Outcomes Assessment of Student Learning for an Educational Robotics Program

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Abstract

Modeling the fields of engineering and science, robotics technologies represent a practical high-tech application, and provide a very powerful approach to demonstrate a variety of engineering concepts. In addition, robotics appeals to a broad range of interest and allows an effective access to science, technology, engineering and mathematics for many types of learners. As a result, educational robotics programs have been steadily expanding in the past years in higher education to train today's young people to be qualified for successful careers in tomorrow's high-tech environment. By taking place in Holyoke Community College (HCC), one of 29 public state universities and colleges in Massachusetts, USA, with its very diverse and large student population, its Robotics program has been growing rapidly over five years. The Robotics courses at HCC provide construction and design oriented engineering classes to fulfill the laboratory science requirement of the College and the Massachusetts Commonwealth Transfer Compact. The Robotics courses also provide students with a foundation of knowledge and skills for limitless potential.

The purpose of this paper is to explore the development of Robotics curriculum and to discuss the outcomes assessment of student learning in Robotics courses. The assessment includes faculty evaluation measures and student evaluation input. A special survey for Robotics classes was designed and conducted recently. The survey has also shown student backgrounds, intentions, comments, thoughts and desires for future career. More significantly, the both faculty evaluation measures and student feedback have indicated the positive outcomes of student learning. The results of this study would help enable faculty to upgrade Robotics curriculum to meet student needs.

INTRODUCTION

Modeling the fields of engineering and science, robotics technologies represent a practical, high-tech application and provide a very powerful approach to demonstrate a variety of engineering concepts. In addition, robotics appeals to a broad range of interests and allows effective access to science, technology, engineering and mathematics for many types of learners. As a result, educational robotics programs have been steadily expanding in the past years in higher education to train today's young people to be qualified for successful careers in tomorrow's high-tech environment [1].

There is a rich history of educators bringing robotics into undergraduate classrooms over the last ten years. Sklar et al. [2] reviewed the educational robotics development and presented "Robotics Across the Curriculum." Kumar [3] used robotics in an artificial intelligence course and incorporated robotics into the undergraduate curriculum in various capacities. Also, other studies addressed hands-on artificial intelligence curriculum and programming environments using robotics [4, 5]. At the beginning of the educators' efforts, those applications were mainly used for computer science or artificial intelligence programs.

On the other hand, educators not only use robotics to teach science and engineering, but also use robotics as a component of a general education course [6, 7, 8]. Educational robotics programs also cover the connection between high school and university. A typical application is the 2+2+2 robotics program, which connects a high school robotics program to associate and baccalaureate programs at the university [9].

In addition to the practice at universities, educational robotics programs have been growing rapidly in community colleges. For example, more robotics programs were developed and the grants were obtained to develop robotics programs [10, 11, 12].

By taking place in Holyoke Community College (HCC), one of 29 public state universities and colleges in

Massachusetts, USA, with its very diverse and large student population, it's robotics program has been growing rapidly over five years. The robotics courses at HCC provide construction and design oriented engineering classes to fulfill the laboratory requirement of the College and the Massachusetts Commonwealth Transfer Compact. The robotics courses also provide students with a foundation of knowledge and skills for limitless potential. Currently robotics classes are popular on campus; 6 classes of EGR/SEM 110 Robotics I and 2 classes of EGR/SEM 111 Robotics II are offered for students with any majors, and all classes have been full with high enrollment every semester for two years.

The purpose of this paper is to explore the development of Robotics curriculum and to discuss the outcomes assessment of student learning in Robotics courses. The assessment includes faculty evaluation measures and student evaluation input. A special survey for Robotics classes was designed and conducted recently. The survey has also shown student backgrounds, intentions, comments, thoughts and desires for future career. More significantly, the both faculty evaluation measures and student feedback have indicated the positive outcomes of student learning. The results of this study would help enable faculty to upgrade Robotics curriculum to meet student needs.

In this paper, the Objectives of Robotics Courses, Faculty Evaluation Measures, Primary Goals of a New Robotics Course, Student Evaluation Method, are addressed in turn; then the Findings from the student survey are analyzed; and finally, Discussions and Conclusions are made.

OBJECTIVES OF ROBOTICS COURSES

The purpose of robotics courses at HCC is to provide a construction and design oriented laboratory class for non-engineering majors which fulfills the laboratory science requirement of the College and the Commonwealth Transfer Compact in Massachusetts [13]. The objectives of EGR/SEM Robotics I course are as follows:

- Introduce students to the excitement of engineering and science in a supportive and cooperative environment.
- Motivate the student learning of engineering and scientific principles through challenges in construction and design.
- Provide an entry level science based engineering course that is open and accessible to all students regardless of background.
- Provide a supportive, non-threatening, hands-on opportunity to explore the possibilities of science, technology, engineering and mathematics disciplines.
- Provide a forum to explore the potentials and limitations for science, technology, engineering and mathematics to solve humanitarian, social and environmental problems.
- Learn the history of robotics, current applications and future development.
- Learn to use a variety of control procedures in designing robotics for specific tasks or multitasking.
- Learn to program a microprocessor based robot control for engineering applications.
- Develop problem-solving strategies and skills for engineering problems through experimentation.
- Develop team-working experience and skills in a cooperative, hands-on work environment.

To achieve these objectives, students work on a dozen projects in class. They use a variety of robot elements and machine parts to design and complete robots, such as Track Runner, Wall Bumper, Table Cleaner, Maze Buster, Basketbot, Roboarm, and so on. Importantly, basic principles and theories of engineering are addressed in the Robotics course.

FACULTY EVALUATION MEASURES

At the College the faculty evaluation is so important; and the measures include the following stages:

- Engineering Department
- Science, Engineering and Mathematics Division (SEM)
- The College Curriculum Committee
- HCC Senate

To ensue that the objectives of Robotics courses are achieved, a faculty evaluation procedure takes place. First, the Engineering Department regularly discusses the curriculum issue for several times per semester. If the department members make a consensus, then the Department needs to forward a proposal to the Academic Dean for consider-

ation. At SEM Division meeting, the proposal is discussed and a vote is taken by all faculty members. If the proposal passes, then the proposal is forwarded to the College Curriculum Committee to discuss and approve. Again, a vote is required at the Curriculum Committee. If the proposal passes, it is forwarded to the College Senate to approve. The Senate is the highest authority to evaluate and approve the curriculum change or development of a new course. All Senate members should discuss and take a vote. If the Senate approves the proposal, finally, the proposal is effective at once and delivered to the Library for the official archives.

For example, the Engineering Department made proposals to change the course title and course contents, and finally the proposals were approved through the above stages. From several years' practice, the Robotics course objectives are fulfilled.

In addition, to meet student demands, a new Robotics course EGR/SEM 111 Robotics II was created and approved through the above procedure two years ago.

PRIMARY GOALS OF A NEW ROBOTICS COURSE

Based on the successful practice of EGR/SEM 110 Robotics I course, a new course EGR/SEM 111 Robotics II is offered to students. The primary goals of the course are as follow:

- To encourage students to expand on their experience in design, construction and programming (Robotics I uses RCX, Robotics II uses NXT).
- To introduce text-based programming language (NXC – Not eXactly C).
- To explore the details of sensor mechanics and programming.
- To encourage project planning.

STUDENT EVALUATION METHOD

Duan [14] conducted a survey of high school students on their future careers in science, engineering and technology to obtain their thoughts and perspectives, the survey results helped educators to enhance engineering education with a partnership between k12 and higher education. At college level, it is important to find out what are thoughts and perspectives of students about engineering programs?

At HCC, every semester students evaluate all classes they take by means of a nationwide student evaluation instrument, which helps instructors to improve teaching methods. To obtain college student assessment and feedback for specific robotics classes, in addition to the regular student evaluation, a special survey was designed and conducted just for all six EGR/SEM 110 Robotics I classes recently. A total of 80 completed student survey forms were received.

The author of this paper designed a survey instrument - one questionnaire for participating students with 13 questions as follows:

- What is your gender?
- What is your age?
- Are you a first-year college student?
- What is your major?
- Are you a full time/part time student?
- Why did you choose the robotics class?
- How much time do you prepare for the robotics class?
- Is Robotics I your first engineering class at college?
- Did you take a robotics class before?
- What is your career plan in the future?
- Do you want to take Robotics II after Robotics I?
- How well were you satisfied with the Robotics class?
- What are your comments/suggestions?

This survey took about 10 minutes to complete and the information that students provided remained anonymous and confidential. The survey was conducted at the end of the spring 2008 semester.

FINDINGS

The survey results are shown in tables 1 through 10.

- Gender of Students. Usually engineering classes have many more male students, but Table 1 shows the percentage of female students reached 40%. It means a strong interest and decent participation rate of female students in the Robotics class.
- Age of Students. Table 2 shows a wide distribution of age for students taking Robotics classes from very young to old students. About 1/3 (32.5%) were below 20; however, more students were in the range of 20 to 30 (37.5%). It seems that most students took the Robotics class at age 19 (20%) or age 20 (15%). In addition, middle-aged students and older students also took Robotics class.

Table 1. Characteristics of Participants by Gender

Gender	Number	Percentage
Male	48	60.0%
Female	32	40.0%
Total	80	100.0%

Table 2. Characteristics of Participants by Age

Age	Number	Percentage
Below 20	**26**	**32.5%**
17	1	1.3%
18	9	11.3%
19	16	20.0%
20	**12**	**15.0%**
Above 20	**42**	**52.5%**
20-30	30	37.5%
30-40	6	7.5%
40-50	4	5.0%
50 or Higher	2	2.5%
Total	80	100.0%

- Years at College. Table 3 shows 43.8% were first-year students at the College. It is good for them to take the Robotics class to gain experience in engineering at the beginning. The most students were at the College for 2 years (22.5%) or 3 years (21.3%) when they took the Robotics classes. Fewer students stayed for only one year (2.5%) or more than 5 years (3.8%).
- Student's Major. Table 4 shows a variety of majors. Business and Liberal Arts were the top 2 accounting for 32.5% and 23.8% respectively.
- Student's Status. Table 5 shows that more than 3/4 were full-time students (76.3%), while part-time students were less than 1/4 (23.7%).

Table 3. Characteristics of Participants by Years at College

		Years At College For Non-First Year Student				
	First Year Student	1	2	3	4	5 or above
Number	35	2	18	17	5	3
Percentage	43.8%	2.5%	22.5%	21.3%	6.3%	3.8%

Table 4. Characteristics of Participants by Major

	Business	Lib. Arts	Humanities	Science	Engineering	Communication	Criminal Justice	Computer Science	Other
No.	26	19	2	3	6	4	7	3	10
%	32.5%	23.8%	2.5%	3.7%	7.5%	5.0%	8.8%	3.7%	12.5%

Note: "Other" includes-Visual Arts 2, Music 1, Theater 1, Education 1, Food Administration 1, Not Indicated 4.

Table 5. Characteristics of Participation by Status

Status	Number	Percentage
Full-Time	61	76.3%
Part-Time	19	23.7%
Total	20	100.0%

- Student's Intention. Table 6 shows a variety of reasons why students take Robotics classes. It is significant that more students (45%) took Robotics classes due to recommendations from other people. Continuing, the next 2 reasons were "Interests" (33.8%) and "Science Request" (32.5%) considerations.

Table 6. Characteristics of Participation by Student's Intention

	Science Request	Interest	Someone Recommended	Engineering Career	Other
Number	26	27	36	7	4
Percentage	32.5%	33.8%	45.0%	8.8%	5.0%

Note: Some participants chose more than one choice."Other" indicated: 1-Learning Disability replacing math, 1-combined lab & lecture, 1-program elective, 1-need lab other than biology

Table 7. Characteristics of Participants by Student's Preparing Time per Week

	3 hours or less	4 hours	5 hours	More than 5 hours
Number	59	9	6	4
Percentage	75.6%	11.5%	7.7%	5.1%

Note: Two participants did not respond to this question.

- Preparation Time. How much time do students need to prepare for the Robotics class? Table 7 indicates that the majority of students (75.6%) spent 3 hours or less per week; about 20% of students spent 4 to 5 hours, and 5.1% of students spent more than 5 hours per week in preparation.

Table 8. Characteristics of Participants by Student's Career Plan

For a Bachelor Degree				
	Transfer to UMass	4-Year State College	Private University	Find a Job
Number	23	34	9	14
Percentage	28.8%	42.5%	11.2%	17.5%

Table 9. Characteristics of Participants by Student's Background

	Took Robotics in High School	Took Robotics in Other College	Robotics I as 1st Engineering Class	Want to Take Robotics II
Number	5	3	76	42
Percentage	6.3%	3.8%	95.0%	52.5%

Table 10. Characteristics of Participants by Student's Satisfaction

	Very Satisfied	Satisfied	Moderately Satisfied	Slightly Satisfied	Unsatisfied
Number	60	12	6	1	1
Percentage	75.0%	15.0%	7.5%	1.3%	1.3%

- Student's Career Plan. Table 8 indicates several choices for students' careers. Significantly, the majority of students (82.5%) planned to go to a 4-year college or university for a Bachelor's degree, while only 17.5% of students wanted to find a job. Due to a strong connection and transfer partnership, over 1/4 (28.8%) of students planned to go to the University of Massachusetts, and 42.5% would go to other 4-year state colleges. Meanwhile, about 1/10 (11.2%) chose to attend a private university.
- Student's Background and Desire. Table 9 shows that the majority of students (95.0%) took Robotics I as their first engineering class at college, while a few students had already taken a Robotics class either at another college or in high school. As an important finding, more than half the students (52.5%) wanted to take Robotics II course.
- Student's Satisfaction. Table 10 indicates that the majority of students (90.0%) were satisfied with the Robotics class (in particular, 75.0% were "very satisfied"). Also, students gave very good comments on the attached "comment" sheets. It is clear that students enjoyed the class very much. In addition, each semester there were a couple of disabled students taking Robotics classes. The faculty and technicians provided them with the necessary accommodations and assistance for these students to participate. These disabled students expressed their satisfaction and enjoyed the Robotics classes.

DISCUSSIONS AND CONCLUSIONS

In this paper, the development of educational robotics programs in higher education is reviewed first, and the Robotics classes and the assessment procedure at Holyoke Community College are introduced; then the survey results are reported. At this point, the following discussions and conclusions may be made:

- **Success of Robotics Courses.** The Robotics classes at HCC have been very successful in terms of rapid growth and significant enrollment. Currently, the Robotics classes are very popular on campus. Many students have taken the Robotics course because of recommendations from other people due to the quality and reputation of the classes.
- **Positive Student Learning Assessment.** The majority of students rated the course as "very satisfied." In addition, 45 students provided comments and suggestions. All of the comments were positive. For example, some students said "I think this class was a favorite. Plus, the professor made the course very satisfying and fun. I would take another robotics class." "This class is fun and hands-on. It is challenging. It makes you think and problem solve." "Very fun and challenging at the same time." "Robotics was fun. I learned a lot of scientific things." "Really great class. I would recommend it to anyone." "I had great time learning about robots." "I really enjoyed this class because it allowed me to be creative in a setting I wouldn't normally find myself in." "Excellent class." "Offer more Robotics courses so more people can join the class."
- **Objective Achievement.** The purpose of the Robotics courses at HCC is to provide a construction and design oriented laboratory class for non-engineering majors for transfer purposes. In the regular student evaluation, students gave Robotics instructors very positive assessment; one of full-time faculty member who teaches the Robotics course was at the top 20% ranking of the student evaluation. This special designed survey found un-

covered important facts and valuable information based on the Robotic course. Significantly, this study found that the objectives and goals of the Robotics course have been achieved. Additionally, the survey indicated that nearly half of students taking Robotics 1 were first-year students, and the majority (95%) took this Robotics course as their first engineering class, which would help them to learn engineering and gain experience in the engineering field. Most importantly, the majority of students (82.5%) would go to a 4-year college or university for a Bachelor's degree, and this Robotics class could be a required science/engineering laboratory piece as a part of their transfer credits, which would benefit their career development.

- **Demands of New Robotics Courses.** The survey found that more than half of students wanted to take more Robotics courses. Therefore, in order to meet the students' requests, the Robotics curriculum should be advanced and more Robotics courses need to be developed.
- **Upgrading Equipment.** Valuable suggestions were obtained from the students. Several students suggested: "getting new equipment for future students." "It seems the equipment is getting old and unreliable. Perhaps an upgrade should be considered." Obviously, it is a challenge for faculty and staff to upgrade the equipment or obtain new equipment with the limited funding and resources available. All of the feedback and suggestions are very helpful to educators in advancing the Robotics curriculum.

References

01. RoboNexus Robotics in Education Conference, October 6-9, 2005, San Jose Convention Center, California. Available at: http://www.robonexus.com/educationconf.htm (December 16, 2008).
02. Sklar, E., Parsons, S. and Azhar, M.Q., "Robotics Across the Curriculum," Robotics and Robot Venues: Resources for AI Education: AAAI 2007 Spring Symposium, Harvey Mudd College Website. Available at: http://www.cs.hmc.edu/roboteducation/ (January 12, 2009).
03. Kumar, A.N., "Three Years of Using Robots in the Artificial Intelligence Course-Lessons Learned," Journal on Educational Resources in Computing (JERIC), Special Issue on Robotics in Undergraduate Education, Part 1 4(3), 2004. Available at: http://phobos.ramapo.edu/~ amruth/r/jnls/jeric/05/paper.pdf (January 13, 2009).
04. Schafer, J.B., "Hands-on Artificial Intelligence Education Using Lego MindstormsTM: Lessons Learned," Proceedings of the 33rd SIGCSE Technical Symposium on Computer Science Education, 2004. Available at: www.cs.uni.edu/~schafer/publications/MICS_2004.pdf (January 13, 2009).
05. Hasker, R.W., "An Introductory Programming Environment for LEGO MindStormsTM Robots," Midwest Instruction and Computing Symposium 38th MICS, April 8-9, 2005, University of Wisconsin - Eau Claire, WI. Available at: www.cs.uwec.edu/mics/CD%20image/papers/papers87.pdf (January 13, 2009).
06. Beer, R.D., Chiel, H.J. and Drushel, R.F., "Using Autonomous Robotics to Teach Science and Engineering," Communications of the ACM; June 1999; 42(6). ABI/INFORM Global pp. 85. Available at: www.robot-hosting.com/academic/autonomous-robot-teacher.pdf (January 13, 2009).
07. Maher, R.C., Becker, J., Sharpe, T., Peterson, J., and Towle, B.A., "Development and Implementation of a Robot-based Freshman Engineering Course," Proceedings of American Society for Engineering Education Annual Conference & Exposition, 2005. Available at: http://www.coe.montana.edu/ee/rmaher/ee101/ECEbot/asee_robot_maher_revised.pdf (January 20, 2009).
08. Imberman, S.P., and Zelikovitz, S., "Robotics as a Component of a General Education Course," American Association for Artificial Intelligence, 2007. Available at: http://www.aaai.org/Papers/Symposia/Spring/2008/SS-08-08/SS08-08-010.pdf (January 20, 2009).
09. Pikulsky, J., "The Sky's the Limit for New Robotics Program," Pittsburgh Tribune-Review, Sunday, November 20, 2005. Available at: http://www.pittsburghlive.com/x/pittsburghtrib/s_395442.html (January 12, 2009).
10. News - Borough of Manhattan Community College: "BMCC Receives a $191,584 National Science Grant to Fund Educational Robotics," August 6, 2007. Available at: http://www.bmcc.cuny.edu/news/news.jsp? (December 11,2008).
11. Des Moines Area Community College Teaches Robotics. Available at: http://www.automation.com/content/fanuc-robotics-announces-des-moines-are… (December 11, 2008).
12. Program of Study, Robotics Integrated Manufacturing, Terra Community College-Robotics. Available at: http://www.terra.edu/academics/Robotics.asp (October 27, 2008).

13. Holyoke Community College Format for New Course Proposal, Robotics: Exploration in Construction and Design, August 2002.
14. Duan, X.R., "Survey of High School Students on Their Future Careers in Science, Engineering, and Technology: A Case Study of Partnership," Proceedings on International Conference for Engineering Education and Research 2007, Melbourne, Australia, December3-6, 2007. Also, Innovation 2009: World Innovations in Engineering Education and Research, edited by Aung, W. et al., iNEER, Arlington, VA, August 2009.