AC 2011-281: DEVELOPING A ROBOTICS TECHNOLOGY CURRICU- LUM AT AN URBAN COMMUNITY COLLEGE

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Developing a Robotics Technology Curriculum at an Urban Community College

Abstract

It is well recognized that to be globally competitive in the 21st century, the United States must invest in Science, Technology, Engineering, and Mathematics (STEM) training and education to prepare a technically skilled and knowledgeable workforce. More academic and industrial partnerships and collaborations that address K-12 challenges, post-secondary curricula, and workforce needs in STEM related fields must be created and supported to accomplish this. An urban community college, seeking to be a national leader in this effort, applied for and was awarded an Advanced Technology Education grant from the National Science Foundation to develop a Robotics Technology Curriculum. The goals of the grant project are to: (a) develop the curriculum for a unique robotics technology associate degree program at the urban community college that trains students to be super technicians who are qualified to be hired as robotics, automation, manufacturing, and/or electronics technicians; (b) set up a state of the art robotics laboratory at the urban community college to offer students an abundance of hands-on, practical experience that prepares them for immediate entry into the workforce upon completion of the program; (c) increase the success rate of the electronics, computer information system, and computer aided drafting & design technician programs at the urban community college by incorporating robotics-related activities and instruction into their curricula; (d) introduce robotics concepts to 11th and 12th graders in select high schools in the city's public school system and improve their math problem solving skills through hands-on robotics exercises; (e) develop an articulation agreement between the urban community college's robotics program and a local four-year university's school of engineering for students who wish to pursue an engineering-related bachelor's degree; (f) provide internship and job opportunities to the robotics program's students and graduates; and (g) improve underrepresented students' awareness of and attitudes towards robotics technologies. This paper discusses the efforts made towards achieving these goals as well as the results and outcomes of each goal.

1. Introduction

The robotics industry has achieved a high level of prominence in the 21st century. The Robotics Industries Association (RIA) estimates that in August 2010, more than one million robots were being used worldwide[1]. The RIA also notes that the United States ranks second, behind Japan, in overall robot use with an estimated 198,000 robots in use in factories[1]. While an economic downturn slowed the growth of the robotics industry in 2009, data from the International Federation of Robotics (IFR) shows that the estimated worldwide shipments of industrial robots each year from 2005 – 2008 was more than twice the number of shipments in 1992[2]. The IFR predicts significant increases in robotics sales in the years 2011 – 2013 due to huge consumer markets opening up in China, India, Brazil, Russia, and the Middle East. In North America, the IFR predicts robotics sales to rise during this time as companies, especially those in the automobile industry, continue to innovate and increase the amount of automation in their production lines[2].

This data makes it clear that to be globally competitive in the 21st century, the United States must invest in Science, Technology, Engineering, and Mathematics (STEM) training and education to prepare a technically skilled and knowledgeable workforce. Investment in STEM training and education is necessary because the World Economic Forum ranked the United States a modest 52nd out of 139 countries in quality of math and science education in its 2010-2011 Global Competitiveness Report[3]. This follows being ranked 48th in the previous two reports[4-5]. President Obama highlighted the need for investment and improvement in a speech given at the National Academy of Sciences. President Obama said at this time "science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before," and "other countries are now beginning to pull ahead in the pursuit of this generation's great discoveries[6]." More academic and industrial partnerships and collaborations that address K-12 challenges, post-secondary curricula, and workforce needs in STEM related fields must be created and supported to achieve the improvement in STEM education necessary to keep the United States globally competitive, especially as technical fields, such as robotics, continue to exhibit rapid growth around the world.

An urban community college, seeking to be a national leader in the effort to educate and train highly skilled, globally competitive technicians in STEM related careers, applied for and was awarded an Advanced Technology Education (ATE) grant from the National Science Foundation to develop a Robotics Technology Curriculum. The goals of the grant project are to: (a) develop the curriculum for a unique robotics technology associate degree program at the urban community college that trains students to be super technicians who are qualified to be hired as robotics, automation, manufacturing, and/or electronics technicians; (b) set up a state of the art robotics laboratory at the urban community college to offer students an abundance of hands-on, practical experience that prepares them for immediate entry into the workforce upon completion of the program; (c) increase the success rate of the electronics, computer information system, and computer aided drafting & design technician programs at the urban community college by incorporating robotics-related activities and instruction into those curricula; (d) introduce robotics concepts to 11th and 12th graders in select high schools in the city's public school system and improve their math problem solving skills through hands-on robotics exercises; (e) develop an articulation agreement between the urban community college's robotics program and a local four-year university's school of engineering for students who wish to pursue an engineering-related bachelor's degree; (f) provide internship and job opportunities to the robotics program's students and graduates; and (g) improve underrepresented students' awareness of and attitudes towards robotics technologies. The remaining sections of this paper discuss the efforts made towards achieving these goals as well as the results and outcomes of each goal.

2. Goal a: Develop the curriculum for a unique robotics technology associate degree program

The first goal of the grant project is to develop the curriculum for a unique robotics technology associate degree program at the urban community college that trains students to be super technicians who are qualified to be hired as robotics, automation, manufacturing, and/or electronics technicians. This goal was accomplished by creating four new robotics courses and combining them with existing courses from the electronics, computer aided drafting and design,

and math & science departments to form a four-semester, 63-credit curriculum. The program's curriculum is outlined in Table I.

Table I: Robotics Technology Associates Degree Curriculum

Semester 1 (15 credits)	Semester 2 (16 credits)
PRE 100 Preparation for Academic Achievement ELC 101 Mathematics in Electronics ELC 120 DC Circuit Analysis MAT 128 College Algebra * RBT 101 Introductions to Robotics HLF xxx Health and Life Fitness Elective	ELC 121 AC Circuit Analysis ELC 151 Digital Fundamentals EGN 101 Engineering Graphics RBT 102 Fluid Power and Components CSC 108 Programming in C HLF xxx Health and Life Fitness Elective
Semester 3 (16 credits)	**Semester 4 (16 credits)**
ELC 131 Semiconductor Devices PHY 101 College Physics I * RBT 201 Computer Assisted Manufacturing ELC 251 Digital Systems/ PLCs CADD 208 CADD Mechanical Applications	ECO 201 Macroeconomics RBT 203 Robotics Applications ENG 101 English Composition SP 101 Fundamentals of Speech Social and Behavior Sciences Elective

* Students who want to transfer to a four year university to pursue a bachelor's degree will be advised slightly different in math and physics courses.

This curriculum is unique because it is the only robotics associate degree program in the community college's state and neighboring states. The curriculum is also unique because students are immediately immersed into robotics courses in the first semester which captures and fosters their interest in robotics. The immediate, hands-on interaction with robots inspires and motivates students to remain in the program after the first semester. Many technical curricula miss this retention opportunity by having students take only general education courses in the first semester.

Students began enrolling in the program in the fall 2009 semester. The fall 2009 cohort consists of 12 students (measured by the enrollment in RBT 101 at the beginning of the fall 2009 semester). The fall 2010 cohort consists of 20 students (measured by the enrollment in RBT 101 in the beginning of the fall 2010 semester). The first graduates of the program are expected in the spring of 2010.

3. Goal b: Set up a state of the art robotics laboratory

A 1200 square-foot state of the art robotics laboratory was set up as a part of the grant project effort in order to provide students in the Robotics Technology Program with an abundance of

hands-on, practical experience that prepares them for immediate entry into the workforce upon completion of the program. The following equipment is housed in the robotics laboratory:

- 14 Lego NXT Mindstorm kits with additional sensors (RBT 101)
- 2 LabVolt 5250 educational robots with additional accessories (RBT 101/201)
- 1 Centari hydraulic robot (RBT 102)
- 1 LabVolt Hydraulics/Pneumatics Training Bench (RBT 102)
- 1 Denford CNC Router 2600 (RBT 201)
- 12 VEX Superbundles (RBT 203)
- 1 KUKA KR5 Scara Robot (RBT 203)

Students in the Robotics Technology Program will not only work with each of the robots listed above, they will also work with a variety of software packages to program, simulate, and control these robots.

4. Goal c: Increase the success rate of students in other technician programs at the college

Currently, only 75% of students pass the core courses in the technicians' programs at the community college. Two courses that serve as pre-requisites to the core courses in the electronics, computer information system, and computer aided drafting design technicians' programs at the community college are CSC 108: Programming in C and CIS 118: Programming with Visual Basic. In the fall 2009 semester, a pilot study was conducted with the CSC 108 and CIS 118 courses in which Lego NXT Mindstorm robots were used as an assistant or tool to teach students about programming principles. The purpose of the study was to determine if using robots as a virtual instructor enabled, mixed reality learning intervention increases the students' success rates in these courses. The use of robotics as an educational tool is growing in popularity and researchers believe this approach will revolutionize the way science, technology, engineering, and mathematics skills are taught[7, 8, 9]. The details and results of the pilot study are discussed in remainder of this section.

In the fall 2009 semester, two sections of CSC 108 and one section CIS 118 were offered at the community college. One section of each course was chosen to participate in the pilot study while the second section of CIS 118 was used as a control group. After students in the experimental group learned about the principles of for loops and functions in their respective classes, they were issued Lego NXT Mindstorm robots, given a 60 minute introduction to the robot's hardware and RobotC, a C-based programming language developed by a major research university for Lego NXT Mindstorm robots, and assigned the task of programming their robots to drive the perimeter of a square. The students were required to use one for loop and three functions in their program.

When the students finished the assignment, they were given a 10 question quiz on the principles of for loops and functions. The quiz questions were conceptual in nature and multiple-choice in format. Each question was assigned a full point value of 10 points so the maximum number of points that could be earned on the quiz was 100. Students in the control group, who learned about the principles of for loops and functions in their classes, but were not given the hands-on robotics assignment, were also given this quiz.

Seventeen students completed the robotics assignment and quiz. The mean score on the quiz for these students was 76.5 and the standard deviation was 16.6. Twelve students in the control group completed the quiz. The mean score on the quiz for the students in the control group was 57.9 and the standard deviation was 25.9. A two sample t-test assuming unequal variances was done to test the null hypothesis which shows there is no difference in the mean quiz scores for the two groups. The alternative hypothesis is that the mean score for the students who completed the robotics assignment is greater than the mean score for the control group. The one tail p-value for this test is 0.02. It should be noted that an F-test was done to test for equal variances. The p-value of the F-test was 0.05, which is borderline significant. If a two sample t-test is done assuming equal variances, the one tail p-value is 0.01.

Regardless of whether the variances of the two samples are considered equal, the results of the pilot study are significant. The results suggest that using robots as a virtual instructor enabled, mixed reality learning intervention has increased the students' success rates in the community college's CSC 108 and CIS 118 courses.

5. Goal d: Introduce robotics to 11th and 12th graders in select high schools

Faculty in the Robotics Technology Program conducted robotics seminars at 10 high schools/middle schools near the community college. The robotics seminars were structured to have six parts: (1) a pre-seminar student survey; (2) videos of various robotics applications; (3) a PowerPoint presentation on the Robotics Technology Program, scholarships and importance of mathematics; (4) demonstrations Lego Mindstorm robots; (5) distribution of Robotics Technology Program brochures and scholarship flyers; and (6) a post-seminar student survey and questions/answer session. Each robotics seminar lasted 60 - 90 minutes. By April 1, 2010, 250 juniors/seniors and 80 middle school students attended the robotics seminars.

The following survey results are based on data from four robotics seminars held between August 2009 and February 2010. Total attendance at these four seminars consisted of 48 high school students and 37 middle school students. More than half, 53.5%, were females, 58.3% were black, 15% were Asian, and 16.7% were white. Nearly all (96.1%) indicated they had fun learning about robotics. When asked how much the presentation impacted their knowledge and interest, 56% said the presentation increased their knowledge about robotics and 41.1% reported a high interest in participating in robotics. Students expressed similar levels of interest in taking college-level robotics courses (36.9%) and exploring careers in robotics (39.8%).

In addition to the robotics seminars, the community college used the robotics grant to co-sponsor two robotics competitions for high school students: the 2009 VEX Robotics Competition and the 2009 Juxtopia Atlantic VEX Coastal Regional Championships. Approximately 500 high school students participated with 25 receiving direct mentorship from personnel in the Robotics Technology Program.

6. Goal e: Develop an articulation agreement with a local four-year university

Students who graduate from the Robotics Technology Program at the community college will have the option to either enter the workforce or pursue a bachelor's degree in industrial engineering with a concentration in robotics at a local four-year university. A block transfer agreement is being developed with the university to allow students to transfer seamlessly into the program. The university is also developing a special summer program that emphasizes advanced mathematics skills in robotics, which will be an entrance requirement for students transferring from the community college's Robotics Technology Program to the university's engineering program.

7. Goal f: Provide internship and job opportunities for robotics students

One of the grant project's local industrial partners has agreed to provide internships for three students in the Robotics Technology Program during the 2010-2011 academic year. One intern will work at the company's location and the other two will conduct their work in the robotics laboratory on the community college's campus.

Negotiations are also underway between faculty in the Robotics Technology Program and Advancing Robotics Technology for Societal Impact (ARTSI) Alliance. The goal of the negotiations is to get two students in the Robotics Technology Program summer internships at ARTSI institutions during the summer of 2011.

8. Goal g: Improve underrepresented students' awareness of and attitudes towards robotics

In April 2010 an online questionnaire was disseminated to students in the Robotics Technology Program. Students were asked to provide their perception of the effectiveness of the program's robotics courses as well as their perception of their readiness for careers in robotics and electronics.

Among the 29 respondents, 86.2% were males and 93.1% were African Americans. Nearly all students (96.5%) felt that the robotics courses better prepared them to identify, prepare, and solve problems in the field. All students (100%) said the robotics courses increased their interest in pursuing positions in the field. Nearly all students (93.1%) said their robotics courses improved their qualifications for future positions in the field. Also, nearly all students (93.1%) reported that they intended to pursue future positions in the robotics/electronics field as a result of the skills and knowledge they gained in their courses. A majority (64.3%) planned on enrolling in a four-year institution to pursue further studies in robotics/electronics before entering the workforce.

The results of a survey conducted with high school and middle school students were given in Section 5 of this paper. The results of this study indicate that the robotics seminars conducted at the high schools and middle schools left the students with a positive impression of robotics and a desire to pursue post-secondary education and careers in robotics.

9. Conclusion

An urban community college, seeking to be a national leader in the effort to educate and train highly skilled, globally competitive technicians in STEM related careers, was awarded an Advanced Technology Education (ATE) grant from the National Science Foundation to develop a Robotics Technology Curriculum. By all measures, the grant project has been successful. Significant efforts have been made towards achieving each of the project goals and promising results have been obtained. The curriculum for a robotics technology associate degree has been developed and students are currently enrolled in the Robotics Technology Program, a 1200 square-foot state of the art laboratory has been set up at the community college, it has been shown that other technician programs at the community college are benefitting from robotics instruction, high school and middle school students are being introduced to robotics, an articulation agreement with a four year university and internship opportunities for students in the robotics program are being established and developed, and students' awareness of and attitudes towards robotics are improving as a result of the robotics courses in the program.

10. Acknowledgement

11. References

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