USING INTRODUCTORY ROBOTICS TO ENCOURAGE PROBLEM-SOLVING WITH PRE-SERVICE K-8 TEACHERS

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Abstract

This paper describes our ten year experience with a robotics theme in the capstone course for pre-service K-8 teachers specializing in science and mathematics. The course is structured as an interdisciplinary course with closely integrated science, computer science, and robotics labs leading up to an extensive, independent final robotics project. A hands-on and inquiry-based approach is used throughout the course. Both our own observations and the student comments lead us to the conclusion that the structure and methods employed in the course help to incrementally build student confidence throughout the course and to improve the ability of the students to independently solve problems that arise during the robotics project work.

Introduction

The Science and Mathematics for Elementary Education (SMEE) program provides a co-major for students majoring in Elementary Education at the University of St. Thomas. Every Elementary Education major is required to complete a second major. Since it is very difficult for a student to complete the requirements for a second major in one of the lab sciences, computer science, or mathematics in addition to the elementary education requirements, the SMEE major was created to allow students to complete a broad interdisciplinary major with a solid foundation in mathematics, computer science and lab science. The SMEE Capstone course, SMEE 359, is an interdisciplinary, theme-based course. There have been many versions of the course with many different themes. This paper describes our experience with using robotics as the theme for the capstone course.

The Lego Mindstorms Robotics System

Hardware

From the first offering of the robotics theme version of the course in the spring of 2001 until the present, the SMEE 359 course has always used a version of Lego Mindstorms. We began using the Lego Mindstorms Robotic Invention System in 2001 and migrated to the Lego Mindstorms NXT system in 2007. Both of the Lego Mindstorms versions are compatible with standard Lego parts and pieces and feature a computer “brick” that can be built into larger Lego robotic structures. In addition, there are compatible Lego motors and sensors for each version.

The original Lego Mindstorms Robotic Invention System was centered around the RCX yellow brick computer and display. The RCX unit had an IR interface that allowed programs to be downloaded to the RCX from the user’s computer and the IR port allowed multiple RCX units to communicate with each other. The RCX unit provided input ports for 3 sensors and output ports for 3 actuators. The actuators were either light bulbs/lamps or standard Lego motors. The available sensors included touch sensors, light sensors, rotation sensors, and temperature sensors. The actuators and sensors were connected to the RCX with standard Lego wires. A Lego digital USB web cam with “Vision Command” software was also available and usable with the RCX-based robots although the camera had to be tethered via the USB cable to the user’s main computer. The Robotic Invention System is intended to work with standard Lego bricks and Lego Technic pieces (for gears, pulleys, motors, etc.).

The newer Lego Mindstorms NXT sets are based on the NXT unit computer and display. The NXT unit communicates via USB for program downloads from the user's computer and has Bluetooth capability for communicating to other NXT units or other computers and Bluetooth devices. The NXT has 4 input ports for sensors and three output ports for the NXT servo motors. The provided sensors include touch sensors, light sensors, sound sensors, ultrasonic sensors, and rotation sensors built into the servo motors. The sensors and motors are connected to the NXT unit using heavy duty cables that have connectors similar to phone and network plugs. The NXT system is intended to work with the Lego beams, axles, and compatible connectors as well as standard Lego Technic pieces.

There are many programming languages and environments that can be used to create the software for the RCX and NXT computers.

Programming Environment

Even though there are many possible software solutions for the Lego Mindstorms robotics systems, we decided to use the programming environments provided with the Mindstorms sets. For our student population, the visual programming environments seemed particularly suitable. The original programming interface for the RCX units was a very logical and intuitive system of snapping functional blocks onto a start point to create the program. The functional blocks included power, on/off commands for the actuators, ifelse and loop constructs, and sensor blocks. The provided programming environment for the NXT system is also a visual programming interface built on the LabVIEW programming system. This programming environment is also visual and provides structures for loops and decisions, output to the motors, the speaker, the display and to Bluetooth devices, input from the NXT buttons, Bluetooth, and the sensors. With the structure of the course providing opportunities for the students to gradually build up their programming skills, both of these programming environments allowed our students to successfully create the necessary programs to control the robots for the robotics projects.

SMEE Program Requirements

The SMEE major requires that the student completes a set of requirements to ensure a solid foundation in each of the lab sciences, in computer science, and in mathematics. To this end, the student is required to take two math courses, "Mathematical Sampler" and "Structures of Elementary Mathematics", one computer science course, "Computers in Elementary Education", and one of a set of selected courses in each of Biology, Chemistry, Geology, and Physics. SMEE majors are also required to take two semesters of the SMEE Seminar to explore ways to apply college-level science to elementary and middle-school classrooms. In addition, SMEE majors are required to take at least two more courses in mathematics or computer science or one of the departments in lab science. This requirement is intended to provide a deeper understanding of the material in at least one of the SMEE content areas. Finally, SMEE majors are required to take the SMEE Capstone course. The capstone course is intended to be completed after the rest of the SMEE requirements have been completed so that it can build on the common foundation provided by the other required courses. The capstone course is a theme-based, interdisciplinary course that should provide a deepening of the student's knowledge in the disciplines related to the theme and show the interdisciplinary nature of the topic.

Multi-Discipline Nature of SMEE 359

SMEE 359 is taught as a "Capstone" course for elementary education majors with Science/Math as their emphasis. With robotics and computer science, the other discipline involved at UST is Physics. As students progress through various programming levels, we intersperse physics concepts as applied to robotics in the laboratory experience. Examples of the way in which the physics concepts and labs work together with the computer science and robotics topics will be described below. Because we meet with a fairly small-sized class (4 – 15 students) and because of the laboratory surroundings, we are informal, and communication, as problems develop and are solved, flows fairly easily. The instructors interact with the students as the students work to understand concepts and applications. The laboratory and "hands on" operation of the course and the fact that the students work in teams on all activities helps to encourage experimentation, questioning, and peer interaction.

Basic SMEE 359 Course Structure

First Half of the Course

The course syllabus (see Appendix 1) is constructed in a manner that intersperses Mindstorms robot building and programming with supporting physics laboratory activities. For the first half of the course, it is typical to introduce a physics concept in one lab session and follow-up by using that knowledge or concept with the Mindstorms robots in the next session. This organizational scheme breaks up the robotics work into small modules and pairs each robotics element with a relevant physical science topic.

A physics lab session often begins with a brief concept discussion to review a topic that was covered in the introductory physics course or to introduce a new physics topic that fits well with the next robotics unit. Each physics lab session asks the students to conduct an experiment, usually using some element of the Mindstorms Robotic Invention System. For each experiment, the students follow the usual physics lab process of recording the results and observations, analyzing those results and summarizing the lab by providing a lab write-up and answering follow-up questions. This work forms the basis for a discussion at the beginning of the next class and acts as a lead-in for the robotics work for the day.

A robotics lab session also often begins with a review of a concept covered in the Computers in Elementary Education course, a brief computer science concept discussion on something new, or a demonstration of a new programming element or a feature in the Mindstorms programming environment. A robotics lab will usually ask the student teams to build and program a robot to perform a task or set of tasks. Each of the initial robotics labs will usually focus on one sensor or one specific programming structure.

With a thread of concept development throughout, this structure supports student understanding by packaging the content into small conceptual units and builds student confidence by allowing the student to master (or succeed in accomplishing the goals for) each small package and building on what has come before. In addition, the students work on every lab and task in teams and the students must work together to successfully complete the task. This process prepares the students for independent work and problem-solving in the project portion of the course.

Final Project

The students in the robotics version of the SMEE Capstone course form teams and complete a robotics project. The project requires that each team build a fully autonomous robot that senses its environment and responds to changes in the environment. The robot must perform useful work and it must do something that would be similar to a "real world" robotics task. The robot must use at least two sensors. Throughout the ten years that we have done the robotics version of the capstone course, every team has created a robot that at least met the minimum requirements of the project and most have exceeded both those basic requirements and the expectations of the team members. (see Appendix 2 for an example project scoring rubric.)

Much of the second half of the semester is devoted to work time on the robotics project. The process begins with the students brainstorming ideas for useful tasks and functions that a robot or a robot team could perform. Often the students think of using robots to perform tasks that they would prefer not to do themselves like washing, drying, and folding clothes. Once the students have created lists of possible robot project areas, each student is asked to choose three favorite topics and elaborate on what would be involved in creating and programming a robot to accomplish that task. Each student presents her list of topics to the whole group and the group decides which topics hold the most interest for the group. The students rank order each of the final topics and the teams and the topics are determined by consensus. This process seems to give the students a commitment to the topic and ownership of the project. It is also true that a friendly competition occurs between the groups as the projects progress.

Encouraging Problem Solving

To test ideas prior to actual robot project designing and building, students were asked to perform several basic physical investigations as to certain properties and characteristics of the materials with which they would be working. These physical science sessions were either preceded by a Mindstorms robotics or computer science session that would motivate the desire to understand the physical concept or followed by a robotics or computer science session that would implement or test the physical science concepts.

Concept Development Cycles

In order to have students develop their understanding of concepts, the instructors:

1. Raised the question to be studied.
2. Asked students to propose their own related questions.
3. Asked students to propose methods of testing their ideas.
4. Counseled students as they continued with their testing.
5. Monitored students' as they developed their plans.
6. Reinforced students as they advanced in their process.
7. Encouraged students to log their solutions in a display of data so all could see and compare results.
8. Encouraged students to develop their solutions as data indicated.
9. Encouraged students to summarize and apply their results.

Examples of concept development and the pairing of the physical science concepts with robot building and programming

Building Structures Students were divided into teams and given an assignment to build a structure to hold a weight suspended horizontally away from the base. Their task was to build and design a cantilever structure using Mindstorms parts. The designs were tested by determining the maximum weight the structures would support at a distance from their base. Because structures become the basis of robotic devices, building structures for a specific purpose reinforces these skills. Team members interacted with each other to suggest solutions to problems and to share ideas for improving the structures.

This structures activity was preceded by a session where the group decided what the essential elements of a robot are (including a physical structure) and the students measured the performance of pre-built Mindstorms robot vehicles.

Work, Torque, Power Students were given the task of measuring torque supplied by a Mindstorms motor using a pulley and known mass. They also were given the task of measuring work output and power output of the motor by timing the lifting of known masses. Several robotic devices need to: propel themselves, lift masses, move objects from place to place, or exert forces, so having measured the outputs of the motor systems gives students some knowledge of what they can expect from the equipment.

These labs were followed by a robotics session where the students applied these concepts using gears and pulleys with the Mindstorms motors. The required tasks asked the students to build and program vehicles to meet differing goals such as maximizing speed, climbing and towing ability, and traction. The teams competed with each other to post the fastest run times or the steepest hill climb. Each team was allowed to incrementally modify the vehicles and the programming between runs to achieve an improved performance. The team members worked together and learned from the other teams as they solved problems that surfaced during the test runs. For example, every team working to increase the angle of the "hill" that was climbed eventually had to solve problems of spinning wheels and vehicles that flipped over backwards. Through discussion, argument, and trial and error, the teams always found ways to solve those problems by adding weight to the vehicle, modifying the center of gravity, and often the solution involved a cantilevered weight out over the front of the vehicle. This behavior showed the application of both the "work, torque, and power" labs and the "structure" lab.

Battery Output to Electrical Load Students were asked to measure current and potential of standard batteries by plotting "drawdown curves" for those batteries under load. Because the Mindstorm systems are all powered by batteries (mostly AA cells in series), the students could gain some understanding of how long the batteries can produce current under load, thereby gauging how their robotic devices useful "lifetimes" prior to battery replacement.

There are no specific robotics or computer science sessions that implement these concepts but the students quickly learn which robot activities (like Bluetooth communication) are the heaviest battery users and they design programs that will allow the robots to perform consistently as the batteries wear down.

Audio and Physical Range of Sound Sensors The Mindstorms sound sensors respond to a range of audio frequencies. They also respond to audio signals of a range of intensities or loudness values. Consequently, students were asked to try to ascertain these ranges by direct measurement using audio sources and by plotting frequencies vs sensor response.

This lab was followed by a robotics session in which the students were split into teams and asked to create robots that initiate an action in response to a sound at or above a specified level. In addition, the teams were asked to create and program a robot that would follow or go toward a sound. This is an interesting task and always results in the students trying to solve the problem of the sound of the robot's own motors interfering with the detection of the sound the robot should move toward.

Light Sensor Sensitivities and Wavelength Ranges The light sensors likely will respond to certain ranges of visible wavelengths of light. Students were asked to conduct investigations to measure these ranges. They also were asked to measure the sensors' response to illumination ranges of light sources.

The physical science sessions on the characteristics of light and the characteristics of the Mindstorms light sensors, are followed by a robotics session to implement the light sensor in a robot. The teams are asked to create and program a robot that will measure and display the reflected light intensity as the robot moves over a gray-scale pattern and over a color palette. The teams are also asked to create and program a robot to follow a path or a line on a surface. This task is one in which the main problems to solve are related to the logic of the program. The light sensors are a commonly used sensor in the robot projects.

Cone of Sensitivity of the Ultrasonic Sensor The ultrasonic sensor detects objects in front of it by sending 40kHz pulses, but what is its "cone of vision?" To find out, we asked students to measure the angular size of this cone by a means of their own design. If they are to utilize this sensor, they need to know what it can see and what its limits of ultrasonic "vision" are.

This session is followed by a robotics lab where the teams are asked to implement these concepts in Mindstorms robots. The first task is to create and program a robot that will use the ultrasonic sensor to measure and display the distance between the sensor and a surface. The second task is to build and program a robot vehicle which will use the ultrasonic sensor to move to within a certain distance of a wall and back up and turn 90 degrees and continue. The third task is to add a second ultrasonic sensor to the back of the robot so that a wall is sensed either in front or in back of the robot. The ultrasonic sensor is also frequently used in the robotics projects.

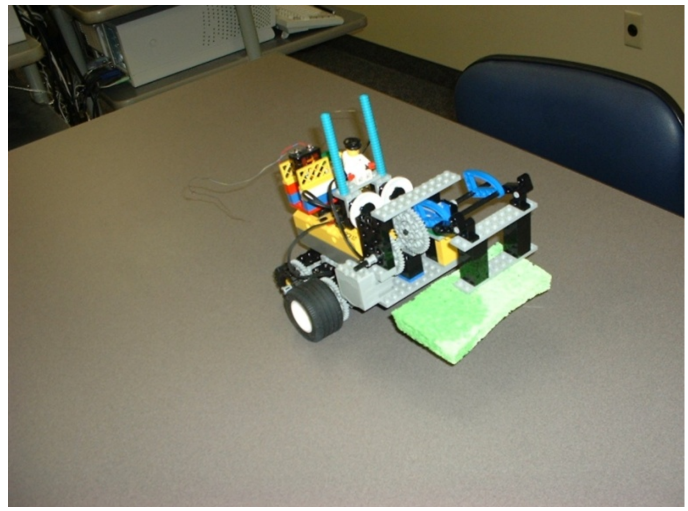
Example Robot Projects and Problem-Solving Elements

There have been a wide variety of interesting and creative projects. Below is an annotated list of some of the projects. We will focus on the projects that illustrate the students solving problems as they come up in the project work.

Spongebob Squarepants Project

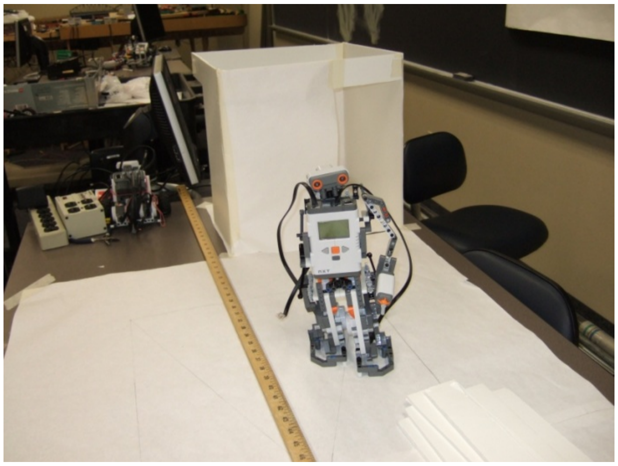
The robot found and cleaned up liquid spills. The team wanted to create a robot that would drive around a building and search for liquid spills. Once a liquid was discovered on the floor, the robot would turn around and clean up the spill using a sponge. The main problem to solve for this project was how to detect a liquid on the floor. None of the existing Mindstorms RCX sensors would work as-is for this function.

Several attempts were made to design and build the liquid sensor. With a few suggestions from the instructors, the team created a two-wire sensor that would complete a circuit when it encountered a liquid. The completed circuit would light a bulb and the lit bulb could be sensed by the light sensor. This was a unique and interesting solution to the problem.



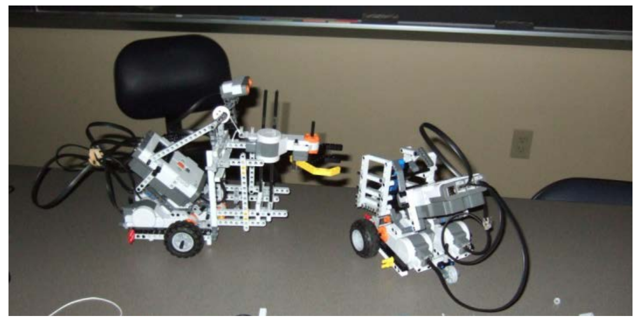
Security Robot

The team created two robots to provide security in a building. One robot was a walking guard that patrolled the building (that they built) and another robot was the front door guard. A third NXT unit provided a "building visitor" function, where the visitor was either a valid visitor or an unwanted intruder coming to the front of the building. The problems to be solved included how to provide communication between the visitor and the front door robot and how to provide communication between the front door robot and the patrolling robot, and how the patrolling robot could open and close doors. The communication issues were solved by using Bluetooth communication between all robot NXT units and an interactive menu system to validate the visitor. The door opening and closing problem was solved by the team building the doors with magnetic latches.



Golf Caddy Robot

This team wanted to create a golf caddy robot that would roll along with the human golfer, measure the distance to the hole, suggest a club to use, hand the club to the golfer, and once on the green, pick up the flagstick for putting and replace it after the golfer completed the hole. The team's main issue was how to use only the three available motor ports on one NXT unit to accomplish all of the tasks. One motor was required for each of the two powered wheels to provide forward motion and steering, one motor was required to grasp the flagstick and a fourth motor was required to lift and lower the flagstick. During the early design and testing phase, the team gave up on "hand the club to the golfer" function. The team solved the motor problem by creating a second robot vehicle which acted as the golf bag. The golf bag used two of its three motor ports to provide forward motion and steering and that left the third motor port free to provide the "lift the flagstick" function. A cable connected the free motor port on the bag robot's NXT unit to the motor on the caddy that controlled the lift motion. In order for the bag robot to stay close to the caddy robot, the caddy robot communicated with the bag robot via Bluetooth and the caddy robot told the bag robot every move it was making so the bag robot could mimic exactly the caddy's movements and trailer behind it. When the caddy robot determined that it was time to pull the flagstick, it sent a message to the bag robot to turn on the appropriate motor. The caddy robot also used an on-screen display to tell the golfer the suggested club or putter for the remaining distance. This robot project was one where the successful solution far exceeded the expectations of the team. Below is an image showing the caddy robot on the left and the bag robot on the right. During the completion of the golf hole, the bag robot would be behind the caddy robot. Note the free cable end on the bag robot in the picture.

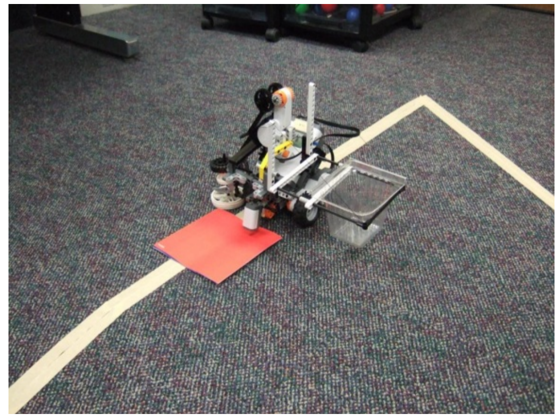


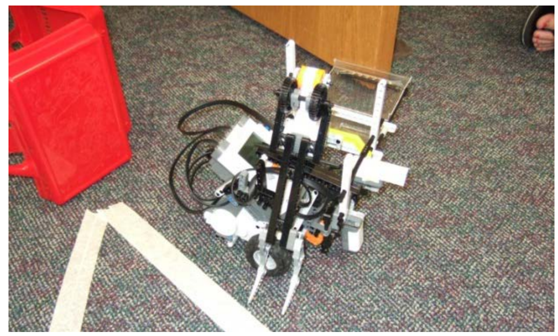
Dance Instructor Robots

The team first created a dance instructor robot that demonstrated dance moves and danced along with music. Secondly, the team created a pair of dance instructor robots that mimicked each other's dance moves side-by-side along with the music. The team originally thought that the project would be a success if the first task was completed. They very quickly added the second dancing instructor and found that there was still time to work on the dance partners. The team was able to create a dance partner pair that danced together and responded to each other. This was an amazing project. The issues that the team had to respond in the final partner task included how to start the dance with the music, how to signal to the partner that the first robot dancer was in front of them, and how to keep the dance partners in synch with each other and with the music while they completed mirror-image movements. This team solved each problem in sequence and never seemed to be discouraged in the process. A sound sensor was used to recognize the start of the music, a touch sensor on each partner was used to recognize when the partners touched, and Bluetooth communication was used to keep the dancers movements in time with the music and paired with the other dancer.

Trash Collecting and Recycling Robot

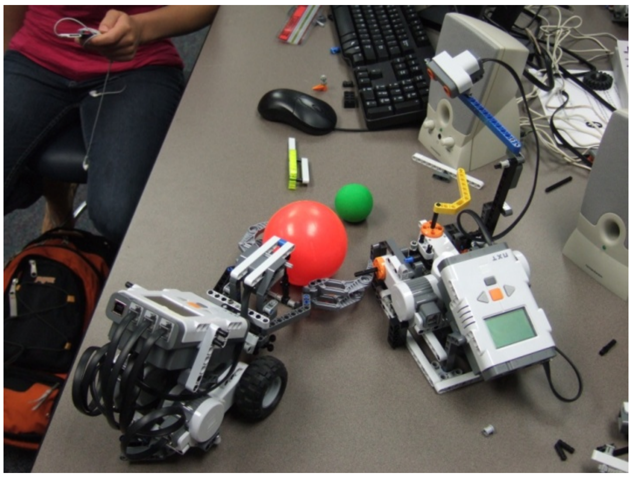
The team created a robot that followed a route, recognized when it reached a trash collection point, picked up the trash container and dumped the contents into the bin on the robot, repeated the process for each of four stops on the route, recognized when the route was completed and finally returned to the “dump.” Most of the issues in sensing the route, sensing the stops, and sensing the end of the route were fairly straightforward uses of two light sensors. The major problems to be solved involved designing and building trash cans that could be dumped into the bin and designing and building the lift arm so that it could pick up the trash can, rotate the arm over the robot, dump the trash into the bin, and replace the trash can in its original position. The arm design turned out to be a straight, one-piece arm that rotated using one motor. The team spent most of its time trying to get a parallel set of “tongs” that could successfully fit under the trash can, keep the can in position as it went over the robot and dumped the contents and most difficult of all, set the trash can back down and clear it. This problem was solved by experimenting with many different arms and trash cans until one combination was successful.

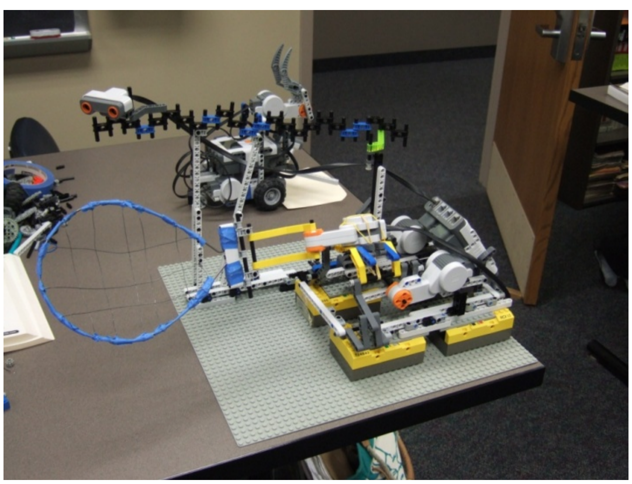




Tennis Robots

The team created a pair of robots. The first robot used an ultrasonic sensor to sense the approach of the ball and hit the ball against a backboard. One of the more challenging aspects for this robot was to build a tennis racquet that could be powered by and attached to the Lego Mindstorms motors. The team created and tested four very different tennis racquets before they finally built one that was light enough to be swung by the Lego motor but yet large enough and stiff enough to actually hit the ball. The instructors were amazed by this team’s approach to building the tennis racquet base and the attachment for the ultrasonic sensor. The team just kept adding pieces in a seemingly haphazard fashion but the resulting structure worked. The second robot was a ball retriever that was designed to find a tennis ball after it was hit and return it. The team began with one ball retriever design and after building it and testing it, they abandoned that robot completely and started over fresh with a new design. The second robot was able to find and capture the ball easily but the team had a great deal of difficulty getting the robot to bring the ball back. They eventually solved the problem by creating a skid that the ball would roll up on and the robot would trap the ball on the skid for return transport. It was again a unique design, far from the original robot design, and the result of a cycle of design, build, test, and modify until a successful solution is achieved. Below is an image of the original retriever robot design on the left with a first version of the “hitting” robot on the right. The second image shows the final version of the “hitting” robot in the foreground with the final version of the retriever robot in the background.





Student Responses

Overall, student responses were positive and reinforcing of the conceptual approach utilizing interdisciplinary and hands-on work. Students seemed to appreciate the opportunities to tie applications of physics and biology to the robotic projects they are developing. Comments from students from the ten-year duration of the course follow. We have included only comments that are primarily related to the structure of the course and/or to the hands-on, problem-solving elements of the course. For 2001 through 2005, the course included biology, physics, and computer science/robotics. In 2006, the course included only biology with computer science and robotics. For 2007 through 2010, the course included only physics as the primary focus with computer science and robotics.

2001

"The robotics (CS), Physics, and Biology connection was a great idea and it worked!"; "I liked the robot project.”

2002

“It was a good finalization of the whole major.”

“It did a great job of pulling together everything that I learned from the SMEE Program. They were all very prepared and knew their material.”

“I thought this course was a fun way to bring together three of the SMEE components. Sometimes I didn’t see the direct correlation between the different sessions, it all came together in the end. Each professor did a wonderful job of engaging the class and finding interesting ways to investigate particular topics.”

“It was an interesting course and provided an excellent theme under which it was easy to integrate concepts and ideas from other fields of study.”

2003

"I really loved how everything was hands-on, it brought learning to life."

"The course held my attention and actually made me look forward to coming. The robotics was great."

"(The instructors were) Very enthusiastic and gave continual support and encouragement as well as pushing us to do more and to test our limits."

2004

"This is a great course where I was able to use my science knowledge from previous courses to create a hands-on final project. :)"

"I think that all of the professors did a great job in conveying relevant knowledge!

"The combination of sciences is a very good course for future SMEEers."

2005

"I liked that much of this course was hands-on and creative."

"Great Class Different than all others. Goes well with Education - You always tried to make it new & interesting. There if we had any questions."

2006

“Both of the instructors worked well together and worked great comparing how biology and robotics/technology are similar.”

“The course challenged my thinking with seeing the comparisons of biology and robotics.”

“I learned quite a bit about biology and computer programming. I see how the two areas are related and can apply that knowledge to everyday experiences.”

“I liked the hands-on parts the best because there was a strong link between the biology and the programming of the robots.”

2007

“Great class – different from all others.”

“I liked having the lab every class period. I liked the robot theme. I think that it crosses into interdisciplinary courses well.”

“The group work with the NXT was effective because we bought the aspect of working together and testing new ideas with the robots.”

2008

The course had achieved its goals of showing the interdisciplinary connections between physics, computer science, a little biology and robotics.

2009

"Overall, I really enjoyed and learned a lot from this class." "I think that the course completely met the goals and not much should be changed. I had fun and learned a lot."

“I think the end project was the most effective part. I was excited and interested to figure out new ways to make my robot work.”

2010

“<u>I liked that almost every activity prepared us for obstacles we ran into at the end project</u>.”

“The hands on approach worked well with my learning style.”

Conclusion

Over the last ten years, the structure of the SMEE 359 course suited our students’ needs well. With integrated lab and project work, the students bought into the process, worked hard to complete every task and seemed to enjoy the experience. They thrived on the varied activities and problem-solving opportunities as they interacted with each other.

Utilizing physics investigative activities to determine the capabilities and limitations of Mindstorms components before integrating those components into a working robot seemed to provide some understanding of function prior to utilization. Following every physics investigation, lab, and discussion with an opportunity to put that knowledge, sensor, gear, motor, structure, etc. immediately into a functioning robot seems to be an excellent motivator for continued interest in and curiosity about the course content. This organization of course content also allows the students to learn to program the robots to accomplish different small tasks as they go along. By the time the students need to put it all together in the final robotics project, they are prepared for the challenge.

The hands-on lab/inquiry mode likewise held the students interest and made them want to come to class and to get to work on the tasks and activities. It also enhanced the understanding of function and limits prior to utilization. This process also created some dependency between working partners, thereby strengthening their mutual success in reaching goals.

The small class size certainly allowed the instructors to maintain contact and improved understanding of the problems that the students encountered while attempting to master tasks. They could ask for assistance any time and be sure one of the instructors would be available for guidance. This, in turn, provided for a high degree of instructor/student interaction in the process of developing ideas and problem solutions.

The instructors observed increased confidence levels of students as they progressed, solving their own problems with less and less assistance at time went on. This trend made the final end project of developing a robot to perform specific tasks autonomously a more doable process. Often students, when asked if assistance was needed, would thank us and proceed to try to solve their own problems by this time.

The course theme, structure and organization, the hands-on lab/inquiry mode, the small class size and the high degree of student-instructor interaction combine to provide an experience that seems to encourage and improve problem-solving in our SMEE students.

Bibliography

1. Bers, Marina U., Iris Ponte, Katherine Juelich, AlisonViera, and Jonathon Schenker, **"**Teachers as Designers: Integrating Robotics in Early Childhood Education," *Information Technology in Childhood Education Annual* (2002), 123-145.

2. Castledine, Alanah-Rei, "LEGO Robotics: An Authentic Problem Solving Tool?," *Proceedings of STEM in Education Conference*, November 2010, Queensland University of Technology, Brisbane, Australia.

3. Chambers, Joan M., and Mike Carbonaro, "Designing, developing, and implementing a course on LEGO robotics for technology teacher education," *Journal of Technology and Teacher Education*, v11 n2, 2003, 209-241.

4. Lee, E. and Y. Lee, "The Effects of Robot Programming on Pre-Service Computer Science Teacher Training," *Proceedings of Society for Information Technology & Teacher Education International Conference* 2008 (pp. 3826-3831). Chesapeake, VA: AACE.

5. Nowak, Jeffrey A. and Carlos Pomalaza-Raez, "EDUA F500 Lego Robotic Design for Teachers Course Syllabus," http://www.ipfw.edu/edst/assets/documents/pdfs/F500Lego.PDF, last accessed on May 9, 2011.

6. Pye, Jordan, "JMU Hosts Annual LEGO Robotics Competition,**"** November 17, 2010, http://www.jmu.edu/cisat/news/legoleague.html.

7. Rutter, Dylan, “Tech robotics school program reaches out to community,” April 17, 2011, http://www.daily toreador.com/lavida/article_03ff3168-6940-11e0-8f74-001a4bcf6878.html.

Biographical Information

Mark Werness received his Ph.D. degree from the University of Minnesota. He has taught for 30 years in the Computer and Information Sciences department at the University of St. Thomas (UST) where he was department chair from 1991 to 1995 and Program Director for Science and Mathematics for Elementary Education (SMEE) from 1998 to 2008. He is currently the Program Director for the new Statistics major at UST. His current academic interests are statistics, computer applications in experimental science, robotics, and STEM teacher preparation.

John Koser received his undergraduate degree from University of Northern Iowa and Masters from St. Cloud State University. He taught physics and astronomy for 35 years at the high school level, participated in the Physics Teachers Resource Associate program with AAPT, was a developer of the Project STAR astronomy program at the Harvard/Smithsonian Center for Astrophysics, and is a contributing author to the Active Physics curriculum sponsored by AAPT. He has taught graduate level methods courses, supervised student teachers, and is currently teaching intro physics courses at the undergraduate level. His current interests include flying (private pilot), amateur radio, and astronomy.

Appendix 1

SMEE 359 Syllabus for Spring 2011

Day	Topics	Lab
1	Course introduction and overview Theme, organization, and assessment areas	Measure the performance of a pre-built Lego NXT robot
2	Physics: Intro to structures, connections, forces	Lego structures to support an object
3	Physics: Experiment with electrical parameters	Batteries: Potential difference, current, logic, using momentary indicators
4	CS: Logic, algorithms, and control structures	Programming simple actuators
5	Robotics: Mindstorms NXT touch sensors	Programming: touch sensors
6	Physics: Rotation, torque and simple machines	measuring static torque output
7	Physics: More work, torque, simple machines	Analyze the work and power output of the NXT motor
8	Robotics: Machines that use pulleys and gears	Build and program vehicles to meet differing goals such as speed, climbing ability, traction
9	Physics: Sound and Ultrasound	Experiments with sound
10	Robotics: The NXT sound sensor	Using the sound sensor in a robot
11	Robotics/Physics: Ultrasonic sensors	The cone of sensitivity and the ultrasonic sensor in a robot
12	Physics: electromagnetic spectrum and “light”; light sensors	Experiments with light, spectra, and light sensors
13	Robotics: The NXT light sensor and its properties	Programming the RCX to follow a path
14	Physics: Light	More experiments with light
15	CS/Physics: Temperature sensor and robots with multiple sensors	Building and programming more sophisticated robots with multiple sensors

16	Robotics: Communication between multiple robots – Bluetooth	Programming robot teams
17	CS/Physics: More with sensors: accelerometers, gyroscopes, and compasses	advanced sensor lab
18	Robotics: Begin Robotics project sessions	Work session
19 to 26	Robotics: Robotics project sessions	Work session
27	Robotics: Robotics project presentations	Presentations, course summary and student opinion forms

Appendix 2

SMEE 359 Robotic Project Evaluation Rubric

Names: ____________________, ____________________,
____

Criteria / Evaluations --->	Inadequate (1)	Adequate (2)	Above Expectations (3)	Exceptional (4)
1. Standard requirements (3X) a. fully autonomous robot b. senses its environment c. responds to changes in the environment d. robot must perform useful work e. similar to a "real world" robotics task f. must use at least two sensors				
2. Task performance as designed (3X)				
3. Complexity of tasks performed (2X)				
4. Documentation quality (3X)				
5. Presentation of project (1X)				
TOTALS --> (12 to 48 points possible)				