Infusing a Concurrent Engineering Model into Academia

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John Wadach is a professor and department chair of the Engineering Science and Physics Department at Monroe Community College in Rochester, NY. He has taught a variety of physics and engineering courses in his 30 year career. Wadach is most inspired by the use of design-build projects in his engineering courses.

Infusing a Concurrent Engineering Model into Academia is the title of the NSF TUES grant that he and co-PIs George Fazekas and Paul Brennan were awarded $200,000.

Wadach has been the co-organizer of the ASEE TYCD Model Design Contest for the past 10 years. His teams have finished first six times.

Wadach's awards include earning the State University of New York Distinguished Teaching Professor Rank, the American Community College Trustees William H. Meardy Faculty Award, and the 2014 Carnegie Foundation-CASE US Community College Professor of the Year.

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Abstract

Many Community Colleges offer both AS and AAS degrees in Engineering Science and Engineering Technologies respectively. Unfortunately, students in different disciplines are often segregated from each other in core courses. We have designed two entry-level courses that are designed for both AS and AAS students to take together.

In our Mechanical Design and Prototyping course both Engineering Science and Precision Machining students learn to use CAD and CAM software in lecture and then fabricate their designs using manual and CNC machines in lab. Faculty from both departments team-teach the course which entails a final design-build project and course competition. A series of short instructional videos have been created to supplement class instruction.

Our Digital Electronics course is taken by both Engineering Science and Computer Technology students. This course has been developed and is taught by faculty from both departments. The course includes the use of discrete components and Field Programmable Gate Arrays (FPGA). A set of custom hardware components have been developed that can be interfaced to an FPGA and a microcontroller. Instructional videos help students prepare for laboratory exercises and the course concludes with a final design-build project.

The overall goal of this project is to teach students how to work in multi-disciplinary teams and to make it easier for students to switch between AS and AAS programs. A Capstone Design course is being developed where small teams comprised of Precision Machining, Engineering Science, and Computer Technology students will solve a semester long design-build project.

Introduction

For nearly 15 years our Engineering Science program has infused design-build experiences throughout our curriculum. In the first semester students learn how to design and fabricate mechanical assemblies in our Mechanical Design and Prototyping course. In the lecture portion of the course students use SolidWorks software to create parts, assemblies, and detailed drawings. In the weekly machine shop lab, students are taught how to use manual and CNC mills and lathes so that they can fabricate the parts that they have designed using SolidWorks. Faculty members from the Engineering Science Department teach the SolidWorks portion of the course, while Precision Machining faculty members instruct the students in lab. The course concludes with a project in which students design and build a shoebox sized electric vehicle.

A course in digital electronics is taken by our students in the second semester that covers the typical topics included in courses of this type including combinational and sequential logic circuits. In addition to these standard topics students also learn how to create systems to monitor and control common robotic components such as DC and Servo motors and a variety of sensors. Faculty from both Engineering Science and Computer Systems Technology share the teaching load. This course concludes with a design-build project that requires students to create a system to monitor and control an automated process that includes most of the components used previously in the course.

In their final semester, Engineering Science students take a design lab course in which they are usually assigned a project from an intercollegiate competition. Teams of four students are created and are required to design and build a solution to the assigned project. The course is structured much like an independent study as students spend most of their time working without direct supervision. Students are kept on track by being required to keep an engineering notebook and attend a weekly progress review meeting with their instructor. At the conclusion of the course the students participate in a college wide completion. A final written and oral design report is also required from each team. As with our other two courses, a cross-disciplinary faculty team from engineering science, computer systems technology, and precision machining share the teaching load for this design lab course.

Problem Definition

Although we have successfully integrated faculty from three departments to support our courses that impart design-build skills to our students, the student composition in these three courses has been almost exclusively only engineering science students. The problem with this lack of student diversity becomes very apparent in our design lab course that acts as a capstone experience for our students. In this final course students must design and create a working prototype that requires knowledge of mechanical and electrical systems, programming, and fabrication. Typically our teams are strong in mechanical and electrical systems but lack the necessary programming and fabrication skills to successfully create a fully functioning prototype.

The goal of this project is to create teams with more diverse skill sets in our capstone design course. This will be accomplished by having students from our Precision Machining and Computer Systems Technology programs enroll in our design lab course along with Engineering Science students. In order for students from these three programs to be more successful they will first learn to work with each other in either our Mechanical Design and Prototyping or our Digital Electronics course. Nearly all Engineering Science students will take both of these courses while Precision Machining students will enroll in only the Mechanical Design and Prototyping course while the Computer System Technology students will enroll in only the Digital Electronics course.

Having a single course serve students from two different academic programs presents several challenges. The first is design an experience that teaches the necessary skills for each program at a level of difficulty that is acceptable to both groups of students. In the Mechanical Design and Prototyping course Precision Machining students will have far more experience working with machining equipment while Engineering Science students will usually be more competent in the use of SolidWorks. Likewise in the Digital Electronics course the Computer Systems Technology students will be stronger programmers but Engineering Science students will be more adept at creating and analyzing circuits.

Another challenge to this project is college's administrative and budget structure that unduly complicates implementation of collaborative projects such as this. Concerns about faculty workload and which department gets the credit for student enrollment in the dual enrolled courses have slowed but not stopped our progress.

Overcoming the fears of professors who are used to a faculty centered approach to education in which they closely control the topics covered is another impediment to progress. The project based pedagogy used in our Engineering Science courses is a more chaotic and student centered. This requires faculty to become comfortable guiding students as independent learners as opposed to closely controlling the learning process.

The large percentage of students in the engineering science program who don't complete their degree is another problem to be addressed by this project. By exposing all the Engineering Science students to the faculty and students of the Precision Machining and Computer Systems Technology department we hope to persuade these students to switch to one of these related STEM fields instead of dropping out completely.

Curriculum Design

Thus far the Computer Systems Technology Department has formally changed their curriculum to require their students to take Digital Electronics and Engineering Design Lab from the Engineering Science Department. Additional sections of Digital Electronics are now being assigned to faculty from the Computer Systems Technology Department so that they don't experience a drop in workload.

The first cohort of Computer Systems Technology students will be taking digital electronics along with engineering science students in the spring of 2015. In the spring of 2016 Computer System Technology students will begin taking the engineering design lab capstone course with Engineering Science students.

Progress has been slow in out attempt to integrate the Precision Machining students into this program. Thus far the Precision Machining department has not formally approved any curriculum changes to adopt Mechanical Design and Prototyping into their program. In the spring 2015 semester however, a group of about 10 machining students will take our mechanical design course for the first time. We hope that a positive outcome in this

initial experience will reassure the Precision Machining Department to formally adopt the course into their program.

Although verbal commitments have been made by the Precision Machining program to adopt the Engineering Design Lab, no formal approvals have come forth. As mentioned above, the replacement of formal teaching of specific machining techniques with an open-ended capstone course has caused progress to be slow. We hope to convince the machining department that the problem solving and teamwork skills obtained by working with engineering and computer students is a highly valuable skill set for their students.

Instructional Material Development

To support our concurrent curriculum design we have developed instructional materials so that a diverse set of students are able to learn the material successfully. In our Mechanical Design and Prototyping course we have created a set of instructional videos to supplement the instruction in the classroom. Providing students with these online tutorials allows them to work at their own pace. The tutorials can be viewed on youtube.com by typing in ENR 153 in the search bar.

The Mechanical Design videos cover SolidWorks part modeling, assembly creation, animations, and detailed drawings. A set of videos on surface modeling using nPower Surfacing software demonstrates how to create organic shapes such as a car body. nPower software is an add-in tool for SolidWorks that allows users to model objects with complex curvature by using the mouse to pull and push a virtual piece of putty. The end result of this process is a solid model that is fully editable in SolidWorks.

To better appeal to the needs of machinists we have created a set of CamWorks videos that demonstrate how to create toolpaths for SolidWorks models. CamWorks is also an add-in to SolidWorks that allows the user to create toolpaths that are fully associative with the SolidWorks model. This means that if a change is made to the model in SolidWorks, the CamWorks toolpaths will either update automatically or flag the user that changes must be made.

Using CamWorks is also a highly beneficial activity for engineering students as it allows them to understand the manufacturing impacts of their design choices. For example if a student designs an interior pocket in a part with 90 degree corners, they will find out that this feature cannot be created as designed when a CamWorks machining simulation is run. The CamWorks simulations show the tools and the paths they will follow on a 3D model on the computer. At the conclusion of the simulation, CamWorks color codes the edges of the machined model to indicate the magnitude of the difference between the SolidWorks design and the machined part.

Due to requirements form four-year engineering schools and the Computer Systems Technology Department, we have transformed our Digital Electronics course from one that uses discrete IC components to one that utilizes an Altera FPGA module. Instead of

manually wiring discrete IC components together using breadboards, instruction now focuses on designing digital circuits using either schematic capture methods or VHDL programming. To assist the students in learning these new techniques we are in the process of creating a full set of videos. These videos can be viewed at youtube.com by typing in MCC ENR 157 in the search bar.

In order to prepare both Engineering Science and Computer Systems Technology students for their capstone course, we have developed a new laboratory manual that contains many robotic applications such as Servo and DC motor control, IR navigation, color sensing and closed loop control.

We are currently designing and fabricating a series of boards that will connect with the Altera DE0-Nano similar to how Arduino shields connect to Arduino microcontrollers. We are currently testing our power supply, motor driver, IR sensor, and color sensor boards. Our goal is to have a wide set of boards that will be available for purchase by students at affordable prices so that students can work with the boards and the DE0-Nano outside of class. This set of hardware may also be appealing to those wishing to include laboratory experiences for online courses.

In our capstone course titled Engineering Design Lab most students work in teams of four to design and build a solution to the annual ASEE Two-Year College Division Model Design Competition (see http://faculty.tcc.edu/PGordy/ASEE/index.html). The ASEE projects are ideal for interdisciplinary design teams as they entail building robotic systems that require mechanical, electrical, programming, and fabrication skills.

In the past our Engineering Science students were the only students who took Engineering Design Lab. Engineering Science students are knowledgeable designing mechanical and electronic systems but have been very weak programming and machine shop fabrication skills. Inclusion of Computer Systems Technology and Precision Machining students on our teams will alleviate these deficiencies in our teams. More importantly these multidisciplinary teams will allow students to learn how to effectively work in a way that will be expected of them in industry. Full implementation of this integrated approach will begin in the spring of 2016 so no data is presently available on this effort.

Conclusion

This three-year project is in the second year so many efforts are still in progress although some preliminary observations have been made. In the fall of 2014 we tested the use of our instructional videos in Mechanical Design and Prototyping. Many students found the videos very helpful but commented that some of the videos presented the material too quickly especially when software tools were being demonstrated. We will be editing or replacing these videos to slow the pace so that students won't have to constantly stop and rewind the videos to grasp concepts.

The nPower Power Surfacing software was well received by the students. The car body designs that they created and printed out with our 3D Stratysis printer were far more complex and impressive than we have seen in prior years using only SolidWorks tools. Some students did find the software to be frustrating when their surfacing designs would not convert into editable SolidWorks models. This problem seemed to occur when students created intersecting geometry. Another difficulty that students encountered was when the solid model would not shell in SolidWorks due to curves with too small of a radius.

The first cohort of Precision Machining students is taking Mechanical Design and Prototyping for the first time in the Spring 2015 semester. Data on this experience will be ready to report by June of 2015. Individual Precision Machining student have taken this course in the past and completed it successfully but many commented that the workload was heavier than they expected.

Over the past two semesters Engineering Science and individual Computer Systems technology students have taken Digital Electronics together. The number of computer students has been fairly small but it appears that they have been able to perform similarly to the engineering science students. Both sets of students have voiced frustration with several nuances in the programming of the Altera DE0-Nano that have caused system crashes. We have noted the most common problems and are emphasizing how to avoid them in our instructional videos for the course.

The shield type sensor and motor driver boards will be ready for testing for a select number of laboratory exercises in the spring of 2015. Observations of student experiences will be ready for reporting by June 2015. Pricing and availability of the boards may also be known by the ASEE Convention in Seattle.

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