Experiences in Developing a Robotics Course for Electronic Engineering Technology

Dr. Antonio Jose Soares, Florida A&M University/

Antonio Soares was born in Luanda, Angola, in 1972. He received a Bachelor of Science degree in Electrical Engineering from Florida Agricultural and Mechanical University in Tallahassee, Florida in December 1998. He continued his education by obtaining a Master of Science degree in Electrical Engineering from Florida Agricultural and Mechanical University in December of 2000 with focus on semiconductor devices, semiconductor physics, Optoelectronics and Integrated Circuit Design. Antonio then worked for Medtronic as a full-time Integrated Circuit Designer until November 2003. Antonio started his pursuit of the Doctor of Philosophy degree at the Florida Agricultural and Mechanical University in January 2004 under the supervision of Dr. Reginald Perry. Upon completion of his PhD, Dr. Soares was immediately hired as an assistant professor (Tenure Track) in the Electronic Engineering Technology department at FAMU. Dr. Soares is conducting research in education (STEM), Optoelectronics, nanotechnology and robotics.

Dr. G. Thomas Bellarmine P.E., Florida A&M University/Florida State University

Biography Dr. G. Thomas Bellarmine Professor Florida A&M University Tech. Bldg. B, Room 202 Tallahassee, FL 32307 850-599-868 (Office) 830-561-2739(fax) gnanasigamani.bellar@famu.edu Dr. G. Thomas Bellarmine is currently working at Florida A&M University as Professor of Electronic Engineering Technology. He is currently teaching Electronic and Computer Engineering Technology Courses. He obtained his BSEE degree from Madras University and MSEE degree from Madurai Kamaraj University in India. He received his PHD in EE from Mississippi State University and M.S. in Computer Science from The University of West Florida. He is currently an IEEE Senior Member and a Member in ASEE. He is also a Registered Professional Engineer. His research interest includes power systems, energy management systems, and computer applications in communications.

Dr. Doreen Kobelo, Florida A&M University/Florida State University
Prof. Rabbani Muhammad, Florida A&M University

Rabbani Muhammad AIA NCARB, Reg. Architect Rabbani Muhammad Architects AIA. NCARB 1801 Meridian Rd Suite B Tallahassee, Fl 32303 r.muhammad @att.net rabbani.muhammad@famu.edu Cell 850-264-5268 Education:

Pennsylvania Institute of Technology, AAD Arch, Industrial Structural Design, Eng. Technology Howard University, Washington D.C. B. Arch Harvard University, Cambridge, Mass. M. Arch Mass. Institute of Technology Pennsylvania Institute of Technology A.Dp Eng.Tech; Industrial Structural Design; Architectural Design

Teaching Experience:

Maryland Institute of Technology Illinois Technical College Temple No.2 Adult Education Classes Umm Al- Qura, College Of Engineering, School of Islamic Architecture, Kingdom of Saudi Arabia Florida A&M University, College of Engineering, Sciences, Technology and Agriculture Project Area Coordinator, Construction Engineering Technology Florida A&M University College of Architecture, Master Thesis Reviewer

Academic Administration:

Interim Director of Division of Engineering, CESTA 1996-98 Program Area Coordinator, Construction Engineering Technology

Related Membership Organizations:

American Institute of Architects National Council of Architectural Registration Board National Historical Preservation Society Alpha Rho Chi National Architectural Fraternity Alpha Phi Omega National Service

Fraternity Kappa Alpha Psi National Social Fraternity National Alliance of Black School Educators National Black Engineers Society

Licenses to Practice Architecture:

Washington D.C. State of Illinois State of New York State of Pennsylvania State of Florida

Awards:

Teacher of the Year, Florida A&M University, Division of Engineering Technology, College of Engineering, Sciences, Technology and Agriculture 1993, 1994 and 2000 Zeta Educational Thespian Association Design Award Kopper Corporation Design Completion Design Award, 1st Place

Research Travels:

Mexico City, Mexico Dakar, Senegal Edmonton, Canada Lagos, Nigeria London, England Santo Domingo, Dominican Republic Paris, France Nassau, Bahamas Roma, Italy (Guest of Pope John Paul II) Amsterdam, Netherlands Athens, Greece Lisbon, Portugal Istanbul, Turkey Seville, Spain Makkah Al- Mukarama, Kingdom of Saudi Arabia (Hajj 1982, 1988, 1996) Beijing, China Jakarta, Indonesia Accra, Ghana Cairo, Egypt Lome, Togo Munich, Germany Brussels, Belgium Jeddah, Kingdom of Saudi Arabia Addis Abba, Ethiopia United Arab Emirates Rabbani Muhammad Architects Design Projects Overview

Housing Project Current Planning Stage:

23 unit housing sub-division, Nashville, Tenn. (Design) 11 unit hosing sub- division, Saluda, South Carolina (Design) 30 assistant living facility units, Definaick Springs, Fl. (Design)

Completed Planning and Approval Stage Projects:

24 – Three –bedroom town homes, Markham, Illinois (Design)

Completed Renovation Projects:

Shabazz Cluster Housing 39 units Harlem, New York (Design) Washington D.C In-fill sites 100units (Design) 58 units Housing for the Elderly, Greenville, South Carolina (Design) Many single family units

Completed New Housing Units:

124 units mixed use housing project Lincoln Ave Apartments, Chicago, Ill (Design) 12 units -Student Housing Apartments, Tallahassee, Fla. A&M University (Design) Shabazz development Housing 40 three family town homes, Harlem, NY (Design and Project Administration)

Projects Under Design/ Construction Stage:

Graceline Condominiums 104 West 116th Street 58 units w/ Commercial (Design) Booker T Washington Shopping Plaza, Chicago, IL Columbus, Ohio, Afro-American Basketball, Museum and Educational Center

Large Scale Projects International:

1996 Kingdom of Saudi Arabia: Madinah New town, a community that is composed of 1100 signal family housing units. These units where built with 3-bedrooms, 2.5 baths, living, dining and kitchen. Also, included in this project were commercial, retail and security buildings. A major play areas where placed throughout the internal park system. (Design and Construction Management) Madinah, KSA Sk. Fausi Tafik Villa, Makkah, KSA Sk. Aggah Villa, Makkah, KSA

Preservation Projects:

Matilda Mosley House (Zora Neal Hurston Residence) Eatonville, Fl. Design and Construction and management) Malcolm Shabazz Masjid Preservation Project

Religious Projects:

National Primitive Baptist Convention Multi- Purpose Building and Memorial Park, Huntsville, Al (Present) St. Johns MEB Educational Facility, Tallahassee, Fl. 1997 St. Paul's AME Church Addition, Tallahassee, Fl 2004 Antioch AME Church Addition, Quincy, Fl 1995 Masjid Al-Nalh, Masjid Addition, 2007

Munree Cemetery Planning and Design, Tallahassee, Fl

Hotel Projects:

Days Inn Renovation, Tallahassee, Fl Scottish Inn Hotel, Jacksonville Fl. Days Inn Renovation, Live Oak, Fl Dutch Inn Renovations and Addition, Tallahassee, Fl

Food Preparation Projects:

Ferrell Restaurant Renovation, Tallahassee, Fl 2006 L'Jau's Restaurant Renovation, Albany, Georgia 2007 Halal Abattoir, New Plant, Jackson County, Fl 2000 Ferrell Ice Cream Shop, Tallahassee, Fl 2005 159th St Shopping Center, Markham, Ill 2005 Banquet and Social Hall, Prince Georges County, Md 2007 Got Fish Fast Food Restaurant, Chicago, Ill

Medical Facility Projects:

200 Bed Hospitals, Kingdom of Saudi Arabia, 1987 100 Bed Hospitals, KSA, Arar, KSA 1986 Southeast Medical Clinic, Washington D.C. 1973 Doctors Office, Pioneer Building, Chicago, II 1976 Glover Dental Offices, Albany Georgia, 2006

Urban Planning and Design Projects

14th Street Urban corridor, Washington D.C Anacostia Southeast Washington D.C. Plan 8th Street Corridor Washington D. C. Harlem, New York 116th Street and Malcolm Shabazz Blvd. Revitalization and Restoration Plan East New York High School, Planning and Design, Brooklyn, New York Calvert County High School, Planning and Design, Calvert County, Maryland

Community Service:

Religious Advisor Volunteer from 1970 to Present to the following Departments of Corrections Florida Department of Correction Death Row Inmates, Lecturer Mass. Department of Corrections, Education Virginia Department of Corrections, Lecturer Federal Department of Corrections, Lecturer

STEM Educational Project Papers ASEE paper on the STEM Summer Educational Institute in Magnolia Terrace, Tallahassee, Fl ASEE paper on co authored a Paper in Robotics in the Building Design

Dr. Chao Li, Florida A&M University

Dr. Chao Li is an assistant professor in Electronic Engineering Technology at Florida A&M University. He teaches electronic and computer engineering technology courses. He obtained his B.S.E.E. degree from Xi'an Jiaotong University and M.S.E.E. degree from the University of Electronic Science and Technology of China. He received his Ph.D. in E.E. from Florida International University. He is an IEEE senior member and an ASEE member. His research interests include signal processing, biometrics, embedded microcontroller design, and application of new instructional technology in classroom instruction.

Dr. Salman A. Siddiqui, Florida A&M University

Salman A. Siddiqui received his B.S., M.S. and Ph.D. degrees from Florida State University, Tallahassee, FL, from the FAMU-FSU College of Engineering in the field of Electrical Engineering in 2000, 2002, and 2012, respectively. The M.S. degree was in the field of communications while the Ph.D. degree was in the field of Robotics. He has a passion to teach and to make it interesting and simple for students to advance in the field of Electrical/Electronic Engineering and STEM in general. He has been teaching as an adjunct Professor at the FAMU Electronic Engineering Technology program since 2010.

Mr. Stacy Tinner

Experiences in Developing a Robotics Course for Electronic Engineering Technology

Developing a robotics course for an engineering technology program has proven to be a challenge. Most textbooks and/or robotic programs are designed for engineering programs. As such, there is a great deal of mathematical modeling and analysis which is not fitting for a technology curriculum. At the other end of the spectrum, there are a myriad of low level robotics based curriculum such as the LEGO or the Parallax Boe-bot robot platforms. These are normally used in K-12 educational and summer programs. This paper presents the process of developing a suitable robotics course for electronic engineering technology program (EET). We first present the challenges encountered when developing the course content to suit the engineering technology curriculum. The curriculum content for both classroom lecture and laboratory sections are then discussed. A discussion of competition-based projects designed to enhance and gauge the overall understanding of the course material is then presented. Finally, initial efforts to make the course an interdisciplinary course are discussed.

Challenges

The initial steps in designing this course were to conduct research on existing technology programs offering similar courses. There are several programs offering robotics course which are designed for electrical engineering, manufacturing and/or Mechatronics. Most of these courses emphasize modeling of robotics motion, controlling actuators and machine programming techniques such as Computer Numerical Control (CNC) [1, 2]. The modeling of motion using kinematics and reverse kinematics principles can be very involved and requires a great deal of matrices manipulation. This calls for the instructor to dedicate a great deal of time introducing or reviewing mathematical principles such as vectors, dot product, cross product, matrices, etc. In order to follow a manufacturing curriculum, one must have some infrastructure to implement the laboratory which our institution does not own at this time. On the other hand, there were many courses and summer programs on robotics which make use of robotic kits such as the LEGO MindStorms. The curriculum is normally designed for K-12 students and short summer programs. The issue with these curriculums is their simplicity. The same trend was observed when researching for books to be used for the robotics course [1, 2, 3, and 4]. There wasn't a middle ground which would be suitable for an engineering technology program. On one hand we have complex curriculums and on the other simple curriculums. The solution was to make use of information from the upper and lower level and create a new curriculum which is balanced and adequate for our program.

Curriculum

It is imperative that the course educational objectives correlate with our program goals and the Accreditation Board for Engineering and Technology (ABET) educational outcomes. In addition, when designing the curriculum, existing courses that may serve as pre-requisites must be taken into account. This will ensure that course content doesn’t become redundant and helps in designing course topics. Some courses that correlate with this new course include C Programming, Circuits Design, Controls, Instrumentation, Electronics Design and Digital Electronics. Based on these factors, comprehensive course description was developed and reads as follows: “The Introduction to Robotics and Automation course introduces students to the fundamental concepts of robotics, automation and Mechatronics. Students will learn how to design robots using a Mechatronics approach. Principles of mechanical systems, electronics, and programming as applied to the design, building, and mobilization of autonomous robots. Topics include microcontrollers, actuators, sensors, communication systems and interfaces, and programming using the Parallax Boe-Bot Robot. In addition, students are briefly introduced to industrial robot modeling and programming using CNC Technology. Experiments using the RS-55 industrial robot arm will reinforce the theory introduce in class”.

Course Objectives and Outcomes

The course is structured into a three credit hour lecture and a one credit hour laboratory. The lectures included conventional power point presentations and in class demonstrations. In the laboratories students implemented concepts learned during the lecture. The content of the lecture was set in a progressive fashion so that the construction of the laboratory platform coincided with the topics being discussed in the lecture. By mid semester the platform was complete and additional peripherals such as the different type of sensors, motor drivers, controllers and displays were added as the theory behind them was being introduced in the lecture.

The overall objectives of the course were:

- To understand the process of robotics design, modeling and programming
- To understand the main component of a robot and a robotic system
- To gain knowledge of different types of robots and their application
- To be able to design and program robots based on a set of specifications such as light, sound, and obstacles
- To gain some knowledge in robot kinematics and robot modeling
- To be exposed to Mechatronics design procedure and concepts
- Be able to complete projects individually and in group
- To gain critical thinking skills when making robot design decisions
- Be able to perform laboratory experiments using a robot kit
- Be able to write technical reports
- Be able to conduct research in innovative robotics topics for class presentation

Students were given weekly assignment and quizzes. Quizzes were given at the beginning of class to ensure students get to class on time. There were also group quizzes where students were given a problem to solve and then form groups to discuss with each other. Then a student from one of the groups came to the board and solved the problem. This method helped students that may have missed the concepts and also ensured that the students were working in the group.

Upon successful completion of the course, students were able to:

- Describe the history and evolution of robots
- Describe the fundamental components of a robotic system
- Demonstrate knowledge in principles of automation and industrial robot systems
- Explain the basic principles of robot motion and kinematics
- Identify different types of robots and their applications
- Explain the science of Mechatronics
- Explain the operation of light, touch, and rotation sensors that are used in robotics.
- Describe the operation and application of microcontrollers.
- Develop computer programs used to control robots
- Build and test robots using a specific platform
- Participate in team projects to compete with other design teams
- Develop and maintain a team webpage to share information

Course Content

To achieve the course goals and due to the limited amount of time in a semester, the Parallax Boe-Bot robotic kit platform was selected. Figure 1 depicts different kits. The main reason for selecting this kit was the fact that the instructor had several sets available and is suitable for demonstrating basic robotics principles. The course content was divided into four main parts: (1) Mechanical; (2) Electrical; (3) Microcontroller and Software; and (4) Automation and Mechatronics.

Figure 1 The Parallax Boe-Bot Robot Kit

The mechanical portion of the course covered topics relevant to the design of a robot and introduced some related physics and mathematics topics. We started by studying different types of materials for building robots based on applications. When designing a robot the type of material can make a big difference when it comes to energy consumption and functionality. We then introduced simple machines such as inclines, levers, pulleys, and springs. In this portion of the course several physics concepts are introduce. Some of these include mass, weight, force, torque, spring physics, velocity and acceleration. In addition, some mathematical topics, such as trigonometric functions, are discussed.

The electrical module of the course was designed based on the enrolled students' background. All enrolled students were in a junior level. As such, they had been exposed to most of the electrical principles needed to design and understand a robotic system. However, a brief review was needed on basic topics such as electrical charge, current, voltage, resistance, Ohm's Law, and voltage and current division. In a higher level, diodes, transistors and OPAMPS were discussed. Several relevant circuit configurations were presented in great details. These included diode voltage regulators, transistor switches and drivers, OPAMP inverters, summers and amplifiers. Other electrical components specific to moving robots were also discussed. Different types of motors (AC, DC, Stepper, and Servo Motors), their functionality and application were presented. Mechanical, electrical and optical sensors were also discussed in great detail. They included the whisker, infrared, sonar, and phototransistor sensors.

General principles of microcontrollers are introduced. Although several microcontrollers are discussed, the one used by the Boe-Bot platform is discussed in depth as it is the one used in laboratory experiments. Topics include types of memory, interfacing, and analog and digital signals. The Parallax Boe-Bot Robot uses the BASIC Stamp 2 module shown in Figure 2[5]. Over the years several versions (BS2, BS2 OEM, BS2sx, etc.) of the module has evolved. The difference among these modules includes upgrades on memory, speed and additional features. The module used in this course is the BASIC Stamp BS2 Module.

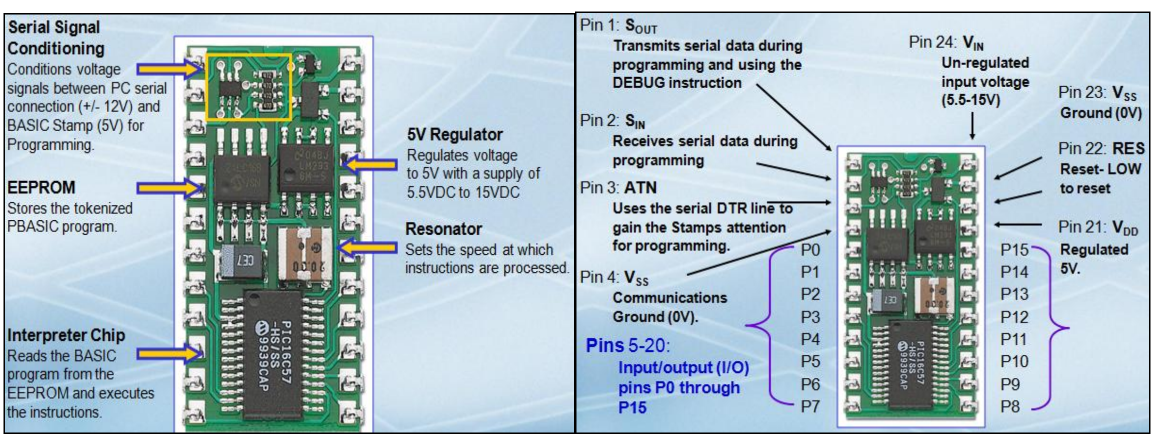

Figure 2 BASIC Stamp 2 Module with components (shown on left) and I/O Pins (on right)

The BASIC Stamp is programmed in **PBASIC**, a version of BASIC programming language. The BASIC Stamp is programmed using a free software package, BASIC Stamp Editor. Code is written in the editor and downloaded to the BASIC Stamp [4, 5].

The BASIC Stamp can be used on a variety of **carrier boards**, used for programming and testing. The board makes it easy to connect a power supply and programming cables to the BASIC Stamp module and makes it easy to build circuits to be connected to the BASIC Stamp module to perform a variety of functions. The most popular carrier boards used to support the BASIC Stamp are the Board of Education (BoE) and the HomeWork Board (HWB) which are depicted in Figure 3. The HWB has the module integrated into it while on the BoE the module is mounted on an IC and can be removed and replaced [5, 6]. The Boe-Bot uses the BoE carrier board.

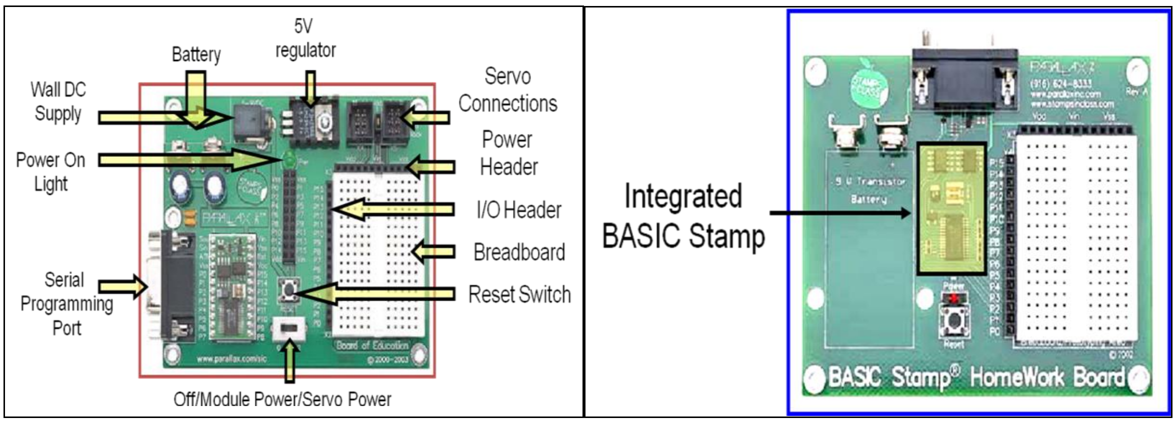

Figure 3 Board of Education (Left) and the HomeWork Board (Right)

In the early stage of the course this stand alone embedded system was used in laboratory experiments to illustrate concepts related to robotics. Table 1 shows a set of hands on exercises that were performed using the board.

Table 1 Exercises Performed with the Board of Education

Exercise	Deliverables
Intro to BASIC Stamp Software	Install the Software, Write basic programs, use the Debug Terminal display messages, Perform simple arithmetic, ASCII code
Simple Indicator Circuits	Build and test LED circuits, Build LED circuits as event indicator, Controlling LED ON/OFF Cycles
Digital Control Inputs	Build Pushbutton circuits, Control LED circuits using pushbuttons, initiate events using pushbuttons
Frequency and Sound	Build speaker circuit, use speaker circuit as a start and battery indicator, creating melodies
Seven Segment Display	Use the board to control a seven segment display circuit to display digits

The lecture related to these experiments were an introduction to the PBASIC language, a review of resistors, diodes, circuit configurations, current and voltage, digital versus analog systems, and general seven segment display configurations. Due to the limited amount of time and the expected outcomes of the course, students were introduced to the basic concepts and through assignment were expected to build upon them in order to perform the hands on portion of the course.

The Boe-Bot

Once the microcontroller principles were introduced, the course moved towards building and programming the Parallax Boe-Bot Robot. The kit contains all components necessary to construct the robot: aluminum chassis, servo motors, battery case, wheels, and the needed screws and washers. In addition, there are number of sensors such as whisker and infrared. Additional components were provided by the instructor when necessary. Once the board of education is added to the chassis, the servos can be controlled for motion and sensors can be added to achieve specific tasks. Figure 4 depicts the Boe-Bot Robot after all components are added.

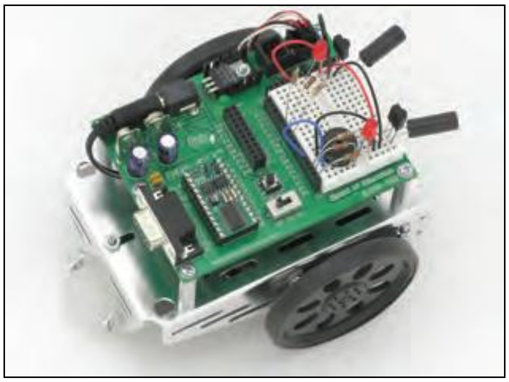

Figure 4 Assembled Boe-Bot Robot with Sensors

This platform can be used for laboratories and projects. Table 2 depicts a list of exercises carried out in the laboratory using the Boe-Bot Robot.

Table 2 Exercises Performed with the Boe-Bot Robot

Exercise	Deliverables
Boe-Bot Servo Motors	Assemble Boe-Bot, Center Servos, Servos control
Boe-Bot Navigation	Forward, Back, Right, left and Stop, Speed control
Navigation with Touch Sensor	Build whisker circuit, Control the Boe-Bot Motion using whisker, decision based on sensor conditions
Navigation with IR Sensor	Build IR circuit, Control the Boe-Bot Motion using whisker, decision based on sensor conditions
Sensing Light	Build Photo resistor circuit, Control the Boe-Bot Motion using whisker, decision based on light conditions

Course Projects

There were three projects assigned to the students. Two were individual projects and one was a group project. In all projects there were a set of specifications given and the students were to build and program the Boe-Bot to these specifications. There was then a competition and a technical report submitted by the group and/or individual students.

In the first project, students were to design a simple robot to follow a trajectory which is shown in Figure 5. When the robot reaches the end it will perform a victory dance and flash LED in a specific pattern. Projects were evaluated based on accuracy, time taken to complete task, a final dance routine and flashing LED at the end of each round.

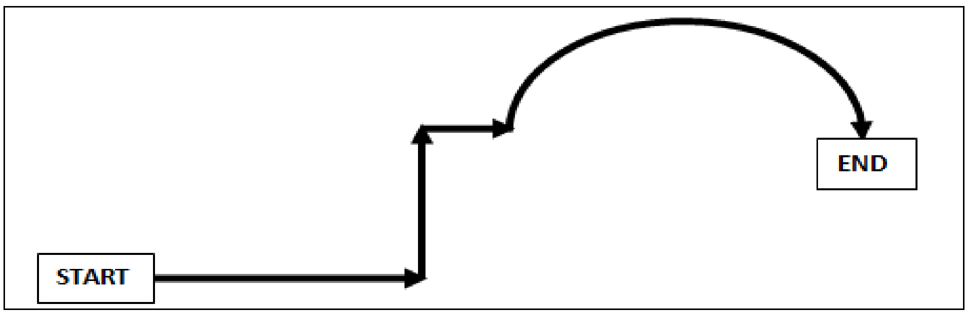

Figure 5 Project 1 Trajectory

For the second project, students were to work on three different cases. The students were to work on the project individually. Each case was assigned to three students. They would then compete amongst themselves and each student was to write a technical project report. Figure 6 shows some of the captured projects images. The groups and cases are as follows:

- CASE 1: Design a Robot to move from Point A to B while avoiding obstacles in its path.
- CASE 2: Design a Robot to move on top of a table without falling off (the table has black tape around the edges).
- CASE 3: Design a Robot that will follow the robot in front of it.

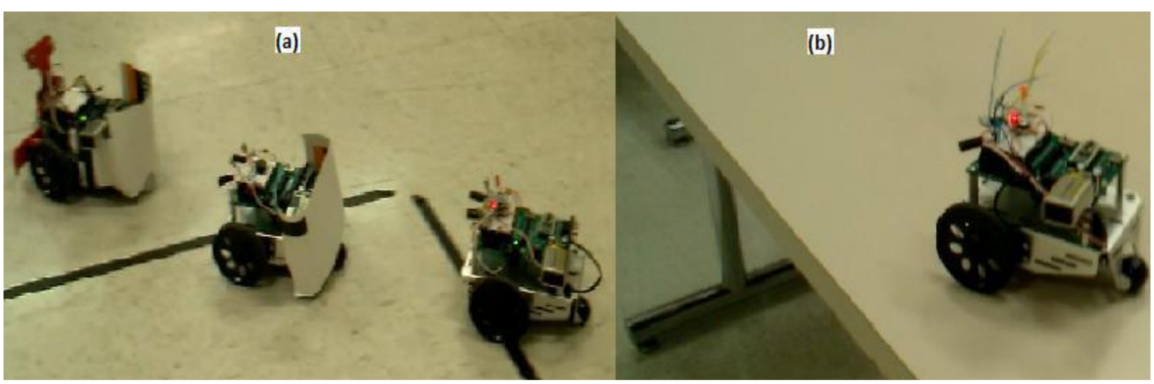

Figure 6 Projects: (a) Following robots in front (b) Move on top of a table without falling

The third and final project was geared towards the annual IEEE SoutheastCon Hardware competition. In this competition students from the southeastern region of the US compete to determine which school will perform best on a set of requirements and rules given by the host university. The objective of this year's competition was to simulate the sorting of containers and packages on a port. Different colored and sized boxes were to be picked up and sorted for shipping either by rail, sea or air[7]. This was a group project. Each group was given a task related to the hardware competition. The students had to use the Boe-Bot platform to demonstrate that their project worked properly. Additional component, such as sensors, had to be provided to the students for certain tasks. The group tasks were as follows:

- Group 1: Use color sensor to determine the color of the blocks and their locations
- Group 2: Devise a method to move and distinguish the blocks by size
- Group 3: Determine robot location on the field and avoid obstacles
- Group 4: Go up a ramp using a tilt sensor to compensate motion (of moving up the ramp) while avoiding falling off

The module of the course dedicated to automation and Mechatronics were not presented in depth due to time limitation. However, general concepts were discussed and students were exposure to an industrial robot arm seen in Figure 7. Topics in this module included degree of freedom, Kinematics, and CNC. The instructor demonstrated how the robot arm can be programmed to perform repetitive tasks.

Interdisciplinary Integration

The engineering technology program at our institute comprises of electronic and construction engineering technology. The goal is to develop this course with these innovations in mind. There will be gradual introduction of building and construction into the course and its derivatives. In construction related fields, building systems requirements in the future will be mandated by codes and law to perform at an optimum efficiency to counter the effects of global warming on the climate.   The use of robotic responsive systems will play a major impact in the way building equipment is planned, designed and operated. The educational requirements to educate competent engineers and technologist will demand a new curriculum approach as well as integrated teaching approaches.

The future engineers and technologist will have an educational experience that would expose the nature of future applications in the areas of electro-mechanically-robotic building systems (EMRBS), distributed energy resources, building envelopes and mechanical ventilation systems able to detect chemical/biological/radiation (CBR) safety, facility performance evaluation, and professional team building. Educational curriculum that integrates robotic program topics, if not classes, will be essential in educating future electronic engineers and technologist to coexist and excel in robotic design and application.

Conclusions

The implementation of the robotics course for the Electronic Engineering Technology program presented some challenges when designing an adequate course curriculum. It was necessary to reconcile teaching material from different sources. After determining the course content, a suitable hardware platform to implement the theory presented in class lectures was considered. Time constraints limited the amount of material covered at the end of the course. There are plans to modify this course to fit an interdisciplinary student body. Construction Engineering Technology and Computer Sciences are the areas to be included in the future. The course was a success as it relates to the students' experience and knowledge gained. It served as a way for students to integrate their knowledge. The passing rate was 100% for both course and laboratory. An end of semester course evaluation and survey showed that the students found the course to be very useful and would recommend the course to other students. The main observation from students was the ability to integrate their knowledge of electronics into applicable robotics projects. The projects were directly tied to the course theoretical lectures. Topics discussed during lectures are implemented and reinforced via projects. This course was originally implemented as a special topic. Due to the positive feedback from students and high demand, efforts are on the way to create an official course which is in line with our continuous improvement portion of the accreditation process. Improvements include providing the robotics platforms for students instead of requiring students to purchase them; introducing pre-requisites that facilitate teaching robotics course, and to have a follow-up course.

Bibliography

[1] Williams Geoff, "*CNC Robotics, Build Your Own Workshop Bot*," McGraw Hill Companies, 2003.

[2] Kandray Daniel E., "*Programmable Automation Technologies: An Introduction to CNC, Robotics and PLCs*," Industrial Press, New York, 2010.

[3] Sahin Ferat and Kachroo Pushkin, "*CNC Practical and Experimental Robotics*," CRC Press, 2008.

[4] Wise Edwin, "*Robotics Demystified, A Self-Teaching Guide*," McGraw Hill Companies, 2005.

[5] Lindsay Andy, "*Robotics with the Boe-Bot, Student Guide Version 3.0*", Parallax Inc., 2003.

[6] Lindsay Andy, "*What's a Microcontroller, Student Guide Version 2.2*," Parallax Inc., 2003.

[7] IEEE SoutheastCon 2013, Hardware Competition Rules, Version 1, March 18, 2012, <http://ewh.ieee.org/reg/3/southeastcon2013/documents >