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Enhancing Students' Math and Science Education though Information Technology Skills in Robotics

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Abstract

This paper describes a project in Biomechanics and Robotics Explorations for Information Technology Literacy and Skills in Rural Schools at the Department of Engineering at East Carolina University funded by the National Science Foundation. The project is designed to show how mathematics and science teachers can combine information technology explorations with mathematical problem solving to develop context rich lessons that attract rural students to careers in science, engineering, and technology. During the summer of 2007, 30 teachers and 60 students participated in a camp designed to provide both theoretical and hands-on experiences in various STEM facets. The teachers spent two weeks at East Carolina University attending workshops in various areas, including robotics, biomechanics, solid modeling, and other IT literacy areas, in preparation for integration into math and science curricula in their schools. Selected students from the same schools spent three weeks participating in similar workshops. This paper focuses on the robotics component of the project and its implementation at the Department of Engineering at East Carolina University. The paper presents information about robotics summer academies for teachers and for students, as well as our experiences from the academies. In addition, information from surveys that were administered in teacher and student workshops is presented.

Background

The structure of the rural economies in North Carolina and other southeastern states is undergoing a huge transformation—from those based on manufacturing and agriculture to complex service economies that demand workers for an increasingly interconnected global economy. Citizens in these regions will need information technology (IT) skills and literacy skills in the related mathematics and science concepts to use these tools effectively. Unfortunately, efforts to fully integrate technology into rural schools are often narrowly focused on the use of computers and popular applications, software such as word processing, spreadsheets, presentation software, and various Internet functions, including e-mail and search engines. Often excluded from consideration are fundamental information technology concepts, such as algorithms that support computation; data organization techniques used to investigate scientific concepts; and hardware tools such as robotics kits and sensors. These tools allow students to explore how microprocessors take sensor inputs to control motors and other actuator outputs.

In addressing these concerns, North Carolina launched a Career Pathways initiative to help teachers link activities in schools to job opportunities outside of school. The Career Pathways initiative provides mechanisms for high schools to restructure themselves into sets of smaller career academies that refocus guidance on students' career interests. Following early career explorations during the freshman year, each school has its own career counselor and teams of teachers who stay with students for three years. The present project was developed to engage university faculty from science, technology, engineering, and mathematics into the Career Pathways initiative as a way to help teachers infuse IT into their mathematics and science lessons, as well as stimulate students' interest in these careers. The approach is to help teachers use realistic tasks as the driving force for infusing IT explorations into the classroom. Here, the goal is to use context-based learning that applies situated knowledge and experiences to motivate and engage students. This strategy focuses teaching on "whole task" approaches that coordinate problem-solving activities with other activities to simultaneously develop laboratory skills. The project provides explorations that integrate sets of learning goals into complex tasks that teachers use to make IT part of a coordinated activity involving mathematics and science, rather than as separate skills taught in isolation. In developing the framework for the project, high school mathematics and science teachers were surveyed to find out what types of IT support and collaboration would fit realistically within their typical workday. Teachers reported that they had the strongest interests in: (1) data gathering using the IT tools in university labs; (2) teacher-directed research supported by graduate students; and (3) IT-infused curriculum modules co-developed with university faculty. These responses match ongoing research [1, 2], indicating that teachers need both targeted and meaningful IT professional development, as well as timely, accessible, and ongoing technical support as they explore ways to integrate IT into their teaching. This is one of the important goals of the project. Our aim is to help mathematics and science teachers integrate IT into everyday classroom practice so that problem solving involves applying lessons in practical tasks for real life problems and within mathematics and science in general [3]. In this sense, IT is used to help students encounter a wide range of problem types—from routine mathematics problems to problems in unfamiliar contexts and open-ended investigations—that make use of relevant mathematics and thinking processes [4].

Project Overview

The objective of the project, Biomechanics and Robotics Explorations for Information Technology Literacy and Skills in Rural Schools, is to broaden teachers' perspectives of how context and applications for inquiry-based science and mathematics lessons can simulate students' interest in science and mathematics curriculum and, consequently, in careers in the STEM field. The project was awarded in fall 2006 and funded for a period of three years. During the first two summers, a summer academy was conducted [Information Technology Academy for Teachers (ITAT)] for 30 high school educators (60 total during the grant) to provide them with skills and technology to incorporate IT into their classrooms. The ITAT is composed of selected teams of mathematic teachers, science teachers, and guidance counselors who participate in a two-week, non-residential summer program (Figure 1). The purpose is to broaden teachers' perspectives on IT tools in biomechanics, robotics, solid modeling, Microsoft Excel, and leadership. The program also provides experiences that help develop inquiry-based science and mathematics lessons that stimulate students' interests in science, engineering, and technology.

Figure 1: Group of Teachers from the 2007 ITAT Academy

For all three years of the grant, an Information Technology Academy for Students (ITAS) was conducted (Figure 2), which provides a three-week resident campus experience for 60 students from these school systems (180 total), along with integrated and hands-on exposure to IT and its applications in science and mathematics. The ITAS centers on the use of math and science. During the three-week session, students attended classes from 9 a.m.–5 p.m., Monday–Friday, and participated in various activities designated to enhance information technology, mathematics, science, and leadership development. Curriculum topics for students included biomechanics, solid modeling, Microsoft Excel, robotics, and leadership. In the evenings, students had the opportunity to participate in various activities from bowling and movie night to water balloon fights. Both the ITAT and the ITAS academies are located on East Carolina University's (ECU's) campus and draw upon the many resources of ECU, such as state-of-the-art educational facilities and a multidisciplinary group of ECU faculty members and counselors.

Robotics Explorations with a BASIC Stamp 2 Microprocessor

For the ITAT and ITAS academies, the parallax [5] Boe Bot kits with Basic Stamp 2 (BS2) microprocessors were chosen and used for robotics explorations. During 2007, ITAT

Figure 2: 2007 ITAS Academy

activities with robotics required teachers to assemble Boe Bot kits and install BS2 microprocessors into the robots as an in-class teaching tool to help students explore the connections between periodic functions and algorithms that engineers use to make microprocessors generate sounds, control motion, and navigate with tactile and infrared sensors. Two faculty members from ECU were helping teachers explore ways to broaden students’ perspectives on how IT tools enable scientists to discover principles that deepen their understanding of the physical world. The approach is to embed technology in complex and long-term activity structures that feature group inquiry and problem solving.

Robotics Contexts for Mathematics and Science

The BS2 programming activities were developed to help teachers transform mathematics, physical science, and computer applications courses associated with the IT Programming and Software Engineering track of the Career Pathways program. Teachers used timing diagrams to help students explore how software engineers develop programs to condition high voltage (V_{dd} = 5 V) signals and low voltage (V_{ss} = 0V) signals to fluctuate with time. During explorations, teachers programmed the processor to blink light emitting diodes (LED) and send high and low signals to control the robot's servo motors. Timing diagrams allowed teachers to help students discover how computers control machines and how periodic functions emerge from algorithms programmed into the microprocessor. Such programs involve PBASIC commands that change the time duration for ***Pin*** arguments. These ***Pin*** arguments are numbers between zero and 15, which tell the BS2 processor which input/output (I/O) pin to connect to V_{dd} (HIGH) or V_{ss} (LOW) voltages. An illustrative algorithm is shown below with a DO…LOOP and PAUSE 500 command that instructs the BS2 processor to leave the circuit in that state for 500 ms. Such algorithms represent oscillations between V_{dd} and V_{ss} signals, where the amplitude represents the difference between the high and low voltages and the PAUSE commands set the period for oscillations.

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DO
HIGH 12
PAUSE 500
LOW 12
PAUSE 500
LOOP
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ITAS Contest

To test students' understanding of the robotics component of the ITAS, a competition among all students was conducted the last day of the ITAS (Figure 3). Teams of three students were formed and students were given two days (three hours of robotics) to re-build their kits and write the necessary programs. Teams were asked to write a program that would make their Boe Bot navigate along the simple obstacle course shown in Figure 4. In addition, teams were asked to complete the following:

1. Add two yellow and two red LEDs to the circuit and make the yellow lights blink when the Boe Bot turns and the red lights blink when the Boe Bot stops.
2. Make the speaker beep with the signal light before each turn.

Although the obstacle course is simple, students have to demonstrate their understanding of programming, including loops and branching. Also, they have to demonstrate their understanding of electrical circuits, light, and sound.

On the day of the competition, faculty from the Department of Engineering and Technology Systems were invited to judge the students. Students were evaluated based on the following judging schemes:

- Program is complete. (The program is error-free, and students demonstrated that they understood programming.)

- Sound circuit is correct, and the sound signals work properly.
- The light circuit is correct, and the light signals work properly.
- Navigation along straight lines and 30-degree, 90-degree, and 120-degree turns.
- Navigation along the circular path.
- Completion of all motions.
- Time of completion.

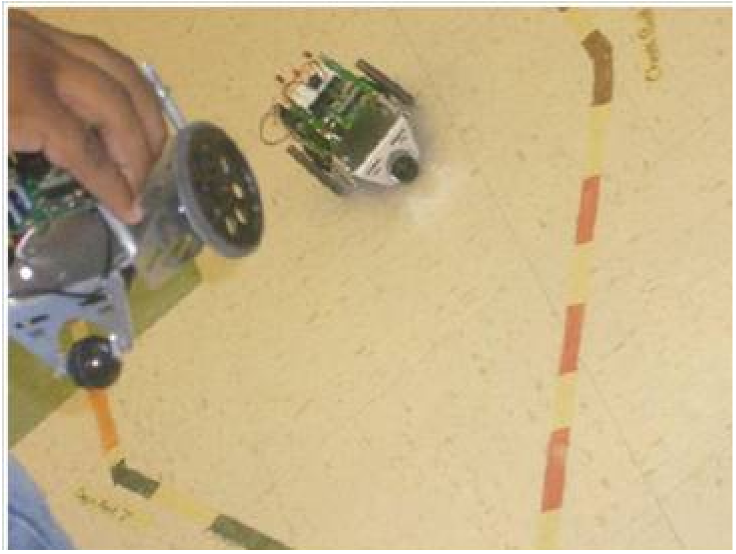

Figure 3: Students' Contest

Assessment

Different pre- and post-assessment instruments were employed to gauge the overall performance of the project and to examine curricular area content. The robotics team also developed an additional survey for the robotics component of both the ITAT and ITAS (Table 1 and Table 2). Some of these results and feedback are presented in this section. The post program rating for all of the curricular areas shows that the robotics component was very successful. Approximately 88 percent of the teachers rated the robotics component of the ITAT as helpful or very helpful (4 or 5 on 1–5 scale) for integrating hands-on learning in their classrooms. Approximately 83 percent of the students found the robotics component of the ITAS to be helpful or very helpful (4 or 5 on 1–5 scale) for understanding more about science, engineering, technology, and math [6].

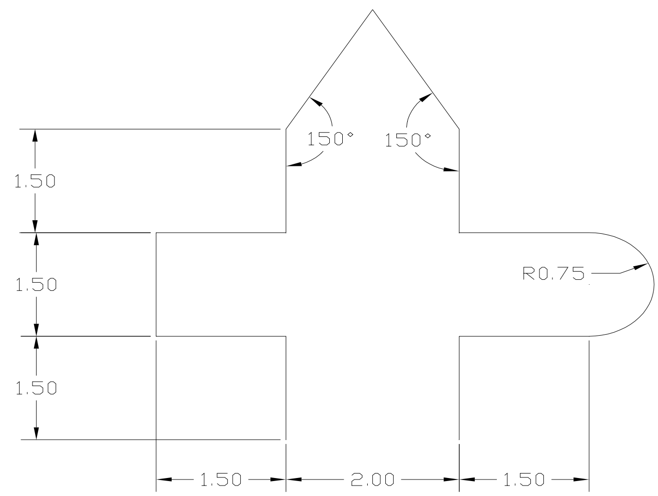

Figure 4: Competition's Obstacle Course

Table 1 shows the responses of the teachers to some questions from the ITAT robotics post survey.

Table 1: Some Questions from the Post-ITAT Survey

Question	% 4 or 5 on 1-5 scale
Rate your understanding of robotics and programming after the ITAT workshop.	74
Rate how comfortable you are in using robotics and/or programming tools in your class.	62
The robotics ITAT workshop made improved my confidence in learning and using new technology.	85
Hands-on activities were helpful for learning and mastering the robotics content.	93
The ITAS trial modules were useful.	81
There is high likelihood of sharing my new knowledge with my colleague(s).	81
I will encourage my colleague(s) to attend future offerings of the ITAT.	93
I will encourage my students to attend future offerings of the ITAS.	97

1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

As a measure of the teachers' confidence of using new technology, teachers were asked to work in groups of three and develop a robotics module on their own (trial module) in the last week of the ITAT and teach it to the students (20 students). Although, none of the teachers had prior knowledge of robotics or programming (some teachers did not feel comfortable when they started to develop the modules), teachers did a good job in developing these trial modules. The post survey shows that about 81 percent of the teachers found the trial modules to be useful. Teachers' feedback was generally positive, and two of the comments are shown below:

- "… I benefited from everything. Every time we did something, I saw how it applied to my classroom. The hands-on approach is the way to go …"
- "… as a counselor, I thoroughly enjoyed the robotics …"

Another measure of the success of the 2007 ITAT is the implementation of the robotics in the classrooms (Figure 5). Many teachers used the Boe Bots to teach their students in different courses, such as discrete math.

Figure 5: Implementaion of robotics in classrooms.
Source:local new, http://www.ecu.edu/itestbiomechanics/news.htm

Students' responses to some of the ITAS-robotics post survey are shown in Table 2. At the beginning of the ITAS, approximately 19 percent of the students showed prior knowledge of programming. At the end of the ITAS, approximately 80 percent felt comfortable writing computer programs and using new technology. Approximately 93 percent of the students found hands-on activities to be very helpful in learning. The survey also shows that 78 percent of the students want to major in engineering, science, or technology at the college level.

Table 3 compares pre- and post-academy responses of students' interests in STEM fields. It is clear from post-academy responses that the ITAS has stimulated students' interests in pursuing engineering and science education, collectively. More than 90 percent of the respondents reported a strong interest in working in the fields of science and engineering, compared to 57.9 percent before joining the academy. Strong interest in working in the IT field has also increased from 12.3 percent before the ITAS workshop (pre-academy) to 28.3 percent post-academy. In general, results in Table 3 confirm that the ITAS goal has been achieved because the majority of students were more eager and willing to work in careers related to science, engineering, and technology.

Table 2: Some Questions from the Post-ITAS Survey

Question	% 4 or 5 on 1-5 scale
Rate your understanding of robotics and programming after the ITAS workshop.	70
Rate how comfortable you are in using robotics and writing computer programs.	81
The robotics ITAS workshop improved my confidence in learning and using new technology.	80
Hands-on activities were helpful for learning and mastering the robotics content.	93
I will go to Engineering, Science, or Technology at the college.	78
There is high likelihood of sharing my new knowledge with my colleagues and friends.	78
I will encourage my colleagues and my friends to attend future offerings of the ITAS.	93

1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

Table 3: Pre-academy and Post-academy Survey Results

Pre-academy How interested are you in working in the following fields?	Not at all	A little	Some	A lot
Science	12.3%	26.3%	33.3%	28.1%
Engineering	14%	28.1%	28.1%	29.8%
Information Technology	19.3%	29.8%	38.6%	12.3%
Post-academy How interested are you in working in the following fields?				
Science	5.6%	22.2%	24.1%	48.1%
Engineering	9.3%	25.9%	22.2%	42.6%
Information Technology	7.5%	24.5%	39.6	28.3%

Some of the students' comments are provided below. It was interesting to discover that many students liked the idea of working in groups with students from other schools:

- "There are a lot of things I enjoyed about robotics. We got to use the robots and had opportunities to do things I would have never have thought I would be able to do."
- "I liked the fact that it was a lot of hands-on and that I was able to learn and understand the technology without it being over my head."
- "I really liked all the hands-on activities in the robotics class. Now that I've been to this camp and taken robotics, I really want to go home and buy a robot. This class has been really fun."

- “The fact that we can work in groups. Actually using robots. Learning how to program robots.”
- “Programming the robot to move, make sounds, turn the LED’s on, and the photoresistors and infrared lights.”
- “The hands-on activities were good in gaining experience. I also liked how they let us put our own creativity into our Boe Bot.”
- “This workshop was very enlightening and has ultimately made me consider a career in this line of work.”
- “It was a great experience! I wish it didn’t end.”

Conclusion

The ITEST project described in this paper is designed to show how mathematics and science teachers can combine information technology explorations with mathematical problem solving to develop context-rich lessons that attract rural students to careers in science, engineering, and technology. The focus of the paper was on the robotics component of the project. The implementation of the robotics component was successful, and the feedback received from teachers and students was positive. Post-academy surveys show that approximately 80 percent of students felt comfortable writing computer programs and using new technology. Moreover, post survey results showed that approximately 93 percent of students found hands-on activities to be very helpful in learning. In addition, approximately 78 percent of students were eager to pursue a major in engineering, science, or technology at the college level.

Acknowledgement

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Biography

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