

Integrating Engineering Topics into Mathematics and Computer Science Courses

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Abstract

Two projects that are designed and implemented to attract and retain qualified students in Appalachia to engineering and science-oriented careers are discussed in this paper. The West Virginia *Engineers of Tomorrow*, funded in part by the NSF project number 0525484, and the *Agile Robotics* projects are both large scale undertakings with multiple objectives and tasks. *Tools for Integrating Math and Engineering (TIME) Kits* and *Using Robotics Concepts to Teach an Introductory Computer Science Course* are the components presented. TIME Kits are designed to reach a broad audience of high school students. They are developed collaboratively by faculty from engineering, mathematics, math education, physics and master mathematics and science high school teachers. Robotics scenarios are used to enhance the critical thinking and programming components of an introductory computer science course. An overview of these two initiatives, results of the preliminary implementation, and a proposed research design are presented.

West Virginia Engineers of Tomorrow

In 2005, West Virginia University (WVU) was awarded \$1,586,965 for the Engineers of Tomorrow Project (NSF project number 0525484). The 5 year project has as its overarching goal, “To increase the number of students graduating in Science, Technology, Engineering, Mathematics (STEM) fields.” In order to reach that goal, the project implements four coordinated strategies to impact both outreach to high school students and retention of college freshmen:

- Tools for Integrating Math and Engineering (TIME) Kits are designed to reach a broad audience of high school students grades 9 - 12 to improve math scores and encourage participation in a science or engineering related career.
- The Summer Experience Program is designed to encourage minority and female students to participate in a science or engineering field and to provide mentorship to students without a support system at home.
- College Credit for High School is a course designed to encourage the exceptional WV high school students to pursue college credit in engineering prior to graduation.
- A Freshman Engineering Retention Program is focused on freshmen in the engineering curriculum at WVU to increase retention, but is designed to extend to all engineering students.

TIME Kits

According to the United States Bureau of Census, West Virginia struggles with obstacles common to other Appalachian states: it is among the top 10 states with

- people living in rural communities (3rd);
- rural children in poverty (3rd);

- students in rural schools (5th);
- schools in rural communities (8th);
- and students in small rural schools (9th);

These figures along with the fact that in 2000, West Virginia had the lowest rural per capita income, suggest that effective rural education is imperative if this project has any chance of improving mathematics scores and encouraging participation in a science or engineering related career.

“Students’ understanding of mathematics, their ability to use it to solve problems, and their confidence in, disposition toward, mathematics are all shaped by the teaching they encounter in school” (NCTM, 2000, p.16-17). In order to effect the education of students in grades 9 - 12, the project will engage 125 teachers in cohort groups of approximately 25 each year. It is expected that these teachers will then impact 12,500 students annually. Teacher teams are invited to participate in a one week workshop to learn about opportunities for their students in the field of engineering and to collaboratively develop units which integrate mathematics, science, and engineering content in addition to 21st Century Learning Skills (2004) for use in their classrooms.

TIME Kits are designed to reach a broad audience of high school students. They are developed by WVU faculty from engineering, mathematics, mathematics education, physics and master mathematics and science teachers. Professional Engineers consult with teams during the development of the units. TIME Kits are authentic problem-based engineering lessons designed to increase student achievement in mathematics and interest in science and engineering. The mathematics and science concepts integrated in the units are tied to the curriculum requirements of the West Virginia Department of Education Content Standards and Objectives (2006). In

particular, the West Virginia Content Standards and Objectives have been modified in recent years to reflect the National Council of Teachers of Mathematics (NCTM) standards. (NCTM, 2000).

The desired outcome is that the implementation of the TIME Kits in the classroom will increase student achievement and interest in mathematics and encourage students to identify a STEM field as a career choice. The original intent of the TIME Kit was that one would include all manipulatives, software, and materials needed for a series of student-centered, hands-on and mind-on activities that target specific mathematics concepts that are inherently abstract and are based on engineering problems that are relevant to students' lives. It is intended that students work together in a problem based learning situation to design, build and evaluate a series of engineering projects. The specific goals of the TIME Kit component are

- Develop sample TIME Kits through the use of collaborative teams.
- Identify engineering concepts that correlate to WV and National content standards that are identified by teachers as grade appropriate and represent concepts that may be represented through a hands-on approach.
- Create a dedicated website to support the TIME Kit integration in all 55 counties of West Virginia and to provide resources for students and teachers including student assessment tools.
- Train participating mathematics teachers to utilize the TIME Kits in their classrooms.
- Evaluate the effectiveness of TIME Kits at participating secondary schools and use suggestions to create a 2nd generation TIME Kit.
- Integrate TIME Kits into pre-service curricula.

- Disseminate results.
- Disseminate the completed TIME Kits through the Ed Venture Group.

Preliminary Assessment Strategies

Formative assessment will include two on-line surveys. The surveys will gather input from 50 mathematics teachers and 500 ninth through twelfth grade students on the TIME Kits that most interest them and the concepts that they find the most difficult to relate to in abstract terms. The feedback will be incorporated into the final design of the TIME Kits. Action research, conducted by the participating teachers, and site visits by the participating WVU faculty members will also be employed. Research will include the use of both quantitative and qualitative strategies. It is anticipated that qualitative techniques will include observations, surveys, interviews and student portfolios. In addition, quantitative data will include standardized test scores and the on-line quiz information associated with each TIME Kit.

The summative evaluation will compare achievement gains and losses on standardized test scores when comparing participating and non-participating classes. The standardized scores, TIME Kit internet quizzes, qualitative results from action research, and teacher evaluation forms will be combined to perform a final assessment of the TIME Kit implementation and effectiveness. In addition, an outside evaluation firm will be contracted to perform a final summative evaluation and report.

Agile Robotics

Support has been secured to begin development of instructional modules using robotics which will address three concurrent objectives:

- Encourage students to the STEM fields and develop their critical thinking skills and scientific method processes.

- Prepare training modules for use by educators that will introduce students to the STEM fields and encourage careers in these areas while teaching the mathematics and sciences. The modules are also designed and intended to be used via distance education for training in the robotics area.
- Develop courses using these modules in conjunction with a general education component to provide an Associate Degree in Robotics Technology.

Using Robotics Concepts to Teach an Introductory Computer Science Course

One of the key areas of robotics is computer programming. The use of a robotics platform such as the Vex Robotics kit by Innovation First, Inc. provides a flexible environment which can be programmed using Intelitek's *EasyC* or Carnegie Mellon Robotics Academy's *RobotC IDE*. Through the use of a program Integrated Development Environment, students can learn programming while "seeing" their results implemented through the robotics platform. While writing program solutions in conjunction to the design of a robotics platform to solve a given task, the student can learn the foundations of Computer Science as well as Engineering and Mathematical concepts.

Using the Vex Robotics kit, a basic mobile platform with front bumper switches will be used in an introductory Computer Science class at California University of Pennsylvania. This robot and the RobotC IDE will be made available to the students to develop C-type programs for introductory problems. The problems include basic movement, turning, and front obstruction contact testing. Generic programming constructs of sequential, decision, and loops are used to solve the problems. Once completed, the programs will be loaded into the Vex robotics platform for actual testing. The students will see their program in action. Currently, a hypothetical robot with limited commands has proved to be beneficial in the learning process of the students. The

students in the first Computer Science class enjoy writing programs when the language and applications are more human like. It is the intent that this robotics platform will provide the physical realization of the effective hypothetical robot currently used.

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