GAINING VALUABLE PRODUCT DESIGN EXPERIENCE THROUGH HELPING HIGH SCHOOL STUDENTS IN BUILDING COMPETITION ROBOTS

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Abstract: For years, many mechanical engineering technology students asked faculty members for opportunities to be exposed to real engineering work through internship or through hands-on design projects that enable them to learn the latest engineering technology used in the industry and gain valuable practical experience in the process. Thanks to a grant from National Science Foundation (NSF) Advanced Technology Education (ATE) division, in fall 2010, a Mechatronics Technology Center (MTC) was established in the department of mechanical engineering technology department to introduce the latest mechatronics technology to the students in mechanical engineering technology department as well as to the students in the computer engineering technology department. Many hands-on mechatronics designed projects have been created for students to learn the latest robotic/mechatronics technology either through classroom setting or through extracurricular design activities. As a result, many students were able to use the products they created for their design projects to participate in various competitions at the college level.

In January 2011, MTC was asked by two high school robotic rookie teams, one from P-tech High School and one from Brooklyn Collaborative Studies High School (BCS), to help them to build robots for an upcoming FIRST Robotic Competition (FRC). FRC is an annual robotic competition event for high school students and is sponsored by a non-for-profit organization called For Inspiration and Recognition of Science and Technology (FIRST). Although the competition is for high school students, the hardware and software used in building the robots reflect the cutting edge robotic technology used by many American companies. Since the robotic technology used in FRC is so advanced, it is almost impossible for high school students to utilize them without the help from outside help. This presents an excellent opportunity for the City Tech students because some of them have been exposed to similar technology through their own hands-on mechatronics design projects. It also posts a great challenge because there are many new high tech contents used in FRC that most college students have never been exposed to.

This paper presents a result on how both college and high school students benefitted from a collaborative learning project on which college students served as mentors to help high school students to build 100-lb robots for FRC.

Keywords: Cognitive learning, experiential and cooperative learning, hands-on learning.

1. Introduction

One of the problems that many engineering technology students face when looking for their first engineering job is: Do you have relevant experience? Employers prefer graduates with relevant experience to those without. Why is
experience so important to employers? Can students accumulate “working” experience while studying in college? Where and how can students gain valuable engineering experience in the college environment? For years, many mechanical engineering technology students asked faculty members for opportunities to be exposed to real engineering work through internship or through hands-on design projects that enable them to learn the latest engineering technology used in the industry and gain valuable practical experience in the process.

Thanks to a grant from National Science Foundation (NSF) Advanced Technology Education (ATE) division, in fall 2010, a Mechatronics Technology Center (MTC) was established in the department of mechanical engineering technology department to introduce the mechatronics technology to the students in mechanical engineering technology department as well as to the students in the computer engineering technology department. Many hands-on mechatronics designed projects have been created for students to learn the latest robotic/mechatronics technology either through classroom setting or through extracurricular design activities. One of the activities is to help high school students to build 100-lb robots to compete in FIRST Robotic Competition (FRC).

To change the views of young people about the science and technology, Dr. Dean Kamen, an inventor and entrepreneur, founded FIRST (For Innovation and Respiration of Science and Technology) in 1989 to engage high school students in science and technology activities through building sophisticated heavy-duty robots and participating in FRC. Since the technology used in FRC is quite advanced for most high school students to understand, FIRST asks high school robotic teams to work with outside professional engineers. When asked by the two high school teams for help, Professors who were in charge of the daily operations of MTC saw this was an excellent opportunity for City Tech students to learn to serve as the “outside professional engineers”, using what they have learnt in MTC to help high school robotic teams to build the robots. Since each high school robot team was given six weeks to finish building the robot for the FRC, it put a lot of pressure for the college students to design, build, test, and program the robots in such a short time frame. This paper documented some details of these activities and demonstrated how college students benefited from this unique opportunity to practice engineering.

2. Cutting-Edge Robotic Technology Used in FRC
Although the FIRST Robotic Competitions are high school events, the hardware and software used in FRC are by no means high school stuff. In fact the robotic technology used in FRC represents the cutting-edge technology used in the industry. Companies are using these components to make actual commercial products. However, building a robot for FRC is not cheap. The cost for a high school team to participate in FRC is at least $10,000.

2.1 Robot Controller
The robot controller for FRC is made from National Instruments. It’s called Compact Real Time Input & Output Controller (cRIO). The cRIO supplements its PowerPC processor with an FPGA controller and plug-in modules used to interface with IO. The FPGA controller is loaded with a provided image which provides functionality such as Quadrature decoders and analog accumulators as well as implements safety features. The cRIO is powered by a 24V power source and communicates with computer through D-LINK DAP 1522 wireless router. CRI0 is considered one of the best robot controllers used in the industry [1]. Figure 1 shows a cRIO
equipped with a NI 9403, 32-channel digital IO module; a NI 9021, 8-channel analog input module; and a NI 9472, 8-channel, 24V logic, sourcing digital output module.

2.2 Electrical Components
The electrical components used in FRC are made from vendors for real product design and development. Figure 2 shows a variety of motors and motor controllers used in FRC.

2.3 Pneumatic Components
To enable high school students to utilize pneumatic power to construct more functional robots, state-of-the-art pneumatic systems which include compressor, valves, and pistons as shown in Figure 3.

2.4 Software
Sophisticated software such as JAVA, C++, and LabVIEW are being used to program the robots through powerful cRIO robot controller. WPI provided the library needed for the software to communicate with the hardware used in FRC [3].

3. Challenges for the College Students
Because of the cost associated with teaching technology, many colleges and universities cannot afford to use robotic components for commercial and industry applications to teach robotic technology in the classroom. This resulted in a situation that the materials that many students learned from the educational robotic kits which use low voltage plastic motors that focus on a particular area only such as programming. The knowledge they learnt in the classroom might not be readily applied to design real products which require high voltage power source. Besides, most students have never been exposed the multidisciplinary field of robotics which require students to possess broad knowledge in mechanical, electrical/electronics, and programming. It takes times for the college students to develop the necessary knowledge and skills so that they will be able to help the high school students in FRC. As a result, to many college students, helping high school students to build FRC robots presented challenges.

4. Practicing Engineering Through Hands-on Design Activities
Thanks to a grant from NSF ATE, similar robotic technology used in the FRC was purchased in the MTC. Students were able to be exposed to the cutting-edge technology and work on their design projects as their coursework. As a result, some of the students were able to help the high school students to build the FRC robots when FRC build season starts in January each year.

Each year’s FRC competition is different. The team learns the details of the competition one day before the build season starts. The team then has only six weeks to build. The following discussed the activities related to building the robots for the 2013 FRC. It requires the teams build robots that can shoot Frisbee as well as to climb a frame at the end of two-minute competition. Two local high school robotic teams, P-tech High School and Brooklyn Collaborative Studies High School (BCS), were involved with this project.

4.1 Mechanical Design
When design a robot, the first thing the team has to do is to design a mechanical system that can accomplish to required tasks. Because of time constraint and limitations of fabrication capability of the machine shop, not all objectives can be accomplished. The team has to choose priorities.
One team wanted to put priority on building a mechanism that can shoot Frisbee effectively. The other team wanted to design a robot that can climb three levels on the tower frame. Based on the different demands of the two high school teams, the college students have designed and built two robots; one was mainly to shoot the Frisbee as shown in Figure 4. This robot uses four powerful CIM motors to drive the chassis frame that has six wheels. The Frisbee shooter uses two AndyMark RS 775 motors along with two Toughbox Nano gearboxes to provide enough speed and power to shoot the Frisbee. Two 12” Bimba Nano gearboxes were used to design a hook mechanism that enables the robot to climb the first level of the tower frame. A VIAIR 090 air compressor was used to provide the compressed air to the two pistons. The highest pressure was set to 120 psi. The working pressure was reduced to 60 psi through pressure regulators.

Figure 5 is a computer model of a robot for P-Tech robotic team. This robot uses two Bimba 24” pistons in conjunction with two 12” pistons. The two 12” pistons enabled the robot to grasp the first level of the tower frame. The two large 24” piston would then be used to climb the second level of the tower frame. In the end, the two small 12” pistons would be released and used to climb the third level of the tower frame.

4.2 Electrical Design
Once the type mechanical systems were chosen, the team started to select actuators needed to accomplish the desired motion. Then proper motor controllers and sensors selected. Figure 6 shows the schematic of actuators, motor controllers, and other electrical/electronic components used for the BSC robot.

4.3 Pneumatic Design
Both team wanted to have some kind of frame climbing capability. One team wanted its robot to climb three levels on the frame. The other team, which set its priority to shoot Frisbee, just wanted its robot to climb the first level. Pneumatic system turned out to be an effective way to design a climbing system. Figure 7 shows the pneumatic design for the BCS robot.

4.4 Software Design
Once the students finished the mechanical design and electrical/electronic design of the robots, the college students had to create computer programs to test the functionality of the robots. Software design involved programming each actuator to accomplish certain tasks that create the desired behavior of the robot for different competition scenario. There was an autonomous code which allows the robot to run without human interference. There was also a tele-operated portion of code which allows students to remotely control the robot during competition. Both teams used JAVA to program their robots.

5. Final Products
After six weeks' of hard work by the college students, two functioning robots were built. Figure 8 is a physical prototype of BCS robot. As can be seen the robot follows closely with the computer model.

Figure 9 is a physical prototype built for P-Tech team. It has four pistons that can be used to climb three levels on the tower frame.
6. Conclusions
Students gained tremendous experience from this project. It allowed them to work under pressure, to work as a team, to communicate effectively with others, and to learn the new hardware and software. They learned how to choose different types of mechanical systems and fabrication methods, how to choose electrical components, and pneumatic components.

This project allowed the students to be exposed to the robotic technology used in the industry. There are a lot of features of the hardware and software that have not been utilized. It takes time for the faculty members and students to learn how to utilize the advanced features that the FRC. This means that this type of hands-on activities needs to be sustained in order for faculty and college students continuously upgrade their knowledge and learn how to apply them in product design projects.

Project based, cognitive and team learning activities are proven to be an effective way for many students to learn [4, 5]. Therefore this type of hands-on design activities should be encouraged by the college whenever possible.

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References

Figure 1 cRIO from NI used in FRC
Figure 2 Motors and Motor Controllers used in FRC

Figure 3 Pneumatic Components used in FRC [2]

Figure 4 CAD Model of BCS’s Frisbee Shoot Robot
Figure 5. CAD Model of P-Tech's Frame Climbing Robot

Figure 6 Electrical Design for BSC Robot

Figure 7 Pneumatic Design of the BSC Robot's Climbing Mechanism
Figure 8 A physical robot prototype for shooting the Frisbee

Figure 9 A physical robot prototype for climbing the frame