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A University/Public School Partnership in K-6 Engineering Education

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Abstract
Massachusetts introduced technology and engineering into its K-12 curriculum frameworks in 2001. With funding from the National Science Foundation (NSF), Worcester Polytechnic Institute (WPI) and the Worcester Public Schools (WPS) have formed a partnership to develop technology/engineering curriculum materials for grades K-6 and to prepare teachers, who do not generally have a technical background, to implement them. The participants are WPI faculty, graduate fellows in engineering and science disciplines, undergraduate engineering and science students, and WPS elementary school teachers. This partnership is innovative because it is the first to address the Massachusetts technology/engineering frameworks in grades K-6.

Project Objectives
NSF has a longstanding interest in addressing pipeline issues in technical education, and this program represents an opportunity to interest young children, especially girls and underrepresented students, in technical careers. The goal of the NSF Graduate Teaching Fellows in K-12 Education (GK-12) Program is to prepare engineering graduate students, not necessarily to become K-12 teachers, but to be informed about and engaged in K-12 education throughout their professional careers. Our project is titled "K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)"; its objectives are to develop partnerships between WPS and WPI; to implement the technology/engineering portion of the Massachusetts Science and Technology/Engineering Curriculum Frameworks (MSTECF)(Massachusetts Curriculum Frameworks, n.d.) in grades K-6; and to develop curricular materials and prepare teachers so that the project is self-sustaining after the NSF grant expires.

Significance
Competition for a limited number of potential engineering majors among institutions of higher education continues to increase, and the future need for scientists and engineers in the U.S. technological workforce far outstrips the anticipated supply. It is becoming increasingly crucial for both academic engineering departments and the U.S. technological workforce that women and minorities, who typically participate and persist in technical fields at much lower rates than white males, are attracted to technical fields in increasing numbers. Typically institutions of higher education attempt to address such “pipeline” issues by interventions targeted at middle and high school students. However, by middle school, students have generally formulated their attitudes toward math and science. Course choices made in middle school, particularly with respect to mathematics, set a student on a virtually irreversible trajectory with respect to preparation for college admission in technical fields. The logical place to intervene is in elementary school, when students’ career aspirations are relatively pliable. From a practical

standpoint, if one wishes to impact large numbers of minority students, urban public schools are an ideal place for such interventions. From a social responsibility standpoint, many students in urban schools have never entertained the notion that they could go to college, so here is a place where engineering educators can make a meaningful difference.

Project Organization

In the three years of the project (2003-2006), we will address grades K-6 in several elementary schools. In the first year (2003-2004), we are working with six classes, one in each of grades 4, 5, and 6 in each of two Worcester elementary schools. A team at each grade level consists of two WPS teachers, two WPI graduate fellows, four undergraduate students and one WPI faculty advisor. Teachers provide grade level pedagogy and curriculum expertise; graduate fellows and undergraduate students provide engineering expertise, ideas, and resources. WPI faculty advisors mentor the graduate and undergraduate students. So that the project will ultimately be self-sustaining, implementation of the curriculum is done primarily by teachers. WPI fellows and undergraduates develop curriculum materials, procure supplies, and support teachers by being present in the classroom to help facilitate the (primarily hands-on) lessons.

In subsequent years, teachers from the first year of the program will mentor colleagues in other schools, and graduate fellow support will be focused on supporting teachers in more schools and developing new curriculum for successively lower grade levels (grades 2 and 3 in 2004-05, and grades K and 1 in 2005-06). After funding expires, teacher mentoring will be sustained by experienced WPS teachers and engineering expertise will be provided by WPI undergraduates.

Personnel

The proposal was written in close collaboration with administrators in the WPS, with whom WPI has a longstanding positive relationship involving multiple collaborations. Once the grant was funded, WPS administrators recruited principals of two elementary schools, who in turn identified interested teachers. The teachers are highly committed to the project; they are also compensated as consultants at the rate of $28 per hour for up to 115 hours on the project each year. The 115 hours include a 35-hour summer workshop, and 80 hours (about 2 hours per week) during the school year.

For the first year of the project, seven graduate fellows (three women, one of whom is an underrepresented minority, and four men) were selected from a pool of about 30 applicants. Graduate fellows are expected to devote 30 hr/wk to the project during the summer and 20 hr/wk during the academic year, including class time, preparation time, and travel time to school. Six graduate fellows are paired with teachers in grade level teams, and one graduate fellow works as an “administrative fellow” to organize meetings, build the project web site, and develop promotional materials. (We anticipate that an administrative fellow position will not be necessary in the second and subsequent years of the project.) Graduate fellows are compensated with full tuition and a $27,500 annual stipend (2003-04). Each fellow has a $150 supplies budget and $50 photocopying budget to use for materials in the classrooms in which they are working. We deliberately kept the budget for consumables low because we want to encourage the development of low- or no-cost lessons that will be sustainable by WPS after the grant expires.

During the first year of the project (2003-04), undergraduate students involved in the project are completing a science-technology Interactive Qualifying Project (IQP) that is a WPI degree requirement, and are not compensated. For the second and third project years, undergraduates who have worked on the project for one year will be eligible to apply for paid undergraduate fellowships, and we will have additional undergraduate support from new IQP students. Undergraduate students spend 12-15 hr/wk on the project during the academic year, including 2-4 hours per week in the classroom at the peak of their involvement. After grant funding expires, ongoing teacher support will be provided by IQP students.

Engineering Curriculum

Curriculum is intended to address the MSTECF and the WPS Benchmarks for each grade level and to minimize disruption to an already full curriculum by integrating engineering with existing science lessons. Lessons are organized around the engineering design cycle concept as a unifying framework. Sample curriculum modules developed to date include

- Brainstorming about such topics as removal of leaves from the school grounds, or the absence of chalk in the classroom;
- Testing the optimum amount of water needed in a water rocket (made from a 2-liter plastic soda bottle and pressurized by a bicycle pump) to introduce testing, data collection and graphing;
- Designing a "dream house" to introduce sketching and economic design constraints;
- Designing, building, and testing (using individual stream tables made out of foil roasting pans) a barrier that prevents soil loss by erosion while letting water pass;
- Designing a habitat to house an animal of the students' choice, to introduce design constraints and user needs;
- Constructing weather station instruments out of common items.

Additional curriculum enrichment is provided by means such as "tool of the month" or "engineering corner" displays in the classroom. In addition, some classes have visited WPI for a robotics demonstration.

Orientation and Training

The project year and the graduate fellowships begin on June 1. We begin the year by scheduling fellows to visit the teachers' classrooms before the public school year ends. A major summer activity is a week-long workshop for teachers, graduate fellows, and faculty right after the public school year ends. The goals of the workshop are to familiarize the teachers with the nature of engineering; to form fellow-teacher partnerships that will last for the entire school year; and to provide the fellows with sufficient direction that they can develop curriculum materials during the summer with very little additional input from the teachers. In the workshop, local experts facilitate hands-on engineering education activities. Once the fellows and teachers have had a chance to interact, a matching process pairs them up, and each pair spends the remainder of the workshop reviewing the teacher's existing science curriculum and planning a year-long schedule of engineering lessons to complement it.

After the workshop, we proceed with an intensive orientation process for the fellows. At twice-weekly project meetings, they hear from a series of experts about topics such as Massachusetts' standardized achievement test, MCAS (Massachusetts Comprehensive Assessment System, n.d.), WPS demographics, and how to support girls and underrepresented students in the classroom.

The fellows write literature reviews on various educational topics, develop and deliver engineering workshops for WPI summer camps for elementary and middle school children, and make frequent presentations to the rest of the group.

Once the school year begins, the entire WPI team (seven fellows, twelve IQP students, and three faculty) meet weekly, mainly to share lesson plans. Each grade level team also meets weekly to review individual classroom activities and to share resources between classrooms. The fellows and teachers meet every two months to review project progress, policies, and draft documents (such as the fellow evaluation rubric, or a proposed lesson plan template). WPI faculty meet every two months with principals, and participate as needed in WPS events such as school committee and parent-teacher organization meetings.

In future project years, we look forward to having experienced fellows and IQP students participating in the orientation of the new team.

Assessment

Quantitative assessment, currently under way, focuses on success in recruiting teachers, graduate fellows, and undergraduate students; teacher satisfaction with graduate and undergraduate students; teacher perceptions of their preparation to deliver an engineering curriculum; student interest in engineering and technology; and student achievement. Assessment instruments include surveys of all participants (including K-6 students), teacher-led in-class assessments, focus groups, interviews, and student performance on MCAS. High student mobility (over 100% in one school) makes it virtually impossible to follow individual students' achievement over time, so assessment is focused primarily on teacher preparation. Because the technology/engineering MCAS test will be administered only in the fifth grade, and because it is reasonable to expect that students will need several years of exposure to technology/engineering curriculum in order to demonstrate learning on MCAS, the time frame for collecting student MCAS data is far longer than the funding period.

Both WPS teachers and WPI faculty evaluate fellows' performance every three months using a rubric that we developed together, with input from the fellows. IQP students receive grades and narrative feedback every two months.

Challenges

Many of the challenges we face are typical of those found in an urban public school system. They include high student mobility (in some cases the same student starts in one class, leaves the school, and comes back, all in the course of one school year); large classes (up to 35 students); high proportions of children with special needs and who do not speak English as their first language or at all; heavy teacher workload; inadequate technology infrastructure; delays in getting criminal records clearance for our students to enter the schools; last minute finalization of teacher assignments to classrooms; and severe budget limitations in the school system.

We had expected the looming technology/engineering MCAS test to be a motivator for participation, but because of the student population in these schools and the priorities of the WPS, the primary focus is on preparation for the reading and mathematics portions of the

MCAS. Nevertheless, motivation and morale among our pilot group of teachers and fellows remains high, and they report a high degree of success and satisfaction to date.

Other challenges are institutional in nature. The PIEE fellowships pay far more (full tuition plus a stipend of $27,500 per year) than other forms of institutional TA or fellowship support. Therefore, institutional interest lies in using these lucrative fellowships to attract outstanding graduate students with research potential who might not otherwise choose to attend WPI. However, the interests of the PIEE project and of the fellows might best be served by awarding the fellowships to graduate students who have established an academic track record at WPI; or, alternatively, by selecting students who may have more interest in pursuing education rather than a research career, and thus may not exhibit traditional academic credentials.

In this first year of the project, the focus is on developing the infrastructure and the relationships that will support ongoing collaboration, and developing a catalog of engineering lesson plans. There is little integration of curriculum between the two classes at each grade level, and much repetition of curriculum between grade levels. In the second year of the project, we will need to pay more attention to coordinating curriculum between classes so as to create a logical progression and avoid duplication from one grade level to the next.

Keys to Success

In spite of the challenges, the PIEE project is proceeding more smoothly than anyone had hoped. A key element of this success is the true partnership between WPS and WPI. Public school personnel, understandably, approach collaborations with higher education cautiously, anticipating that the university “partner” will dominate the relationship and have little appreciation of or respect for the school culture. At the same time, higher education often faults K-12 for not understanding higher education's culture and always expecting "handouts." The PIEE project has drawn consistent praise from WPS personnel, due primarily to their perception that WPI team members approach the project with respect for the expertise and authority of the teachers, and with sensitivity to the culture and constraints of the public schools. By focusing on supporting the schools’ needs, sharing our expertise rather than imposing our own agenda, and by learning about and cultivating the young students who may be our future clientele, we appear to be well on the way to developing a partnership that will benefit all of the players.

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