems.

Capstone I

Project ideas for capstone come from the private, public, and industrial sectors of society. Capstone I product designs must consist of a family of parts. The product manufacturing cell needs to be designed with flexibility in mind. Students are expected to take projects from the ideation phase to the completion of the final documentation required to manufacture and use the product. Project teams in Capstone I also develop a preliminary design of the manufacturing cell. We very much want to drive into the students that the basic design and specifications of a product will many times dictate the production process and determine much of its final cost. It is never too soon to think about manufacturing.

Capstone I is expected to foster the atmosphere of individual achievement through the success of the team. Students are expected to utilize independent thought and research in the solution of a design problem. Students apply previously acquired skills, knowledge, and experience to practical applications encountered in the industrial environment. Students learn to appreciate the structure, format, and procedure necessary in carrying a project through to completion.

Course requirements are based on the expectations of industrial based projects. Students are required to: prepare a formal written report about their semester's project work; maintain a project journal used to record the team's work, calculations, product investigations, research data, and the minutes of every team meeting. Students develop and produce all necessary project layout drawings, including any assembly drawings deemed appropriate. Detailed drawings of fabricated parts are developed, including a complete product Bill of Materials (BOM). A product manufacturing plan and cell layout must also be proposed. Dependent on the project, students are expected to identify and apply the appropriate analytical tools when performing design analysis. All projects must include a cost analysis.

The importance of communication skills in today's engineers is well understood and is constantly cited in the literature as a major area of weakness. To address this need the project teams are required to provide several oral presentations throughout the semester. Initially, teams present their project choice and a timeline for the completion of the project. During the course of the semester, teams perform at least three progress reports. A formal oral presentation is performed at the completion of the semester. When applicable, project operator manuals, maintenance manuals and/or assembly instructions must be developed for the product. To complete the communications requirements of the course, teams are also required to complete a web page describing their project.

Course grades are assigned based on several criteria. Team oral presentations are assessed on the quality, quantity, organization, and materials of the presentation. Teams are also encouraged to present themselves and their work in a professional manner. Project designs are assessed on functionality, safety, reliability, manufacturability, and cost. All students perform peer evaluations on their teammates and the individual final grades are based on a team project grade which is weighted by peer evaluation scores.

Capstone II

As the project moves into Capstone II the design matures and most often requires additional development work, following the same process used in Capstone I. Before finalizing their project, students must provide a proof of design through the use of a prototype.

The second semester capstone course is a student research project of a flexible manufacturing system where they design, build and demonstrate a flexible manufacturing cell that produces a discrete family of parts. Dependent upon the project, groups of six to eight students will comprise a team. Each team of students will design and fabricate the part handling, tooling and the control systems for their projects. They are also required to: produce documentation of the design process; maintain a journal of project evolution and weekly goals; develop electrical, hydraulic and pneumatic schematics and part drawings; produce documentation for the control of the machine; develop an operation manual and design a web page of their study that is loaded onto the Manufacturing Engineering program web site. In addition to the two design reviews held during the semester, students are required to make a final formal presentation to the campus community, industrial sponsors, advisory committee members and student parents, where they defend the design of the manufacturing cell and demonstrate its operation.

Two examples of the types of projects students work on during the capstone experience will be describe in the final portion of this paper. One project that was completed with using program funds and another completed for an industrial partner.

The most impressive Capstone sequence projects have typically been projects that were proposed and sponsored by students or industrial partners. The Automated Juice Cell is an example of a student proposed project. A Capstone I team member, working for a local restaurant while attending Stout, saw the need for an automated beverage mixing machine.

Students identified the specific need and project constraints in Capstone I and determined that the machine should be capable of supporting three different servers. Two principal requirements of Capstone II are that course projects consist of a family of parts and that they are flexible in their operation. To meet the family of parts requirement, it was decided that the cell would be capable of producing 10 or 12 ounce cups of juice. To meet the flexibility requirement, it was decided that the cell would be capable of filling the cups with three different fluids and then sort the drinks to the correct server station. The cell contained both orange and pineapple juices, and a lemon-lime carbonated beverage. The server would select these liquids individually or in any combination. It was also decided in Capstone I that the cell should contain an ice machine and fluid level sensing capabilities. The initial cell design layout can be seen in Figure 1.

The students finalized the design and produced the cell in the Capstone II course. The project group decided that a color touch screen would be used as the operator interface to the programmable logic controller (PLC). Because food service equipment is subjected to very rigorous washing and cleaning processes, it was decided that aluminum and stainless steel be used to build the cell. Through-beam sensors were placed along the conveyor system to verify cup location and were used to initiate response by the various systems within the cell. Students in this group were very cost conscious in specifying and acquiring machine components. Companies where the students had interned donated or discounted many of the components that were used to build the machine. The final design of the fabricated machine is shown in Figure 2. As a final requirement for the course students must make a formal presentation to the university community and the Manufacturing Engineering program's industrial advisory board. After all of the hard work and long hours, students are eager to defend their design and demonstrate operation of their machine. Figure 3 is a picture taken during the final project presentation.

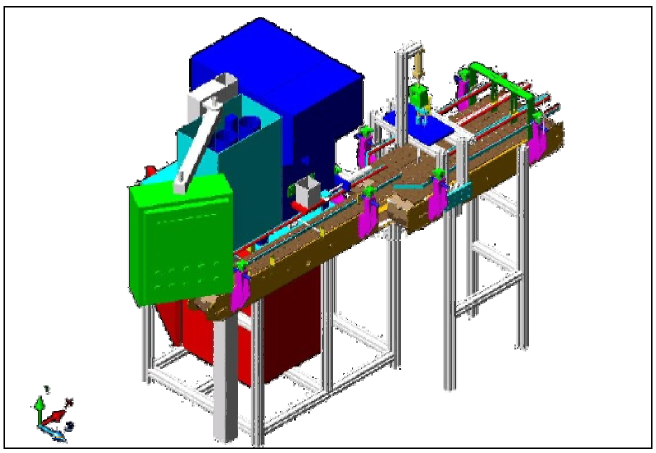
Figure 1. CADD layout of juice cell.


Figure 2. Front view of completed juice cell.

Figure 3. Students presenting and demonstrating juice cell.

The welding cell shown in Figure 4, is another example of a Capstone project. This project was sponsored by two Wisconsin manufacturers. Both manufacturers had been investigating the use of robotic welding for some of their products. Two group members, returning from internships at these two companies, proposed this as a possible Capstone project. The group could not come to consensus as to which part to produce in their welding cell(parts are shown in Figures 5 and 6). The students were strongly encouraged by the instructors to investigate combining both of the parts into the same manufacturing cell, providing the group with a more realistic and valuable learning experience. The robotic welding cell was developed to incorporate an interchangeable palette shuttle system where two parts could be welded alternately or a single part run in a batch mode. The system was PLC controlled and included electrical and pneumatic systems. Major design issues addressed by the students included accurate and repeatable placement of palettes, reduction or elimination of robot non-value added time and the reduction of set-up time by incorporating quick change fixturing. Machine and operator safety was also a major concern in the design of the cell. Protection of the operator, from arc flash while loading palettes, was addressed by the students designing a very creative and simple pivoting curtain actuated by the motion of the palette.

Figure 4. Front View of Actual Automated Welding Cell

Figure 5. Trailer hitch assembly.

Figure 6. Angle reinforcement bracket.

Conclusions

Such an extensive capstone experience is made possible through the use of excellent modern laboratory facilities coupled with a comprehensive manufacturing engineering curriculum. We have found that the students look forward to the capstone experience and are anxious to apply the skills and knowledge they have gathered in their chosen field of study. All of the projects require an extensive amount of time outside of the scheduled course time for group meetings, trips to industrial sites, contacting suppliers, fabricating the machine or cell and troubleshooting. But, it truly becomes a passion for the students to complete an operational flexible manufacturing cell. Many graduates have said that it was the most rewarding experience of their school career because it allowed them to 'put it all together' into one comprehensive project. Students are very proud of their accomplishments and always perform a special demonstration to their parents and families after the commencement ceremony.

References

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Biography

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