

Keeping the STEM Student Pipeline Flowing: An Innovative Partnership Between a K-12 School System and an Institution of Higher Learning

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Abstract

The reauthorization of the Department of Education's Elementary and Secondary Education Act (ESEA) of 2002 established the Improving Teacher Quality Grant Program (Title II). Under Part B of Title II, a grant program that supports innovative mathematics and science partnerships between K-12 schools and institutions of higher education was established. The purpose of the partnership program is ultimately to improve K-12 student academic achievement. Methods to accomplish this goal involve strengthening subject matter knowledge of K-12 mathematics and science teachers by partnering with University scientists, mathematicians and engineers. In addition, Title II, Part B encourages the development of more challenging mathematics and science programs at the secondary education level that would better prepare students for postsecondary study in STEM disciplines. Each state in the country is allocated ESEA monies based on a formula funding model. The 2008 funding estimate for the Title II program is approximately 4.1 billion dollars of a 127 billion dollar education budget to the states.

The Engineering Department at Roger Williams University has partnered with the Rhode Island Department of Education (RIDE) and the Bristol Warren School District under an innovative partnership called PRIMES (Partnerships and Research Investigations with Mathematicians, Engineers and Scientists) to take advantage of the ESEA Title II, Part B opportunities. This article will discuss the background of the STEM pipeline challenge, nature of the joint partnership, its challenges and successes, as well as how other engineering departments might take advantage of the federal appropriation and ultimately affect the pipeline of entering engineering freshmen.

Background of the STEM Pipeline Challenge

There are many reasons cited for the increased attention on strengthening mathematics and science preparation of K-12 students. Foremost among those reasons however is the need to equip our future workforce with the skills and tools required to compete in a changing global economy. An adequate level of mathematics and science preparation is seen as a necessity for the many technical professions that will constitute the workforce of the future. If graduating high school seniors do not have the prerequisite ability in mathematics and science, then the probability of these students choosing a STEM major in college is low. This ultimately will affect the production of U.S. scientists and engineers needed to solve our future technological and research challenges.

To place the K-12 mathematics and science scenario in perspective, when compared to foreign countries, the U.S. significantly lags most with respect to performance. Table 1 presents a compilation of mathematics scores of 15 year olds enrolled in secondary education institutions in OECD (Organization for Economic Cooperation and Development) countries. This international comparison of mathematics performance by 15 year olds indicates that the U.S. falls almost at the bottom of the comparator group.

Table 1 - Mathematics Performance by 15 year olds in OECD Countries

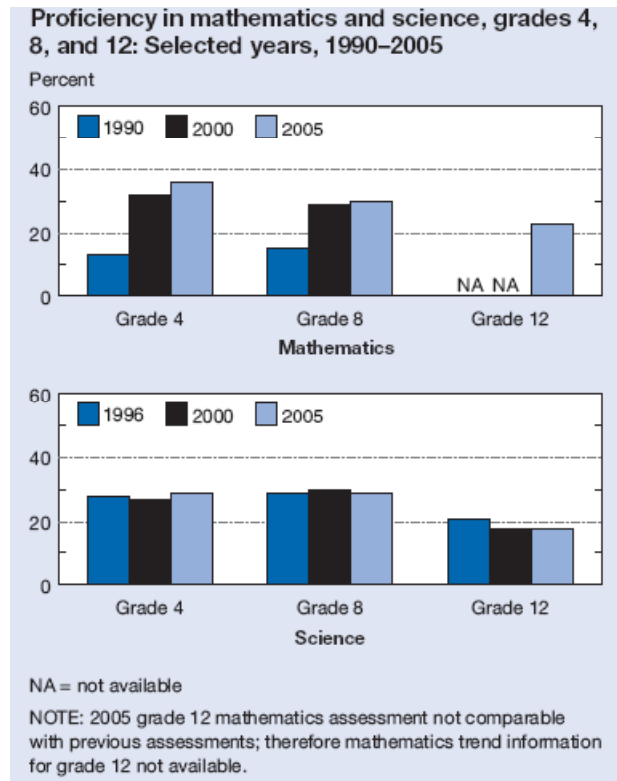
Country	Mathematics Scores
Finland	544
Korea	542
Netherlands	538
Japan	534
Canada	532
Belgium	529
Switzerland	527
Australia	524
New Zealand	523
Czech Republic	516
Iceland	515
Denmark	514
France	511
Sweden	509
Austria	506
Germany	503
Ireland	503
Average	500
Slovak Republic	498
Norway	495
Luxembourg	493
Poland	490
Hungary	490
Spain	485
United States	483
Portugal	466
Italy	466
Greece	445
Turkey	423
Mexico	385

Source: *2007 Education at a Glance: OECD Indicator* (OECD Publishing, Center for Research and Innovation, 2007)

In the U.S., there have been some minor gains in mathematics and science achievement among 4th, 8th and 12th graders over the past ten years in terms of the percentage of students taking advanced courses.

However the number of students that are performing at or above proficiency level in mathematics and science has dropped and remains problematic. Figure 1 presents two graphs from the National Science Foundation’s 2008 Science and Engineering Indicators publication. These graphs show for example, that in mathematics, only 22% and 19% of 12th graders are rated as proficient in mathematics and science respectively.

Figure 1



Source: (National Science Foundation, Division of Science Resource Statistics, 2008) (National Center for Education Statistics, Institute of Education Statistics, 2006) (National Center for Education Statistics, Institute of Education Statistics, 2006)

Comparing Rhode Island to the nation presents a somewhat similar picture. Performance metrics across the board fall under the national averages for all fourth and eighth grade measures. More dramatic are high school assessments with 50% (29) of the 58 high schools in Rhode Island categorized as “not making adequate yearly progress.” (Rhode Island Department of Education, 2008) Table 2 presents an overview of key indicators among Rhode Island students.

Table 2 – 2007 Performance and Proficiency Measures for Rhode Island Students Compared to U.S. Averages

Metric	Rhode Island	United States
Fourth Grade Mathematics Performance Score	233	237
Fourth Grade Mathematics Proficiency	31%	35%
Fourth Grade Science Performance Score	146	149

Metric	Rhode Island	United States
Fourth Grade Science Proficiency	23%	27%
Eighth Grade Mathematics Performance Score	272	278
Eighth Grade Mathematics Proficiency	23%	29%
Eighth Grade Science Performance Score	146	147
Eighth Grade Science Proficiency	26%	27%
Share of Public High School Students Taking Advanced Placement Exams	13%	24%

Source: (Rhode Island Department of Education, 2008)

What Are We Doing to Address the Challenge?

To address the pipeline challenge of not only getting students interested in majoring in STEM disciplines but also assuring that these students have the proper preparation for succeeding in STEM disciplines, institutions of higher learning have increasingly turned to “outreach programs.” These programs are usually geared toward some aspect of the K-12 educational system. It is thought that getting more K-12 students interested in science and technology will result in an increase in their interest to take mathematics, science and engineering classes in high school. This in turn should impact matriculation rates at institutions of higher education. Whether this cause and effect proposition actually holds true requires a great deal of further study. At least from the perspective of total undergraduate engineering enrollment, the pipeline has been little affected over the past five years. (American Society for Engineering Education, 2007) Still, outreach activities initiated by institutions of higher learning provide a primary means to introduce middle and high school students to engineering, mathematics and science applications.

The idea of “outreach” is firmly entrenched in higher education, as shown by the fact that, for example, since 1976, UCLA¹ has had an office devoted to coordinating outreach activities. Despite this, it is interesting to note that this sort of activity is still called “outreach” by institutions of higher education; that is to say, the K-12 system is considered such an entirely different entity that one needs to “reach out(side)” to interact with it.

In terms of STEM disciplines “outreach” can take a number of different forms which are summarized in a review by Jeffers et al. (Jefers, 2004) and include: the development of classroom materials for use in K-12 classrooms, professional development for K-12 teachers, web-based resources, activities that take place at the institution of higher education, activities in the K-12 school (such as design competitions or some member from a higher institution partner– a student or instructor teaching in the K-12 classroom). As with other classification systems, there is room here for crossover, thus there are also “blended models” which would encompass one or more of these forms.

Given the nature of the time scales involved (it might be as many as 10 years after the “outreach” experience occurs that the student makes a decision about what to study) it is somewhat difficult to assess whether one form of “outreach” is more effective at attracting and retaining new students to STEM disciplines.

ESEA Background in Rhode Island

¹ The office even has a presence on the world wide web: <http://www.eaop.ucla.edu/0405/aboutus.htm>

The approximate amount of 2008 funding slated for Rhode Island under the ESEA program is 649 million dollars. One of the programs under the funding act is the Mathematics and Science Partnership (MSP). The monies awarded to State of Rhode Island under the Mathematics and Science Partnership are distributed by the Rhode Island Department of Education (RIDE) in the form of grants for which the School Districts identified as “High Risk²” were invited to apply.

The 2006 State RFP required that districts applying for the three year grants guarantee that 90% of mathematics and science teachers in the applying school districts fully participate in the conditions of the grant. Those conditions involved engaging in common planning times, participating in 100 hours of professional development each year of the grant, providing programs in an “extended day” format, acquiring increased content knowledge in mathematics and science and demonstrating improved pedagogical curriculum plans in the classroom. The latter two requirements are externally validated through the ETS Mathematics and Science Teacher tests and consultant observations of classroom practices.

As the higher education partner, faculty members from mathematics, science and engineering departments had to agree to support the goals of the PRIMES grant, commit to working 36 days over the course of the year with middle and high school teachers on their respective classroom and professional development plans. In addition faculty members serve as liaisons back to the University with respect to facilitating on-campus experiences for the schools and transferring what was learned as a result of the PRIMES interaction at the middle and high schools to University faculty.

An interesting component of the Rhode Island PRIMES grant was the incorporation of computer 3-D modeling requirement placed on programs developed under the PRIMES initiative. Specifically, the simulation software package Pro-Engineer (PTC, Needham, MA) was selected by the RIDE, and made available in the form of a student edition (with some limitations) free of charge to all students, teachers, and higher education faculty taking part in the programs.

Programs Initiated under the PRIMES Grant

To date the authors have engaged in several distinct outreach activities with the Bristol Warren School District in the Middle School (Kickemuit Middle School) and High School (Mt. Hope High School). We describe five of these activities below.

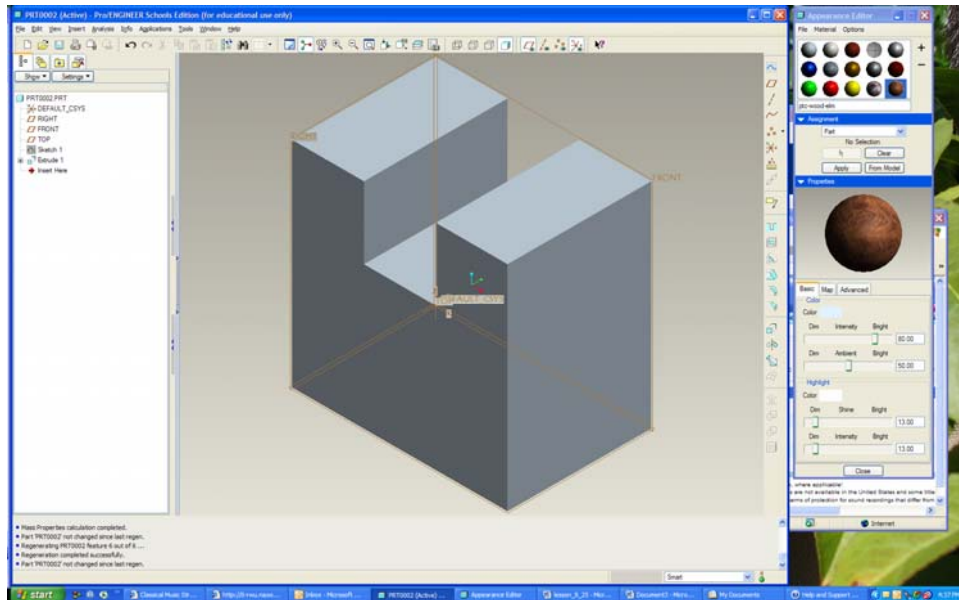
Tutorial for Teachers in Pro-E

As mentioned in the previous section, the software package Pro-E was selected to serve as a platform to assist with 3-D visualization. As such, one of the first PRIMES activities (not organized by the authors) was a two-day training session for the teachers who had decided to take part in the PRIMES program. Based on feedback about this two-day session from the teachers, it was felt that a refresher training opportunity would be beneficial, thus we created and presented tutorials to the teachers from the two participating schools.

² As defined in RIDE’s RFP, a “High Risk” School District is defined as one which “Serves no fewer than 10,000 children from families with incomes below the poverty line or a school district from which 20 percent of the children are from families with incomes below the poverty line; and have a high percentage of teachers not teaching in the academic subjects or grade levels that the teachers were trained to teach or that a high percentage of teachers with emergency, provisional, or temporary certification or licensing.

This outreach, which was presented separately to the middle school and high school teachers, took the form of after school workshops lasting approximately two hours. The authors served as facilitators, one of leading the drawing while the other walked around the room offering one-on-one assistance to the participants.

The material for these tutorials was based on RIDE grade-level-expectations (in the middle school) and grade-span-expectation (in the high school). As an example, GLE M(G&M)-7-10 requires that students demonstrate competency in drawing a net of a solid. In order to show how Pro-E could assist in teaching this aspect of visualization, we arrived with nets printed on single sheets of paper, that when cut out and assembled, would create of a simple solid. After each teacher constructed his or her net, each drew the solid in Pro-E. A screen shot of the solid is show in the figure below.

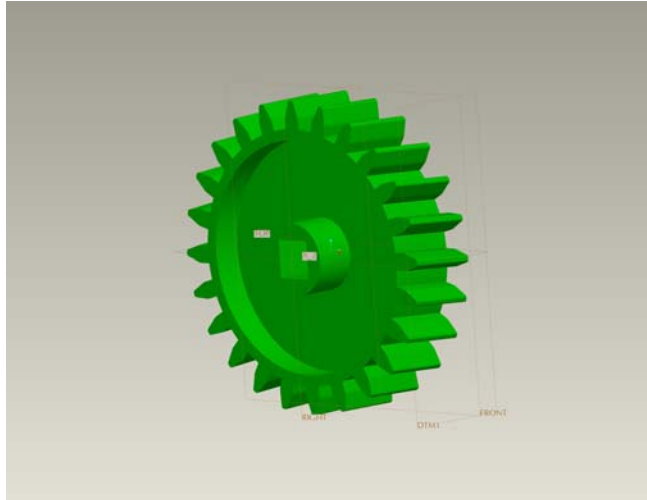


Verbal feedback of the tutorial session was generally positive, although some teachers struggled with the mechanics of the software as more advanced features such as rendering were introduced. Still the exercise provided an excellent connection between grade level and grade span expectations for the teachers and was completely adaptable to an individual teacher's lesson plan.

Although conceived of as an exercise for use in their classrooms, the major result of presenting the tutorials proved to be a means for establishing a relationship between RWU and the BWSO. In fact, the other outreach programs described below have all been a direct result of that initial meeting, and have all been initiated by the teachers in the BWSO.

Robotics Competition

In January of 2008, we began working directly with high school students involved in a robotics competition for which a requirement was to create a 3-D computerized representation of their robot. The students involved in the competition are all members of the same class, thus this particular outreach program was incorporated into existing high school classes during the school day. The sessions consist of instructing the students on how to use Pro-E to draw the various components of the robot and then finally how to assemble them into a representation of their built robot. One example is a gear, shown below.



We have used two methods of presentation: paper tutorial and “lecture-type” instruction. The paper-based tutorial method amounts to having the students follow an extensive set of written instructions to complete the drawing of a component. In the “lecture-type” method we show the students how to draw the part in a rapid manner after which the students follow the same steps. It is remarkable how well the students can remember the (at time complex) steps. Initial feedback indicates that the latter is the preferred mode of delivery.

The Scaled-Back Club

The newest program in the RWU/BWSD program was initiated by two teachers in the middle school in early February 2008. They have titled the program the “Scaled-Back Club” as it is a group that meets in an extended school format (after school). These students and teachers are investigating how to create models of buildings in downtown Bristol RI. The teachers have selected an historic building (one of the elementary schools) for which a 3-D scale model will be made. This activity will involve the students constructing a scale version of the building in balsa wood and the entire building representation in Pro-E.

Other Design Competitions

Depending on the subject matter taught by our partner teachers, several other competitions are under investigation during this first year of the three year grant. For example, this year we have worked directly with the calculus class at Mount Hope high school exploring the JETS TEAMS competitions. JETS (Junior Engineering Technical Society) is a non-profit organization that promotes careers in engineering and technology to high school students.³ The TEAMS competition offers students the opportunity to apply mathematics, science and engineering knowledge to a number of interrelated scenarios. It is a full day morning and afternoon challenge hosted by a number of Universities and Colleges across the country. Students spend approximately in preparation for the competition. This year’s competition focuses on the Beijing Summer Olympics and includes eight scenarios. Each scenario addresses a different area of engineering involving the following:

1. Study, analyze and make recommendations regarding visitor flow to and from the Beijing National Aquatics Center.
2. Compare various transportation modes to ensure a “green” event.

³ See: <http://www.jets.org/>

3. Analyze construction and maintenance alternatives for the Whistler Sliding Center for the 2010 Winter Olympics.
4. Apply aerodynamic principles to analyze track, shot-put and soccer competitions.
5. Understand the dynamics of a pitched ball using science and engineering principles to optimize performance.
6. Consider design parameters of the Water Cube Complex for the Olympic aquatic events.
7. Identify and analyze natural hazards that may threaten Beijing, Tianjin and Qingdao and propose building design criteria for athlete housing facilities to address these hazards.
8. Analyze and recommend techniques that allow large populations of people to communicate simultaneously during the event.⁴

This competition is an excellent venue to bring students that excel in various subject areas together in multi-disciplinary teams to develop solutions to applied engineering problems.

Field Trips to the University

As a component of the partnership, it is important to bring middle and high school students onto the University campus to experience first-hand engineering and science activities and laboratories. In this respect, trips have been arranged or are in the planning stages for several collaborative meetings.

First, due to the nature of our two-semester multidisciplinary senior design class, students from the high school robotics class as well as the middle school science classes will partner with senior engineering and computer science students to experience the excitement of competition design projects. This year, among other corporate sponsored projects, four senior design competition projects are included in the portfolio. They are the ASME Human Powered Vehicle, ASCE Steel Bridge, PEER Seismic, and WERC Environmental Engineering competitions. In each of these projects, direct connections between grade level and grade span expectations in the high school and middle school curricula have been identified. High school and middle school students will rotate through presentations and an experiential learning activities directed by the University students.

Other planned trips for the middle school science classes include visiting and interacting with the University's marine science shellfish hatchery and for the Scaled Back Club, visiting an historical model making exhibit at the architectural school.

How to Get Involved

Each state is allocated a significant budget from the Department of Education for Mathematics and Science Partnership grants and activities. In many cases in the past, some of this budget was directed to University and College departments of education with the directive to get STEM faculty involved. In a review of current 2008 New England MSP RFPs, we find explicit language requiring a partnership with higher education STEM faculty by applicants for the grants in each State. We were fortunate in Rhode Island that the 2006 State RFP was written in a manner directly recognizing the value of, and in fact encouraging the partnering by local school districts with engineering schools.

Even in Rhode Island, the smallest State in the country, the amount of money allocated by the Department of Education for various grant programs is staggering.⁵ We suggest that if interested in mathematics and

⁴ See: <http://www.jets.org/TEAMS/about/index.cfm> and <http://www.jets.org/TEAMS/news/pr013008.pdf> for a press release outlining competition scenarios

⁵ To review a state by state allocation of the proposed Department of Education budget for the various grant programs, see: <http://www.ed.gov/about/overview/budget/statetables/09stbyprogram.pdf>

science partnership grants or other state grant programs presenting synergistic opportunities for engineering departments, that individuals identify key State personnel. In some cases individuals responsible for crafting the RFP for these proposals are the designated program contacts.⁶ In addition, many school districts may refrain from applying for these grants because of the lack of established partnership networks between the districts and engineering departments at institutions of higher education. In some cases, these relationships may already exist at the club and classroom level through such programs as the First Lego Robotics competitions, Girl Scouts engineering badge workshops and National Engineers Week activities.

Conclusion

As a result of the ESEA Title II, Part B Mathematics and Science Partnership grant program the Engineering Department at Roger Williams University has entered into a very successful partnership with the Rhode Island Department of Education (RIDE) and the Bristol Warren School District. The PRIMES (Partnerships and Research Investigations with Mathematicians, Engineers and Scientists) program has allowed both University engineering faculty as well as middle and high school teachers to explore and undertake a range of engineering and applied science outreach activities. These activities, overviewed in this article, have served to establish a bridge that we hope in time will ultimately affect the pipeline of entering engineering freshmen. At the very least, the partnership has provided the authors with a deeper appreciation of the challenges and opportunities associated with middle and secondary education systems in Rhode Island and the nation.

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⁶ For resources associated with the DOE's Mathematics and Science Partnership Grants as well as an Excel[®] file download for each State's designated MSP contact person/s, see: <http://www.ed.gov/programs/mathsci/resources.html>

Author Biographies

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Dr. Charles Thomas presently serves as an Assistant Professor of Mechanical Engineering at Roger Williams University in Bristol, Rhode Island. He graduated from the University of Rochester with a B.S. in Physics, and from Boston University with an M.S. and Ph.D. in Mechanical Engineering. Dr. Thomas's research involves studying the effects of cavitation during high intensity focused ultrasound insonation as well as the design of effective pedagogical approaches for teaching engineering.