

Developing a K-16 Continuum for Science and Engineering Studies

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ABSTRACT: There exists a growing national crisis in science and mathematics in the United States of America. The achievement of students in science and mathematics, a growing shortage of all teachers, the need for continuing teacher development among those who are serving in our schools and the competition from other nations in the global community all require that we develop an educational strategy that addresses these issues. In response, Polytechnic University has fostered the development of partnerships with New York City's pre-college community to focus attention on science, mathematics and technology. This K-16 continuum's several strands benefit students in both secondary schools and colleges, offer instructional reforms, support teacher development and contribute to improved student achievement in science and mathematics.

INTRODUCTION

Science and mathematics often serve as inadvertent gatekeepers for students. Failure to develop a sound background in these subjects may limit access to college studies and prevent students from becoming accomplished in academic life, particularly if as high school students they fail to enroll in sufficient college preparatory courses in science and math to ready them for advanced work. Unless measures are taken to encourage students' interests in the sciences, and assist them to learn, many students fall by the wayside and are *de facto* denied an opportunity to achieve.

From the most recent TIMSS (i.e., Trends in International Mathematics and Science Study) comparison of international achievement in mathematics and science, it is alarming to note that only about three of ten U. S. fourth and eighth grade students achieved the "proficient" level in mathematics, with "proficiency" defined as demonstrated competence with demanding material. Moreover, 30% of third graders and only 20% eighth graders were minimally competent, or able to perform basic computations. Lest this be regarded as an American problem, however, it should be noted that American eighth graders achieved an average score of 502 in mathematics, while the average for the 38 nations participating in the TIMSS study was 487. The challenge is too widespread to be ignored. [1]

Two factors contribute to the American educational crisis that sees relatively few students studying science and mathematics in college, and an even smaller number studying engineering. The first is the weak academic preparation students receive and the

second is a lack of knowledge regarding career options in science and engineering, or even an awareness of what an engineer does. Connecting the university and industry to schools, therefore, becomes a vital tool in attempting to intervene by introducing students to career possibilities in science and engineering when they are at an impressionable age. [2]

The "digital divide" characterizes the inequities which are based on economic differences [3]. In the information age, financial circumstances prevent some students from having computers in their homes, learning to harness information that is available via the Internet, improving their communication skills or developing an interest in unfamiliar locations, events or personalities. No such catch-phrase exists for the "scientific divide," but this is an equally insidious by-product of educational difference.

Many organizations have sought to address this issue. The National Action Council for Minorities in Engineering (NACME) seeks to identify promising minority students, provide them with training and encourage them to study science and engineering. FIRST (For Inspiration and Recognition of Science and Technology) promotes a national robotics competition for high school students and other programs for middle school students in an Olympics-style format. The National Consortium for Specialized Secondary Schools in Mathematics, Science and Technology (NCSSSMST) provides teacher training conferences, offers student meetings and gives students an opportunity to publish their research

findings. Scholarship programs abound on both the local and national levels, with publicity directed to those which offer scholarships and prizes worth many thousands of dollars. The most famous of these are the Intel Science Talent Search and the International Science and Engineering Fair, whose winners become much sought-after by college recruiters. [4]

It may be regarded in some quarters as advantageous to other nations were American economic leadership, based largely on innovation in science and technology, to erode. Other nations hold certain key competitive advantages, including a structure of lower-wages and creative minds and ideas. But increasingly, as we operate within a world-wide economy, nations are increasingly interdependent. Strengthening economic capacity world-wide will benefit all nations, which makes the current predicament one that requires immediate attention by all within the scientific community [5].

As a recent report issued by the National Academies Committee on Science, Education and Public Policy recommended, steps should be taken to enable higher education institutions in the United States to “develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.” [6] But this will not occur without also improving science and mathematics education in science and mathematics, dramatically increasing the number and skills of teachers, and increasing the number of students who study in higher level courses, particularly those which introduce students to laboratory and research experiences.

TEACHING THE TEACHERS

In 1996, Polytechnic University created the Packard Center for Technology and Educational Alliances. With the addition of new contracts, grants and gifts, the center enables the university to provide a variety of services to meet its primary goals, which are:

- to ensure equity of availability, opportunity and access for women and underrepresented minorities in the use of computers, information-age technology, and the study of mathematics and science.
- to build alliances of stakeholders in enabling information-age technology to impact the learning process, and social, economic and educational institutions.

· to serve as a resource for the professional development of teachers to enhance learning in science, mathematics and computer science.

In addition to offering symposia and conferences which target groups of teachers and present them with an opportunity to acquire specific knowledge and skills—e.g., using technology to enhance the teaching of writing, exposure to a laboratory experience in materials science/chemistry, introductory science and mechatronics—traditional courses are offered for credit, as well as workshops to support experiential activities that involve pre-college students. Currently, a New York State Math/Science Partnership Grant affords teachers in one of New York City’s school districts an opportunity to earn graduate credit in mathematics. The targeted group of teachers includes elementary and middle school teachers who may have learned to memorize mathematical algorithms but may have had an insufficient exposure to mathematics in college, or perhaps even in high school, to understand the mathematical concepts behind the formulae or their possible application as a real world experience. In addition, robotics workshops are offered on weekends during the school year to arm teachers with the skills that will help them coach their schools’ robotics teams, preparatory to the scientific competitions organized under FIRST.

The Packard Center serves to integrate additional offerings, as well. For example, a three-year “research experience for teachers” grant from the National Science Foundation trained more than 30 high school teachers as researchers [7]. They discovered, sometimes invented, and applied acquired skills in mechanical engineering, mechatronics and robotics, in a demanding six-week summer experience. These project and prototype development skills were adapted for use in their own classrooms and they also encouraged the teachers to secure grants, themselves, to support their schools’ new curricular offerings. Robotics curricula have been developed by program alumni, with assistance from Polytechnic faculty, and are in place in high schools as a way of broadening academic offerings in science but also as a way of introducing students to engineering and to challenging, untraditional courses.

SUPPORTING PRE-COLLEGE STUDENTS

Polytechnic offers four Principal's Scholars Dinner-Symposia each year, in part as a recruiting tool since eleventh grade students come onto campus, but primarily as a way to introduce students and the teachers who accompany them to topics in science and engineering. Almost 4,000 high school students have participated in these programs, each of which invites principals to select a group of students whom they wish either to reward or more likely to encourage, based on the topic for the evening. A professor discusses a topic in his discipline (e.g., Polymer Composites; Computing in the Age of Miniaturization; Pendularity) following a buffet dinner, questions are posed by the audience, and follow-up is left to the teachers who participate. The evaluations consistently demonstrate that the students who attend, who are evenly divided between males and females, generally share an interest in science but likely do not have a family member who works in the sciences and can provide informed encouragement to inspire them to pursue advanced studies. This is precisely the group we are most interested in serving. An ancillary benefit of this program is the opportunity for students to see their teachers as learners, themselves. Teachers ask questions of the speaker, take notes and presumably discuss the experience after the evening concludes. That so many of the teachers continue to attend year after year is an indication that they value the experience for their students and for themselves.

Funded under a GK-12 Fellows grant by the National Science Foundation, a project known as **Revitalizing Achievement using Instrumentation in Science Education (RAISE)** [8] placed a dozen Polytechnic students in four selected high schools where they devote a minimum of ten hours each week to laboratory instruction, in addition to five hours per week of preparation time in which they devise collaboratively experiments, pursue research and utilize planning time. Known as RAISE Fellows, these undergraduate and graduate students serve as partners with sixteen teachers to integrate modern sensing, instrumentation and monitoring technologies into two required science courses (i.e., Living Environment and Active Physics) and two electives (i.e., Physics and Marine Science). Indirectly, a basic mathematics course is impacted since the use of instrumentation requires a solid foundation in mathematics. Judicious integration of sensing technology within the curriculum and the instructional framework permits students to improve their technological literacy and provides them with

encouragement and exposure to scientists/engineers-in-residence who are young, enthusiastic and knowledgeable, and who often attended similar high schools only a few years earlier. A learning community has been created, including Fellows, teachers and high school students, and additional resources are directed to these inner city schools. For Polytechnic, this collaboration joins the Packard Center with the departments of mechanical engineering and civil engineering. An ancillary benefit is the five published papers which have been accepted for publication, which provides Fellows with a learning opportunity and a chance to enhance their careers, as well. The three professors assist with the writing, but the primary researchers and authors are the RAISE Fellows, who benefit directly from this unique opportunity to be regarded as published scholars.

In collaboration with the American Society of Civil Engineers, Polytechnic organizes the Future City Competition each year. Consistent with a wish to involve younger students in science and engineering, this project calls for a four month preparation period, in which students work in teams, improve their skills with the computer by using a simulation program, research land use and environmental issues, write essays, plot a section of a city which they have devised, build a three dimensional model of their city, and defend their conception before an expert panel, consisting of engineering professors and practitioners. Another experiential competition in science and engineering for younger students is the FIRST Lego League, a table-top robotics competition that now requires activity over two days since the number of school teams has grown so large.

FIRST, which seeks to inspire and recognize students in science and engineering in a manner that can best be compared to a basketball championship tournament, also has designed the FIRST Robotics Competition. FRC calls on high school student teams to solve a design problem, develop a robot over a three month period using a kit with specific materials, and compete against other school teams. The pit area, where robots are debugged and changes made during the competition, is an exciting place, as students wrestle with the application of performance standards that provide immediate feedback to how successfully they have applied their understanding

of engineering principles. The palpable enthusiasm which has arisen has led the New York City Department of Education to invite Polytechnic to expand its management of this project to provide additional teacher training activities.

Polytechnic is also a partner with the New York Academy of Sciences as organizer of the New York City Science and Engineering Fair. Students at all levels enter at the first level, which is unscreened, but only the most accomplished high school projects are then selected to participate in the screened Fair, held at Polytechnic University. The best of these projects are selected, after an exhausting yet inspirational day of judging by scientists and engineers, for the International Science and Engineering Fair, which their creators attend as the New York City delegation.

NEW INITIATIVES

Polytechnic University is engaged in a partnership with a community based organization, the Urban Assembly, to begin a new school, which is scheduled to open in September, 2006. Called the Urban Assembly Institute for Math and Science for Young Women, this sixth through twelfth grade school will enroll girls, as a way of fostering their leadership capabilities and also to direct their attention to career areas in which young women historically have not been well-represented. Implicit is the need to provide strong training in mathematics and science, particularly since students who enroll will offer varied abilities. Polytechnic faculty will be called upon to offer assistance to help develop and enrich the curriculum, Polytechnic students will be called upon to visit the school to serve as mentors and tutors, the school's students will be encouraged to participate in scientific competitions and activities, such as those described earlier, and the school's administration as well as that of Urban Assembly, will be called upon to consult frequently with Polytechnic leadership to ensure that this partnership is a viable one. College admissions and financial aid workshops will be offered to parents to ensure that encouragement to attend college is constant.

ASSESSMENT

A major concern in all of these activities is the length of time between offering a project and assessing its effectiveness. Another is the reliance on soft data—that is, changes in attitude, rather than analysis of measurable achievement. Students, teachers, schools

are exposed to various uncontrollable influences, which inhibit an ability to develop objective results. This is problematic, but one needs to develop such measures to the extent possible, in order both to satisfy funders and to determine effectiveness of the effort. One can examine numbers of participants, stated perceptions of impact, graduation data, attitude change and other objective measures, but it is important to attempt to expand assessment capabilities in the future. Polytechnic is motivated to forge a K-16 continuum to address the crisis in science and mathematics. We believe that as this strategy expands, we will have the best chance to improve student achievement, and enrollment, in science and engineering studies, which would be in everyone's best interest

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