Work in Progress: Introducing Engineering into Math and Science Secondary Education Classes

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Abstract **– This paper describes activities of two graduate students in creating, delivering, and assessing engineering-based lessons in secondary science and mathematics classes. The students are Fellows in an NSF-funded program called Project STEP at the University of Cincinnati; the program partners graduate students with secondary educators to create resources for teaching science, technology, engineering and mathematics (STEM) skills. The lessons are relevant to students' lives as well as aligned with academic standards. The Fellows bring authentic engineering backgrounds and expertise into the classroom to encourage students to consider engineering as a future field of study.**

Index Terms - secondary mathematics/science education; STEM education

INTRODUCTION

Project STEP (Science and Technology Enhancement Program) is a National Science Foundation multi-year project that supports engineering and education university students as classroom assistants in inner-city high schools [1]. Project STEP has three primary goals: (1) to produce scientists, engineers, and secondary science and mathematics educators who are experienced in bringing their technical expertise into the classroom, (2) to design, develop, and implement hands-on activities and inquiry-based projects relevant to everyday life, society and the world, and (3) to encourage secondary students to consider engineering as a field of study in college and as a profession.

Project STEP Fellows are trained by College of Education faculty in a sequence of graduate courses that cover topics including classroom management techniques, lesson planning, instructional delivery, state and national standards, and assessment of student learning. Field practicum allows the Fellows to observe teachers' classroom styles and become acquainted with school culture that may be very different from their own experiences. The Fellows work on STEP activities for approximately 20 hours per week and spend a minimum of 6 hours per week in a high school classroom. Fellows design, develop, implement and assess lessons throughout the school year and conduct annual workshops for teachers to disseminate their results and share their STEM expertise.

The documentation requirements for STEP lessons are designed to increase reusability and adaptability of the lessons. They include target STEM classroom and grade, relationship to engineering, multimedia used, background information, relationship to standards, handouts with answer keys, student work samples, pre- and post-assessment, and reflection.

This paper discusses lessons and results for mathematics and physical science classes implemented by two Fellows in fall 2004. The lessons include teaching graphing techniques using automobile collision data (especially poignant for teenagers approaching driving age) and teaching Newton's Laws using remote control vehicles and skateboards. The use of relevant and familiar examples helped engage students and elicit positive responses. This paper offers observations and reflections about what kinds of activities appear to have an impact on increasing student learning and interest in STEM education.

CRASH TEST DUMMIES

A. Background

"Crash Test Dummies" is a 2-3 day (70 minute blocks) portfolio project that was taught in four 9th grade Integrated Mathematics classes at the Hughes Center (Teaching and Technology program). This portfolio project provides students with a basic understanding of the physics behind car crashes and seatbelt use. After a guided discussion and multimedia presentation, students complete a Crash Test Dummy Packet to perform mathematical analyses of statistical data obtained from the Insurance Institute of Highway Safety concerning car accidents and fatalities.

B. Relationship to Engineering

Students explore the physics concepts behind crash impacts as well as the engineering aspects of seatbelt design.

C. Relationship to Standards

"Crash Test Dummies" was designed to fit standards set by the Ohio Department of Education [2] that are aligned with national education standards. It meets the Number, Number Sense and Operation standard (Benchmarks D and G), Patterns, Functions and Algebra standard (Benchmarks C, D and H), the Data Analysis and Probability standard (Benchmarks A and F) in mathematics, and the Physical Science standard (Benchmark D) for mathematics.

D. Reflection

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The crash test dummy video really sparked the students' interest concerning Newton's First Law, car accidents, seat belts and car insurance. Since driving is of particular interest to freshmen, all of the students seemed engaged. We talked about the design and development of seatbelts and professions that encompass that, especially mechanical engineering. The profession was further highlighted in a discussion about testing and designing seat belts, cars, and stereo systems. This project allowed for the students to explore, learn and practice mathematics in a new and interesting way that applies directly to their lives. Of the students surveyed, 39% of them said that the "Crash Test Dummies" activity increased their interest in math and science and 23% said that the activity made them feel more confident in their ability to learn mathematics.

IV. NEWTON…HE CAN BE FUN!

A. Background

"Newton…He Can Be Fun!" was designed as a single day (70 minute block) lesson that serves as a comprehensive review of Newton's Three Laws of Motion. It was designed and implemented with the help of a 9th grade physical science teacher at the Hughes Center's CAMAS (Cincinnati Academy of Math And Science) program.

Designed as four mini-labs spread throughout the room, students rotate through the various stations in teams while investigating Newton's Laws of Motion. At the first station, students use two small hovercraft vehicles to investigate friction and its effect on the motion of an object (Newton's First Law). Using two pre-constructed lanes, students glide the hovercrafts over lane one (without any interference from friction) and then over lane two (with sandpaper representing the effect of friction). Students then record their observations. The second station investigates Newton's Second Law by having students change weights attached to a hovercraft then observing what happens to its acceleration and deceleration. The Third Law is used in stations three and four. In station three, students use a remote control car and a force spring to investigate the principle of "equal and opposite" forces. In the fourth and final station, two skateboards are used to again investigate "equal and opposite" forces. Two students sit on opposing skateboards and push away from each other. The procedure is repeated but with only one student pushing instead of both. Assuming the students are of similar mass, they observe that it does not matter if both push or if only one pushes; they move the same distance from the midline and at relatively the same velocity.

At the end of the experiments, students are asked to answer a series of questions that require them to apply their knowledge and observations in quantitative areas (such as the force equation) and qualitative areas.

B. Relationship to Engineering

Students are given the opportunity to learn about the operation and physics behind hovercraft vehicles and the forces acting on a car through the use of small-scale substitutes. The goal is to give students a greater appreciation for what they are learning by supplying them with real-world applications of abstract physics concepts. Talking about friction and how it effects the operation of a hovercraft (rather than talking about it in terms of wood blocks) gives students something meaningful to associate with the concept.

C. Relationship to Standards

"Newton…He Can Be Fun!" meets the Physical Sciences standard (Benchmark D) in science and is also aligned with the Mathematical Process standard (Benchmark B) for mathematics [2].

D. Reflection

The "Newton…He Can Be Fun!" lesson was executed smoothly for two blocks of 9th grade physical science. Students enjoyed working with the remote control hovercraft and the radio controlled car, and they enjoyed rotating through the various experimental stations. The lab required that the group switch group member responsibilities at each station, and the students reported that they liked the fact that everyone was able to be part of the experiments. When surveyed, 75% of students reported that the lesson increased their interest in engineering while 93% of students said that this activity made them feel more confident about learning science.

From a teacher's perspective, the lesson went well. The lesson could be improved by altering it to include more practice with the force equation and to add more visual aids (such as a video clip about a hovercraft or about the physics behind race car driving). For this particular set of students, visual cues tend to be more effective than lecture-based methods of instruction. The link to engineering and the ability to experiment on real-world models made this lesson successful.

CONCLUSIONS

Due to a lack of training, background, or time, secondary math and science teachers are often unable to present engineering applications or discuss engineering careers related to the subject areas they teach. Students lack exposure to what engineers do and miss out on educational opportunities that would enable them to study engineering in college. Project STEP is making inroads into secondary education by providing hands-on, engineering-based applications relevant to students' lives in STEM classrooms. Details about lessons and achievements can be found at the Project STEP website [2].

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REFERENCES

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