K-6 Gets a Piece of the PIEE -

Partnerships Implementing Engineering Education

PROJECT SUMMARY

This project focuses on development of human resources related to grade K-6 Science, Math, Engineering and Technology education in an urban public school system, the Worcester (MA) Public Schools (WPS). The talent to be developed includes

- K-6 teachers, who must implement a new state-mandated Curriculum Framework for pre-engineering education;
- K-6 students (nearly half of whom are students of color, with minority numbers growing, whom we would like to encourage to consider technical careers); and
- graduate and undergraduate students at Worcester Polytechnic Institute (WPI) who are majoring in technical disciplines but who would like to gain experience in an educational setting and the sense of using their technical education in a helping role.

The total number of fellows per year are zero to five uP-Fellows and six to seven gP-Fellows, depending on the year of the project.

The goals of this project are:

1. To develop partnerships among graduate and undergraduate fellows, public school teachers and students, and WPI and WPI-affiliated faculty.

2. To implement the Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) in the K-6 curriculum, by using the partnerships to develop specific teaching strategies. These strategies will use engineering design process and data collection analysis to teach math, science, writing and engineering.

3. To assess and disseminate:
    a. The outreach process we develop for recruiting fellows;
    b. Student learning outcomes of the K-6 engineering design curriculum;
    c. Teacher preparation that results from this project.

The 2001 Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) can be found in the Supplementary Documents section of this proposal. Massachusetts is the first state to adopt a framework specifically including engineering/technology. It is planned that the Framework will enable teachers and administrators to strengthen curriculum and instruction from Prekindergarten (PreK) through grade 12. The program proposed here will provide the teachers in the WPS [and through documentation and dissemination, teachers throughout Massachusetts and beyond] hands-on and relevant examples and lesson plans to use to meet these Framework objectives for K-6, a set of grades presently not addressed as well as the middle and high school years.

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PROJECT DESCRIPTION

I. Goals and Objectives

This project focuses on development of human resources related to Kindergarten (K) through 6th grade Science, Math, Engineering and Technology (SMET) education in an urban public school system. The talent to be developed includes

- K-6 teachers, who must implement a new state-mandated Curriculum Framework for pre-engineering education;
- K-6 students (nearly half of whom are students of color, with minority numbers growing, whom we would like to encourage to consider technical careers); and
- graduate and undergraduate students at Worcester Polytechnic Institute (WPI) who are majoring in technical disciplines but who would like to gain experience in an educational setting and the sense of using their technical education in a helping role.

The elementary schools involved are middle schools in the Worcester Public Schools (WPS) system, "feeder" schools for a middle and high school in a quadrant already participating in an engineering pipeline project.

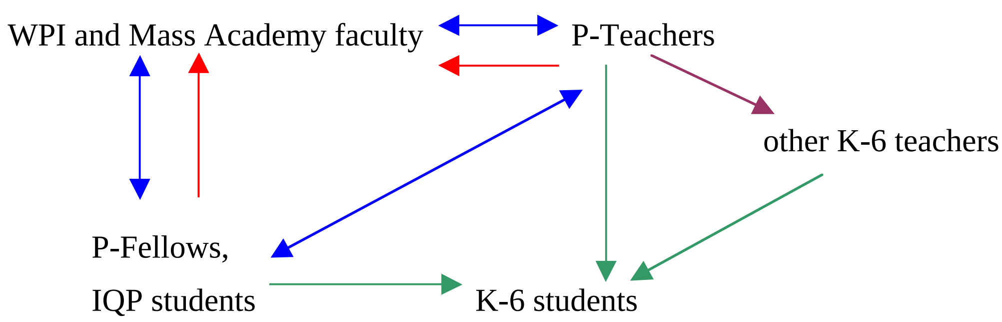

Figure 1: Partnerships described in this proposal.
Activity code: blue - curriculum development
red - reporting for project assessment purposes
green – instruction
purple - mentoring

The goals of this project are:

1. To develop partnerships among graduate and undergraduate P-Fellows*, P-Teachers, WPS K-6 students, and WPI and WPI-affiliated faculty. The relationships to be developed are shown in Figure 1, and are categorized as being part of curriculum

* P-Fellows stands for Partnership Fellows, the name given to the graduate and undergraduate fellowships described in this proposal. When a distinction is necessary, gP-Fellows and uP-Fellows are graduate and undergraduate Partnership Fellows, respectively. P-Teachers are the WPS teachers working on the teams, and are a subset of the general body of teachers in WPS.

development, reporting, instruction to K-6 pupils, and peer mentoring on the part of P-Teachers.

2. To implement the Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) in the K-6 curriculum by using the partnerships described in Figure 1 to develop specific teaching strategies and curriculum. These strategies will use concepts from engineering design process, data collection, and analysis to teach math, science, writing and engineering.

3. To assess and disseminate:
   a. The curriculum developed and refined as part of this project;
   b. Student learning outcomes of the K-6 engineering design curriculum;
   c. P-Teacher preparation that results from this project.

The specific objectives are to produce the following:

1. A cadre of K-6 teachers proficient in science and engineering to support their colleagues in the Worcester Public Schools (WPS) on an ongoing basis once grant support ends. This structure will be designed to serve as a model for other school-college partnerships.

2. A set of lesson plans and lab activities, consistent with the MSTECF, for incorporating technology and engineering into the K-6 curriculum. These methods and materials will be transportable to other Massachusetts elementary schools, and should be adaptable to other states depending on their particular curriculum frameworks.

Specifically, we intend to develop a competitive program to select P-Fellows and to train them to mentor and support teacher teams. Each of the four WPS quadrants has an educational theme; the focus in the Doherty quadrant is science and engineering -- chosen in part to maximize the proximate relationship with neighboring WPI. The schools involved in this project will be from the ten elementary schools in the Doherty quadrant. This quadrant was chosen because we felt that it would have the highest potential for success (when compared to other quadrants in WPS) as the elementary teachers know that their students will be participating in programs related to engineering and technology in their subsequent education *and* there is currently no programming for these teachers to prepare them for teaching these topics. The P-Fellows will work with P-Teacher to assist them to design and implement activities in accord with the new Framework. The P-Teacher teams will be selected competitively so that, as part of their obligations, they will help disseminate their materials both within their school and then (after appropriate revisions) in other schools. The individuals from WPI and WPS together will plan the proposed activities collaboratively, i.e. based on each institution’s experience with the other and their mutual self-interests.

II. Background

II.A. WPI

WPI (Worcester Polytechnic Institute), the third-oldest private university of engineering, science, management and the humanities in the United States, has been a pioneer in technological higher education since its founding in 1865. WPI was ranked among the top national universities in the 2000 edition of U.S. News and World Report's Best Colleges Guide and was ranked among the top national institutions in the magazine's Best College Values report. The current student body of over 3,700 men and women includes more than 1000 full- and part-time graduate students.

II.B The IQP Program

In 1970, WPI adopted a flexible and academically challenging program aimed at helping students learn *how to learn*. Known as "The WPI Plan", classroom experience is synthesized into projects that solve real-world problems. In addition to course requirements, students complete three projects. One is within the student's major, and is known as the Major Qualifying Project. A second is the Interactive Qualifying Project (IQP). This project is the equivalent of 9 credit hours and challenges students to investigate a topic examining how science or technology interacts with societal structures and values. The third graduation requirement is the Sufficiency, which is done on a theme within the Humanities and Arts.

The history and qualities of the IQP are important cornerstones of this project because one thematic focus for IQPs is "Education in a Technological Society." Students who choose this division frequently teach and/or develop curricula for grade levels from K through college. For example, a mathematics enrichment program was successfully designed and tested in a local middle school.[1] Another IQP developed a curriculum for the teaching of computer skills to children.[2] Other IQPs are already addressing the necessary development for the MSTECF challenge *for high school level work*, including new instructional hands-on projects on flight, robotics, and forces and motion.[3]

II.C Worcester Public School System (WPS)

The City of Worcester has a population of over 170,000 and is the second largest city in the state. It is diverse, with more than 46% of the WPS students being non-Caucasian. Section III.C describes how we intend to address the diverse population found in the WPS. The following is demographic information on WPS as recorded in 2000:

Enrollment by Grade:

PreK	K	1	2	3	4	5	6
835	2188	2313	2136	2159	2177	2083	2008

Enrollment by Race/Ethnicity (% of District):

Native American	0.5
African American	10.3
Asian	7.6
Hispanic	27.9
White	53.7

The WPS work with an inclusionary model. Students at the elementary level are heterogeneously grouped, not separated according to perceived ability. For example, students at Elm Park Community School include large numbers of at-risk students: students who are 2nd language learners, and underrepresented minorities, whose families are low-income and highly mobile.

II.D. K-6 Engineering Education in Massachusetts

Massachusetts is the first state to adopt an educational framework specifically including engineering/technology, and did so as part of the Massachusetts Education Reform Act of 1993. The 2001 Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) can be found in the Supplementary Documents section of this proposal. This document describes the Massachusetts guidelines for learning, teaching, and assessment in science and technology/engineering. It is planned that the Framework will enable teachers and administrators to strengthen curriculum and instruction from Prekindergarten (PreK) through grade 12.

This proposal most directly addresses "Strand 4: Technology/Engineering." As examples: PreK-2 teachers need to treat topics such as "Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever." "Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem" is a topic for Grades 3-5. By Grade 6, students should be able to "Identify and explain the components of a communication system, i.e., source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination." The present challenge is that the teachers are in large part unprepared to teach these topics – even in the Doherty quadrant of WPS. The program proposed here will provide the teachers in the WPS [and through documentation and dissemination, teachers throughout Massachusetts and beyond] hands-on and relevant examples and lesson plans to use to meet these Framework objectives.

II.E. Massachusetts Academy of Mathematics and Science

In 1992 the Massachusetts Legislature, in cooperation with WPI founded the Massachusetts Academy of Mathematics and Science (Mass Academy). It is a fully accredited public high school for 11th and 12th grade students with an exceptional aptitude in mathematics and science. Since it is located at WPI, the students have access to extraordinary laboratory and research facilities. In addition, Mass Academy is committed to helping improve educational opportunities by helping to promote new teaching and learning methods through comprehensive professional development programs.

Pauline Lamarche, Principal of the Academy, has participated in every stage of developing this proposal, and will ensure that Mass Academy faculty, along with WPI faculty, implement the administration of the program effectively. She will draw upon ten years of Mass Academy experience in offering summer workshops to train public school teachers in new ways of teaching engineering. These workshops will be one of several models our collaborative will use to assure that the programs developed for the WPS P-Teachers fully meet their needs as well as those of their pupils.

II.F. Existing Partnerships

Unlike most technological universities, WPI has had a long and close relationship with the local public school system. This connection is unusual in that, like most technological universities, WPI does not have a department of education. However, WPI does have a small experimental teacher preparation program that was recently cited as one of the two best experimental models statewide.[4]

WPI’s unique projects program has been the vehicle for WPI’s collaboration with the public schools in Worcester. The single largest topical area of interest to students and faculty for IQPs (described in Section II.B) has been collaborations with public school teachers to improve the quality of pedagogy in mathematics and science. These projects have created a history of significant collaboration and personal connections between faculty and administrators at WPI and WPS.

As part of its mission, Mass Academy, upon request, delivers workshops and provides a range of professional development to the WPS.

Other recent initiatives between WPI and WPS include participation in a $250,000 planning grant and an $8 million full proposal (both funded) to the Carnegie Educational Foundation to replicate throughout Worcester small academies within larger schools, focusing on specific topics. WPI's contribution to this effort involves expanding our existing contributions to the Worcester Engineering Pipeline collaborative, working with nearby middle and high schools. Also, WPI is part of an NSF Teaching Enhancement program that is a collaboration between Tufts University, WPI, and the University of Massachusetts campuses at Lowell and Amherst. Tufts is the lead institution, and WPI will act as a local resource for teachers participating from our section of the state. This program is beginning in 2002-03 at the senior high level. Thus the present proposal, if funded, would be the first significant collaboration for engineering/technology curriculum development between the WPS K-6 levels and an institution of higher learning.

III. Project Plan

III.A. Overview:

In the short term, a considerable infusion of person power in the form of funded P-Fellows and IQP teams will be necessary to develop and pilot test the curriculum. The long-term steady state model will be one in which WPS teachers mentor each other, and IQP teams registered for academic credit provide ongoing support for curriculum updating and enhancement. To meet both the short- and long-term challenges, we have devised a scheme where a specific grade level is first addressed by P-Teachers with a relatively large support group. During the second year, the same grade level at a different school will use the teaching material and the support group will be smaller, aided by the documentation and experience gained by the previous year(s). The support group will be smaller still by the third implementation of the curriculum. By the completion of the funded project, this three-tier systematic structuring of support staff will be complete for the three grade levels used in the first year of the grant (grades 4, 5 and 6). Grades 2 and 3 will have had one year of intensive support and one year of reduced support, and grades K and 1 will have had one year of intensive support.

Year One:

We will begin by targeting contiguous grades (in the first year, grades 4, 5, and 6) in one school. We will assemble one team at each grade level, with a team consisting of 3 P-Teachers, 2 gP-Fellows from different disciplines, one IQP group (usually two to three students), and one WPI or Mass Academy faculty member. (We will henceforth refer to this team structure as the **Initiation Team**.)

The P-Teachers will meet with the PI and other senior personnel in the early summer of 2003 for planning sessions. The entire team (P-teachers, P-Fellows, IQP members and senior personnel) will participate in a week-long workshop later that summer. Both of these are described in Section III.B.1.

Once the school year starts, the gP-Fellows and an IQP group will assist the P-Teachers in the preparation, delivery, and assessment of the lessons. gP-Fellows will be expected to spend a total of about 20 hr/wk during the school year (36 weeks) in preparation, meeting, and contact time. IQP students will be expected to spend about 17 hr/wk for 21 weeks on similar types of activities. WPI faculty will be expected to devote a total of one month during the calendar year to the summer workshop and team activities. WPS P-Teachers will be expected to spend a total of about 120 hours, counting 35 hours of summer workshop time (which will include curriculum development) and two and one-half hours per week during the school year for team activities, such as meetings in excess of their usual class preparation duties. During the school year, P-Fellows and WPI faculty will serve as disciplinary content experts; IQP members will help prepare material; P-Teachers will deliver most classroom instruction and will serve as K-6 pedagogical experts.

Before the start of the next school year, there will continue to be (even after the grant expires) a summer workshop. After the first year, selected P-Teachers and P-Fellows who are experienced in the project will play an active role in delivering the next year's workshop.

Year Two:

In the second year of the project, there will be two types of teams.

The first type of team (henceforth referred to as the **Adaptation Team**) will be centered in grades 4, 5, and 6, but in a second school. This team will adopt and adapt the curriculum developed during the first year of the project, and so they will have just 1 gP-Fellow, 1 uP-Fellow (recruited from among those with IQP experience in the program in the previous year), and one-half month of WPI faculty time to support a team of three P-Teachers. In addition, this team will be mentored by experienced P-Teachers from the Year One Initiation Team and will participate in the summer workshops.

The second type of team in Year Two will be an Initiation Team (3 P-Teachers, 2 gP-Fellows, one IQP group, and one month of faculty time) that will now focus on grades 2 and 3 at the Year One school. Activities for this team will be similar to those described under Year One, but will develop curriculum appropriate to the different grade level.

Year Three:

In the third year of the project, there will be three types of teams.

One or more Initiation Teams will develop curriculum for the grades K and 1 in the Year One school.

One or more Adaptation Teams will transport the new Year Two curriculum (for grades 2 and 3) to additional schools.

One or more **Sustainability Teams** (consisting of 3 P-Teachers and one uP-Fellow or IQP group) will transport the Year One curriculum (for grades 4, 5, and 6) to additional schools.

After funding expires:

Sustainability Teams will continue to provide mentoring for expansion of the curriculum to additional schools and to new P-Teacher hires as needed. The vehicle will primarily be the week-long summer workshops. The P-Teachers and WPI students who run the workshops will be rewarded with academic credit from WPI (for students) and/or with modest funding from WPS. P-Teachers who serve as workshop facilitators or as trainees will continue to receive Professional Development Points (PDPs), applicable to required recertification. As they do now[3], IQP teams will continue to support efforts in the WPS, and Mass Academy can be an ongoing resource to teachers.

III.B. Training and Resources

III.B.1: Summer Workshops

First, a planning meeting for the P-Teachers, PI, and co-PIs will be held before the first summer workshop to better ensure that the workshop time will be used effectively and to determine any educational objectives that the P-Teachers have beyond those described in the curriculum frameworks.

We will then hold a weeklong summer workshop at WPI for the teams of P-Teachers and P-Fellows from the pilot schools. About half the workshop time will consist of formal sessions led by WPS personnel, Mass Academy experts, WPI personnel, and in years 2 and 3, selected P-teachers and P-Fellows already involved with the program. The goals will be to bring all team members to a common understanding of the MSTECF for that grade level, and to develop the students' (P-Fellows and IQP students) understanding of the basic elements of K-6 pedagogy. The WPS personnel to lead workshops will include Patrick DeSantis, K-8 Science Facilitator, who has years of experience working with classroom teachers and on teacher workshops on curriculum following the Curriculum Frameworks, lesson plans, and the Virtual Education Space (VES), described below. He is also a former WPS Teacher of the Year, and is recognized by nationally by BASF as an outstanding science teacher. Dr. Stephanie Blaisdell, WPI's Director of Diversity & Women's Programs and an expert on ensuring that topics related to engineering are presented in an attractive way to girls and students of color, will also participate.

The other half of the workshop time will be team time, devoted to preparation of specific lesson plans. This will include opportunities for the teams to review material that they can include in the coming school year, including but not limited to:

- the extensive number of IQP reports already completed on topics that bring science, mathematics and engineering into the classroom. Many of these reports address K-6, and all have components of testing the curriculum, assessing its value, and making recommendations for the future,
- inquiry-based workshops used in other WPI outreach programs, such as REACH[5] and programs administered through the Diversity and Women's Programs Office[6],
- related programs at WPI, such as the Teachers' Program of WPI's Center for Industrial Mathematics and Statistics – which brings eighty secondary teachers of mathematics to WPI for one week each summer. While at WPI, they will see how mathematics is used in industry, through lectures and, primarily, through participation in group projects focusing on real problems, and
- educational material developed during NSF-supported programs[7],

- existing material on the VES system.

VES is an electronic system that allows teachers and professional staff to access and input curricula and units to be shared by any and all WPS faculty and staff. Curriculum units and enhancement of the science, technology/engineering content in the elementary grades will be integrated into this system to be shared and accessed by all parties. VES has a searchable database of lesson plants, units and courses used successfully by teachers that align to the curriculum frameworks.[8] VES be reviewed so that the teachers are familiar with accessing it to download from and add to the body of information available to Massachusetts' teachers.

III.B.2: School-Year Activities

WPI will design its program to train our students with the help of the WPS, using existing close collaborative ties and a WPI for-credit course to prepare P-Fellows for mentoring responsibilities as well as possible eventual teaching careers. This course (entitled "Teaching Methods") deals with teaching methods for students intending to teach science or mathematics. Focus areas include curriculum planning, assessment, delivery of effective instruction, classroom management, equity, and professional responsibility.

As described in Section II.F, WPI has a small but effective teacher preparation program. We have ten juniors in the program in 2001-2002, and students from this program could also participate in the mentoring activities we are designing for the WPS classrooms. Although the students in the teacher preparation program are preparing for licensure in Grades 7-12, which involves a different set of credentialing than K-6 licensure, the infrastructure that is in place to support these students (such as the IQP; WPI and Massachusetts Academy faculty with close ties to the WPS and knowledge of and interest in pre-college education; and regular academic courses in cognitive psychology, cultural differences, and languages) will also support our g and uP-Fellows. Additional academic courses applicable to K-6 licensure are available on a cross-registration basis at nearby Colleges of Worcester Consortium institutions such as Worcester State College and Assumption College.

In addition to the summer activities, professional development of the P-Teachers will be accomplished through

- working with "Project Lead the Way" and the UMass/Raytheon Engineering Pipeline Collaborative (EPiC) to adapt and refine specific "engineering applications" for the elementary level,
- sessions facilitated by WPS Curriculum Liaisons on integration of Massachusetts Curriculum Frameworks in Science, Mathematics and English/Language Arts to build student capacity for the Engineering Pipeline in the WPS Doherty Quadrant, and
- 2.5 hrs. weekly meetings (total) with P-Fellows to develop appropriate strategies for teaching engineering.

III.B.3. Description of Curriculum Development

Through the activities described in this proposal and shown graphically in Figure 1, new curriculum will be developed and assessed for grades K-6. This curriculum will meet its challenges in the following ways:

- *Following the Curriculum Framework*: which will be reviewed by the summer workshop leaders and returned to during the school year. With the support of WPS curriculum specialists familiar with the MSTECF, WPI and WPS faculty will structure a curriculum strongly emphasizing the concept and practice of engineering as designing products and processes to help people.

- *Age appropriateness:* using the expertise of the P-Teachers. This will mean that the material should be hands-on and exploratory in nature. It is the translation of engineering and technology topics (traditionally taught to upper-level students) to K-6 students that will be the most exciting and rewarding part of this program, and the part that will use the partnerships between WPI/MassAcademy and WPS to its fullest extent.
- *Learning style appropriateness:* The Academic Resource Center at WPI has the facilities and experience to perform a range of learning style assessments.[9] The other side of learning styles, the development of appropriate teaching material, has been addressed by the WPI Center for Educational Development, Technology, and Assessment (CEDTA) through workshops.[10]. These resources will be drawn upon during the summer workshops
- *Attractiveness to a diverse student body*: which will be reviewed in the summer workshops and returned to during the school year, particularly through the assessment process. For all students, this challenge will be partially met by providing as many different kinds of role models as possible, through the students and staff involved and the opportunity for 'guest lectures' in classrooms by WPI students (the selection of whom could be targeted for gender and racial balance). For girls in particular, this challenge will be met by showing ways that engineering can be used to help society, so important to girls when making plans for the future. [11] We will stress engineering as a "helping profession" because of our experience with using this theme to involve young people, especially women and minorities who have not traditionally viewed engineering as a profession that solves social problems.

One example of how this will be achieved is to develop material by drawing upon a workshop currently part of the WPI Camp REACH program[12]. For the past five years, we have conducted a disability awareness/rehabilitation engineering program for middle school girls. Activities focus on the problems faced by the disabled and to show how universal design benefit all persons. Currently, the specific activities include universal design (e.g., elevator controls) versus accommodation (e.g., restroom grab bars). Participants make measurements of the ADA compliance of buildings using the appropriate tools (tape measures, protractors, calipers, spring scales, inclinometers, and stopwatches) applied to hallways, stairs, and ramps. A variety of disabilities are simulated to show that some tools are difficult to use if one has limited dexterity or low vision. Writing exercises have been used, along with small group discussions and meetings with visitors who are physically-challenged.

This kind of unit meets the challenges described above because it would help PreK-2 teachers to encourage their students to "Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever." (part of the curriculum frameworks). While it is currently designed for 6th graders, it could be accommodated for younger children by the P-Teachers and P-Fellows (for example, by changing the amount of time spent on different activities and the expectations for self-discovery). It is learning-style appropriate because it has elements for Visual, Aural, Read/write, and Kinesthic learners. It is also a clear reminder of how engineers help people, which has already proven to be effective for the girls at Camp REACH.

III.C Outreach to Diverse Community

Because students of color make up nearly 47% of the WPS population and 28% are Latino, and because WPS students speak 84 languages and dialects and 25% do not speak English at home, our program design will focus on developing mentoring skills necessary for this audience. For such expertise we will rely heavily on the WPS personnel, who are already skilled at dealing with this student population. We also plan to heavily recruit participation of female and minority undergraduate and graduate students (see Section IV).

Both women and minorities are currently underrepresented in the engineering profession. For example, only 7.3% of practicing engineers are women. Full participation of women and minorities in engineering is needed, not only for reasons of equity, but for economic security. Studies indicate that a critical time in the "pipeline" of women into technological careers is the middle school years, when it is common for girls to lose interest in math and science.[13,14] For these reasons, the summer workshops will include training on presenting engineering in a positive way to girls and students of color. Since elementary school teachers are predominantly female, their excitement about the introduction of engineering and technology based units will provide wonderful role models to their female students.

III.D. Benefits to P-Teachers, P-Fellows, and Schools

The benefits to the P-Teachers will be current engineering and science knowledge, important especially for teachers struggling with new curriculum expectations. In addition, there will be strategies to implement the design as well as the data collection and analysis parts of the engineering Frameworks. We believe the P-Fellows will be effective in providing this support.

For the gP-Fellows, in addition to their stipends supporting their aspirations for graduate study, the program will help develop their potential as teachers at any level, K-graduate school. We do not intend to ask them to make any commitments to become public school teachers (but we would be delighted if some do so). The training programs for the P-Fellows will recognize their desire to “pay back to the community” through their teaching role. And the P-Fellows will also be committing to a program and a selection process to assure a high possibility that the P-Fellows will become involved in improving engineering education throughout their careers, after achieving their degrees at WPI.

The targeted schools and their pupils will benefit from the new curriculum. These students will be better prepared for their later years in the same science and engineering quadrant. Other schools, teachers and pupils will benefit from the dissemination, which will be aided electronically through the use of VES (described in Section III.B.1).

IV. Recruitment and Selection

IV.A. P-Teachers

Selection of WPS P-Teachers will be handled at the individual school level by the school's principal. This selection may not be competitive for a given school as there will be a limited number of candidates (for example, a limited number of teachers at a given grade level) possible for the positions. The P-Teachers will be expected to commit to the full program, both the summer workshop and the following school year. Preference will be given to teachers interested in becoming a resource and trainer for the program. Therefore, the real selection process will be to carefully chose elementary schools from the Doherty quadrant, using identified leaders in the first year a grade is addressed, and then expanding to include the other schools as the curriculum matures. There is administrative support within this quadrant because of the desire to create a seamless pipeline for the existing engineering and technology coursework in middle and high schools.

IV.B. Graduate Fellows (gP-Fellows)

Recruitment for gP-Fellows will take place within and outside of WPI. As described in Section II.B, many WPI undergraduates choose the IQP project topic area "Education in a Technological Society", and historically the most popular of these projects involve developing and teaching SMET curricula in the WPS. Such IQPs are a natural training ground for P-Fellows. In recruiting our gP-Fellows, we intend to target BS/MS students, who by definition have already obtained WPI undergraduate degrees. Our recruiting program will identify those BS/MS students who have completed educational IQPs, and will aim to establish a pipeline (but not the only route) from the IQP to a gP-Fellowship.

Year One (for students within and outside of WPI): Since there are activities planned from the spring of 2003, the gP-Fellows must be selected by June, 2003. In December of each year, the WPI Graduate Admissions Office begins processes to recruit for existing WPI fellowships. Applicants are asked to complete their admission application by February 1, and the fellowship application by February 15. We plan to modify the application form to include information necessary for selection to this program. At that time, with the recruitment funds available, the Graduate Admissions Office will send a mailing to all US applicants and prospective applicants. In addition, we will add it to the Graduate Admissions website, under Fellowships. We can send notifications to gP-Fellows out as early as March 1 and ask award winners to respond by the April 15 (the national reply date for graduate support) as they normally would.

To try to enhance the mentoring aspects of the P-Fellows and IQP students working in the classroom, we will make special efforts to advertise the P-Fellowships and IQP opportunities to women and students of color through WPI's Office of Diversity and Women's Programs, professional organizations [such as the National Society of Black Engineers[15] (NSBE), Society of Hispanic Professional Engineers[16] (SHPE), and Society of Women Engineers[17] (SWE)], and advocacy organizations (such as Women in Engineering Program Advocacy Network[18], National Consortium for Graduate Degrees for Minorities in Engineering and Science [19] , and Women in Technology International[20]). Seeing young women who are putting effort into giving back to their community should prove to be inspiring to the girls in the classroom.

Selection will be based on the applicant's previous experience and interest in teaching (including peer tutoring, etc.), and recommendations. It is not anticipated that academic records in the applicant's discipline will be pertinent (because they would also need to be separately admitted to WPI's graduate program) unless they include courses related to pedagogy. It will also be important to provide diversity in terms of the P-Fellows' disciplines. Given the range of material in the Curriculum Framework, we are targeting the Mechanical Engineering, Electrical and Computer Engineering, and Mathematical Sciences Departments. Letters from the pertinent people in these departments are included in the Supplementary Documents section of this proposal.

Currently, WPI has following kinds of graduate fellowships available: five Goddard, six endowed fellowships, three to six corporate, and six institute. The only one for which we require an application is the Goddard, for which we received 42 applications for the five awards. This shows that there is currently more interest in graduate fellowships at WPI than we have to offer.

Year Two: The number of gP-Fellows increases from six to seven in the second year of the program. It is anticipated that all of the gP-Fellows from Year One will continue in Year Two, so one (or more, if a gP-Fellow does not return) additional gP-Fellow will be recruited.

Year Three: In all likelihood there will be five new gP-Fellows this year, and one returning from the previous year. These P-Fellows will be recruited as described above. In addition, uP-Fellows involved with the program in Year Two would be good candidates for gP-Fellowships if they are admitted to the graduate program.

IV.C. Undergraduate Fellows (uP-Fellows)

uP-Fellows are part of the support mechanism in Years Two and Three. We will recruit for this position through the standard on campus mechanisms as well as to groups supporting women and students of color on campus (including the WPI chapters of NSBE, SHPE and SWE) and through the WPI Office of Minority Affairs. The students involved with the IQP groups from the previous year(s) would be ideal candidates as they would already be well-versed in the curriculum, project goals, etc. We will use previous teaching experience and interest, academic records and recommendations as parts of the selection process.

IV.D. IQP teams

IQP topics are advertised through an extensive website. [21] In addition, we can highlight this special opportunity for students through publications such as the student newspaper. IQP groups are usually formed three to six months before the start of the project, and we will use previous teaching experience and interest, academic records and recommendations as parts of the selection process.

V. Organization and Management

During all three years of this program, the PI will have overall responsibility for the administration of the award, the management of the project, and interactions with the NSF. She and the coPIs will divide the responsibility for various roles, including recruitment (described above), assignments to the different teams, working with the assessment consultant, and meeting with the P-Fellows and IQP students on regular bases.

A letter describing the school district participation is provided in the Supplementary Documents section of this proposal. Other aspects of Organization and Management are described in other sections of this proposal.

VI. Evaluation

Our evaluation plan will incorporate assessment of the following:

1. The outreach process we develop for recruiting gP- and uP-Fellows for K-6 education;
2. Student learning outcomes of the K-6 engineering design curriculum;
3. P-Teacher preparation that results from this project.

The outreach process we develop for recruiting P-Fellows will be evaluated using the following measures. Time points at which measurements will be taken are included in parentheses after each measure. Project year runs from June 1 - May 31; Year 0 refers to pre-project year.

- Success in filling the number of slots we have available with qualified P-Fellows, as measured by:
  - the number of complete teams compared with the planned number; (January of Years 1, 2. 3)
  - the ratio of the number of qualified applicants for student fellowships to the number of slots available; (September of Years 1, 2, 3)
- The extent to which the K-6 engineering curriculum becomes part of the ongoing IQP culture, as measured by the number of K-6 engineering IQPs completed each year; (May, Years 1, 2 3 Year 1 measurement will include comparison with two pre-project years)
- The satisfaction of the P-Teachers with their P-Fellows, as indicated by an objective questionnaire and narrative evaluation in the middle and end of the year of team activity. (January and May of Years 1, 2, 3)

Student learning outcomes of the K-6 engineering design curriculum will be measured in the following ways:

- Student success on the pertinent sections of the standardized statewide grade 4 Massachusetts Comprehensive Assessment System (MCAS) examinations, as compared between schools and classes with and without the GK-6 program, and within the same school before and after participation in the GK-6 program. We anticipate that scores within a given school will continue to rise for several years as successive generations of students participate in a curriculum that starts first in grade 4, then in grade 2, and then in K. (December of Years 1, 2, 3 including data from two pre-project years)
- Survey measures of student interest in SMET, analyzed in terms of underrepresented groups. (May of Years 0, 1, 2, 3)

P-Teacher preparation that results from this project will be measured by:

- Teacher participation over time. We expect teachers to “vote with their feet” for either a successful or an unsuccessful project; (December of Years 1, 2 3)
- A survey of the kind and amount of continuing education credit received by P-Teachers (December of Years 1, 2 3)
- A survey of how many P-Teachers are continuing to use the curriculum they developed at the end of the project; (April of Year 3)
- A tally of the extent of dissemination of the new curriculum through the schools of the Doherty quadrant; (April of Year 3)
- A survey and focus group of participating P-Teachers a year after their paid project participation, probing the extent to which they found the project useful in professional development, and the extent to which they have mentored other P-Teachers. (December of Years 1, 2 3)

The number of P-Fellows and P-Teachers anticipated to be involved in each of the years of the project is as follows:

Year 1: six gP-Fellows, nine P-Teachers

Year 2: three uP-Fellows, seven gP-Fellows, fifteen P-Teachers

Year 3: five uP-Fellows, six gP-Fellows, nine P-Teachers

The totals are five uP-Fellows, twelve distinct gP-Fellows, and forty-five P-Teachers, assuming that when possible, the P-Fellows are supported for two consecutive years.

An external assessment consultant will be hired part-time for each of the project to develop and administer the instrument and analyze the results of the assessment. Miller will oversee the work of the assessment consultant.

The participants (PIs, co-PIs, P-Fellows, P-Teachers, and IQP students) are prepared to cooperate in an overall program evaluation to be conducted by the NSF.

VII. Results from Prior Support

Nicoletti: received an NSF grant for the development of the REACH program in 1996. Camp REACH, now in its sixth year, is a two-week residential program at WPI. It brings thirty middle school girls from across Massachusetts to Worcester to generate interest and excitement about engineering and technology and the ways they can be used to help individuals, organizations, and society. The major innovation was that the girls learned what engineering is as a career by working as an engineer on a real, community service project. Discovery workshops were also developed to expose girls to a broad range of engineering and science topics through engaging, hands-on activities. Both a pre-camp orientation and a workshop on the last day of camp were held specifically for parents. We presented results at an NSF meeting, the 1997 Frontiers in Education Conference in an article entitled "REACH: An Engineering Summer Camp for Middle School Girls," and in an American Society for Engineering Education Conference presentation (June 2000) entitled “Lessons Learned While Inspiring Young Girls to Pursue Engineering." A website was developed: http://www.wpi.edu/~reach.

Miller: has had recent support from NSF and the Davis Educational Foundation, in both cases as PI. All projects concern improvement in higher education, but the pedagogical principles are largely transferable to pre-college education. An NSF IWR grant focused on developing curricular and conceptual “bridges” between pairs of introductory SMET courses, as a way of helping students see the relevance of introductory courses to their majors. Supported by a Davis Educational Foundation grant from 1992-1997, Miller and her colleagues developed and pilot tested a Peer-Assisted Cooperative Learning model that utilized undergraduate Peer Learning Assistants (PLAs) to facilitate cooperative learning groups in large introductory courses. Long-term assessment of outcomes showed that students who took PLA-assisted courses in their freshman or sophomore year achieved a small but statistically significant increased number of A and B grades in their junior and senior years, and that the effect was linear with the number of PLA-assisted courses taken. The same students experienced a 20% increase (from about 65% to 85%) increase in their freshman to junior retention rate, and a similar increase in their 4-year graduation rate, as a result of taking just one PLA-assisted course. These learning gains were achieved with a net savings in faculty time input, and a modest increase in course cost due to PLA wages.

A current project, also funded by the Davis Educational Foundation, aims to improve the first year experience through three interventions. *Insight* is a residentially based personal and academic development program in which students reside with their orientation groups, receive regular visits from faculty consultants/academic advisors in their residences, and get residence-based tutoring and personal development programming. *Course bridging* is based on the successful IWR project described above, and targets the introductory calculus course that is a major academic hurdle for incoming WPI freshmen. The *Tutorial* is modeled after the Oxford-Cambridge tutorial model, in which a small group of faculty and 25 freshmen spend all of their academic time together for the students' first semester at WPI. All three interventions aim to increase student connections with faculty and other students, and to improve freshman-sophomore retention (already quite high at 91%).

Mass Academy: received funding from the Massachusetts Department of Education (NSF PALMS) each of the last four years to conduct a week-long immersion workshop for teachers. The focus of each of the Summer Content Institutes was Engineering Problem Solving. Teachers from Massachusetts received food, lodging, and PDPs including optional graduate credits.

VIII. Faculty participants

PI: Dr. Denise Nicoletti, WPI Associate Professor of Electrical and Computer Engineering, will be PI. A tenured member of the ECE faculty, Prof. Nicoletti co-designed and developed Camp REACH, a 2-week summer residential program to introduce middle-school girls to engineering (initially funded by NSF and last offered July 22-August 3, 2001 for the fifth consecutive year). Prof. Nicoletti's professional experience through Camp REACH in training middle school teachers and WPI students about the engineering design cycle will be invaluable in structuring the P-Fellows and P-Teachers mentoring program. She is also experienced in managing, fund-raising, assessing and disseminating programs similar to this partnership program, as well as presenting oral and written scholarly presentations on such topics.

CoPI: Dr. Judith Miller, WPI Professor of Biology and Biotechnology and Director, Center for Educational Development, Technology and Assessment. Prof. Miller offers a graduate Seminar and Practicum in College Teaching and has extensive publications in pedagogical innovation and experience with mentoring future and new faculty. She will also direct program assessment.

Senior Personnel: Dr. John Goulet, Mathematical Sciences, Director of the WPI Masters of Mathematics for Educators (MME) program and Director of WPI Teacher Preparation programs. The MME program results in qualifications for Massachusetts Licensing in Secondary Education.

Senior Personnel: Dr. Lance Schachterle, Humanities, Assistant Provost, and Director of the Worcester Community Project Center. He is involved in engineering pipeline efforts in Worcester (the UMass/Raytheon Engineering Pipeline Collaborative, EPiC) as well as statewide (Engineering in Mass Collaborative) and co-directs the Worcester Community Project Center, which will supply undergraduate student teams to facilitate and help assess this proposed activity.

Senior Personnel: Pauline Lamarche, Principal, Massachusetts Academy of Mathematics and Science at Worcester; primary developer of Mass Academy teacher in-service programs.

The coPI for the WPS subcontract is Gale Hilary Nigrosh, Ph.D., Development Specialist For Higher Education & Business Partnerships of the Worcester Public Schools. She is charged with developing collaboratives between colleges, universities, businesses, and schools for research, staff development, and curriculum innovation, and with seeking appropriate financial support to sustain projects. With partner institutions, involved in the design, implementation and monitoring of a broad range of academic programs with particular focus on emerging biotechnology and health/science fields, pre-engineering, pre-service teacher training, math/science opportunities for women and minority students, programs in arts and humanities, and preparation for postsecondary education.

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FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory:

Clinical:

Animal:

Computer: **Standard computer facilities available for word processing, webpage development, etc. including color scanners, printers and image manipulations software.**

Office:

Other: ______________________

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

EXCERPTS FROM
Science and Technology/Engineering Curriculum Framework

May 2001

Massachusetts Department of Education
Address 350 Main Street, Malden, MA 02148
Telephone 781-338-3000 **Internet** www.doe.mass.edu

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May 2001

Dear Colleagues,

I am pleased to present to you the 2001 Massachusetts Science and Technology/Engineering Curriculum Framework. This framework presents the revised statewide guidelines for learning, teaching, and assessment in science and technology/engineering for the Commonwealth's public schools. Based on scholarship, sound research, and effective practice, the framework will enable teachers and administrators to strengthen curriculum and instruction from Prekindergarten through grade 12.

I am proud of the work that has been accomplished. The comments and suggestions received on the 1995 Science and Technology Curriculum Framework, as well as on working drafts of this version, have strengthened this framework. The major changes from the 1995 framework to the May 2001 document include the following:

- Standards are more specific, to enable teachers to design instruction and assessment more effectively. Grade spans have narrowed from Prek-4, 5-8, 9-10 to Prek-2, 3-5, 6-8, 9-10.
- The four strands in the 1995 document (Inquiry, Domains of Science, Technology and Science, and Technology and Human Affairs) are now four content strands (Earth and Space Science, Life Science, Physical Sciences, and Technology/Engineering). "Inquiry" is now to be taught with the content of each domain of science.
- High school standards: The 2001 framework has a set of standards for comprehensive, full year courses in each of the four science domains, and in Technology/Engineering. In each domain, a subset of these standards has been identified as core. Only core standards will be assessed by MCAS. In addition, a set of core standards has been identified for a two-year, grade 9 and 10 integrated science program. These standards are a subset of the core standards from each of the four science domains.
- Format: The revised document has a three-column grid for grades Prek-5 that shows the topic and the Learning Standards, Ideas for Developing Investigations and Learning Experiences, and Suggested Extensions to Learning in Technology/Engineering.
- A glossary was added for selected Prek-8 terms and a topical outline was included.

From December 2000 to May 2001 the framework underwent an intensive review for scientific and technological accuracy. The wording was revised and specific examples were added to help clarify the learning standards. Changes at this final stage of review include the following:

- For grades Prek-K, students' sense of geologic time is strengthened in the earth science strand with the standard "Recognize that fossils provide us with information about living things that inhabited the earth years ago."
- Life science standards in the lower and middle grades were strengthened and made more specific to develop concepts of evolution, including adaptation, heredity, and comparison of organisms.
- Based on significant feedback from teachers, the focus on plants and animals in grades 6-8 was extended to include a standard that specified the human organism as a set of systems that interact with each other.

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- The description of the taxonomic system was sharpened by including in the standards for grades 6-8 the classification of organisms into “the *currently recognized* kingdoms.”
- At the high school level, we recognized the growing importance of molecular biology by adding the standard asking students to “Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.”
- In the physics standards, plasma was specified as the fourth state of matter.

We will continue to work with schools and districts to implement the 2001 Science and Technology/ Engineering Curriculum Framework over the next several years, and we encourage you to send us your comments as you use it. All of the curriculum frameworks are subject to continuous review and improvement for the benefit of the students of the Commonwealth.

Thank you again for your ongoing support and for your commitment to achieving the goals of education reform.

Sincerely,

David P. Driscoll
Commissioner of Education

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Acknowledgments

The 2001 Science and Technology/Engineering Curriculum Framework is the result of the contributions of many educators across the state. Because of the broad-based, participatory nature of the revision process, this document cannot reflect all of the professional views of every contributor. It reflects instead a balanced synthesis of their suggestions. The Department of Education wishes to thank all of the groups that contributed to the development of these science and technology/engineering standards: the Science and Technology/Engineering Revision Panel, the Mathematics/Science Advisory Council, the Technology/Engineering Advisory Council, grade-span teacher groups, professional educational associations and organizations, and all of the individual teachers, administrators, scientists, engineers, science education faculty, and parents who took the time to provide thoughtful comments during the public comment period.

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The Science and Technology/Engineering Curriculum Framework is available on-line at the Department's website (www.doe.mass.edu/frameworks/current.html). The Word and PDF files are the same as this printed version. The HTML file is a dynamic version that is continually being updated with new examples and vignettes that are linked directly to the learning standards. If you would like to contribute an example or vignette that has been successful in your classroom, please contact the Office of Mathematics, Science, and Technology/Engineering at (781)338-3483.

Introduction

The Massachusetts Science and Technology/Engineering Curriculum Framework is one of seven curriculum frameworks that advance Massachusetts's educational reform in learning, teaching, and assessment. It was created and has been revised by teachers and administrators of science and technology/engineering programs in prekindergarten through grade 12 school districts, by college and university professors, and by engineers and scientists in the various domains working with staff from the Department of Education. Its purpose is to guide teachers and curriculum coordinators about what content should be taught from PreK through high school.

Organization of the Framework

The guiding principles present a set of tenets about effective PreK-12 programs and instruction in science and technology/engineering. These principles articulate ideals of teaching, learning, assessing, and administering science and technology/engineering programs in Massachusetts. They show how educators may create educational environments characterized by curiosity, persistence, respect for evidence, open mindedness balanced with skepticism, and a sense of responsibility.

The strands organize the content areas into earth and space science, life science (biology), the physical sciences (physics and chemistry), and technology/engineering. Each strand details the essential knowledge and skills that students should acquire through the grades. The learning standards within each strand are organized by grade span and grouped by subject area topics. Following the topics at the high school level are broad concepts to which the learning standards are related. The standards outline specifically what students should know and be able to do at the end of each grade span.

For grades PreK-5, the standards are accompanied by ideas for developing investigations and learning experiences in science and by extensions to learning in technology/engineering. These latter activities are coded to the PreK-5 technology/engineering standards. Additional activities to enhance the PreK-8 learning Standards are found in Appendix III.

For grades 6-8, the science standards are accompanied by examples of sound science-based learning experiences. There are no extensions to technology/engineering associated with the science learning standards at this level because technology education is configured as a separate course in grades 6-8. Examples of learning activities for standards in the technology/engineering strand are included with the technology/engineering standards.

For grade 9 and higher, learning standards are listed for full first-year courses in earth and space science, biology, physics, chemistry, and technology/engineering. Core standards are in boldface type in each set of standards. From each set of core standards in the four sciences, a subset has been chosen for a two-year integrated science sequence in grades 9 and 10 (shown in Appendix II).

At the high school level, the Department will provide discipline-specific assessment options based on the core standards in earth and space science, biology, chemistry, physics, and technology/engineering. The Department will also offer an assessment for the two-year integrated science course sequence in grades 9 and 10 based on the subset of standards chosen for it. Districts will decide what assessment options to provide their students based on the courses they offer in grade 9 and higher.

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Development of the standards

This framework derives from two reform initiatives in Massachusetts, the Education Reform Act of 1993 and Partnerships Advancing the Learning of Mathematics and Science (PALMS). Since 1992, the PALMS Statewide Systemic Initiative has been funded by the National Science Foundation in partnership with the state and the Noyce Foundation. Of the seven initial goals for this initiative, the first was to develop, disseminate, and implement curriculum frameworks in mathematics and in science and technology. The initial science and technology framework was approved in 1995, and was implemented in the field.

Because the Education Reform Act required that frameworks be reviewed and revised periodically, a revision panel was appointed by the Commissioner and the Board of Education in the summer of 1998. The panel examined the standards in the original framework, reviewed comments on them from the field, and reassessed their appropriateness in order to work out a more coherent organization of concepts and skills through the grade levels. The panel referred to the *Benchmarks for Science Literacy–Project 2061*, data from the Third International Mathematics and Science Study, the National Research Council's *National Science Education Standards*, the Technology for All Americans Project, results from the 1998 administration of the MCAS, and advances in science and technology/engineering.

The draft produced by the revision panel was released for public comment in August 1999. Based on comments on this draft from science and technology/engineering teachers and other educators, further revisions were made, particularly at the high school level. Groups of high school science teachers in each domain of science developed a comprehensive set of standards for a course in each domain from which core standards were chosen for discipline-specific assessments. Groups of technology/engineering educators also contributed to the development of a comprehensive set of standards and core standards for the technology/engineering course at the high school level.

Inquiry and Experimentation

Asking and pursuing questions are keys to learning in all academic disciplines. There are multiple ways that students can ask and pursue questions in the science class. One way is to explore scientific phenomena in a classroom laboratory or around the school. Classroom investigation and experimentation can build essential scientific skills such as observing, measuring, replicating experiments, manipulating equipment, and collecting and reporting data. Students may sometimes choose what phenomenon to study, e.g., for a science fair project. More often, they conduct investigations and experiments that are selected and guided by the teacher.

Students can also examine the questions pursued by scientists in their investigations of natural phenomena and processes as reported or shown in textbooks, papers, videos, the internet, and other media. These sources are valuable because they efficiently organize and highlight the key concepts and supporting evidence that characterize the most important work in science. Such study can then be supported in the classroom by demonstrations, experiments, or simulations that deliberately manage features of a natural object or process. Whatever the instructional approach, science instruction should include both concrete and manipulable materials and explanatory diagrams and textbooks.

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Scientific inquiry and experimentation should not be taught or tested as separate, stand-alone skills. Rather, opportunities for inquiry and experimentation should arise within a well-planned curriculum in the domains of science. They should be assessed through examples drawn from the life, physical, and earth and space science standards so that it is clear to students that in science, *what* is known does not stand separate from *how* it is known.

In the earliest grades, scientific investigations can center on student questions, observations, and communication about what they observe. For example, students might plant a bean seed following simple directions written on a chart. Then they would write down what happens over time in their own words.

In the later elementary years, students can plan and carry out investigations as a class, in small groups, or independently, often over a period of several class lessons. The teacher should first model the process of selecting a question that can be answered, formulating a hypothesis, planning the steps of an experiment, and determining the most objective way to test the hypothesis. Students should begin to incorporate the mathematical skills of measuring and graphing to communicate their findings.

In the middle school years, teacher guidance remains important but allows for more variations in student approach. Students at this level are ready to formalize their understanding of what an experiment requires by controlling variables to ensure a fair test. Their work becomes more quantitative, and they learn the importance of carrying out several measurements to minimize sources of error. Because students at this level use a greater range of tools and equipment, they must learn safe laboratory practices (see Appendix V). At the conclusion of their investigations, students at the middle school level can be expected to prepare formal reports of their questions, procedures, and conclusions.

In high school, students develop greater independence in designing and carrying out experiments, most often working alone or in small groups. They come up with questions and hypotheses that build on what they have learned from secondary sources. They learn to critique and defend their findings, and to revise their explanations of phenomena as new findings emerge. Their facility with using a variety of physical and conceptual models increases. Students in the final two years of high school can be encouraged to carry out extended independent experiments that explore a scientific hypothesis in depth, sometimes with the assistance of a scientific mentor from outside the school setting.

Skills of Inquiry

Grades PreK-2

- Ask questions about objects, organisms, and events in the environment.
- Tell about *why* and *what would happen if?*
- Make predictions based on observed patterns.
- Name and use simple equipment and tools (e.g., rulers, meter sticks, thermometers, hand lenses, and balances) to gather data and extend the senses.
- Record observations and data with pictures, numbers, or written statements.
- Discuss observations with others.

Grades 3-5

- Ask questions and make predictions that can be tested.
- Select and use appropriate tools and technology (e.g., calculators, computers, balances, scales, meter sticks, graduated cylinders) in order to extend observations.
- Keep accurate records while conducting simple investigations or experiments.

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- Conduct multiple trials to test a prediction. Compare the result of an investigation or experiment with the prediction.
- Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiment.
- Record data and communicate findings to others using graphs, charts, maps, models, and oral and written reports.

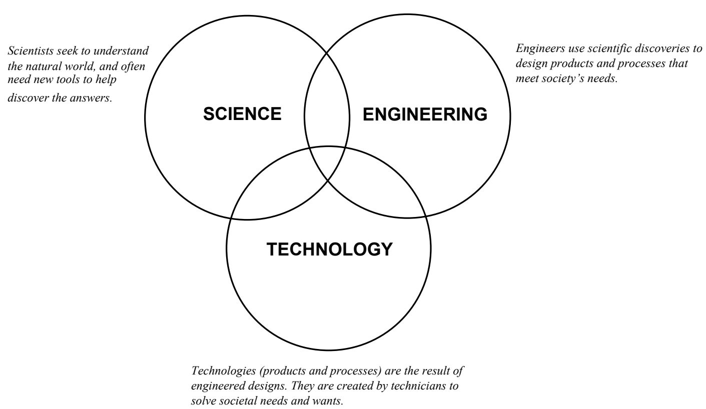
Grades 6-8
- Formulate a testable hypothesis.
- Design and conduct an experiment specifying variables to be changed, controlled, and measured.
- Select appropriate tools and technology (e.g., calculators, computers, thermometers, meter sticks, balances, graduated cylinders, and microscopes), and make quantitative observations.
- Present and explain data and findings using multiple representations, including tables, graphs, mathematical and physical models, and demonstrations.
- Draw conclusions based on data or evidence presented in tables or graphs, and make inferences based on patterns or trends in the data.
- Communicate procedures and results using appropriate science and technology terminology.
- Offer explanations of procedures, and critique and revise them.

Strand 4: Technology/Engineering

Science tries to understand the natural world. Based on the knowledge that scientists develop, the goal of engineering is to solve practical problems through the development or use of technologies. For example, the planning, designing, and construction of the Central Artery Tunnel project in Boston (commonly referred to as the "Big Dig") is a complex and technologically challenging project that draws on knowledge of earth science, physics, and construction and transportation technologies.

Technology/engineering works in conjunction with science to expand our capacity to understand the world. For example, scientists and engineers apply scientific knowledge of light to develop lasers and fiber optic technologies and other technologies in medical imaging. They also apply this scientific knowledge to develop such modern communications technologies as telephones, fax machines, and electronic mail.

The Relationship Among Science, Engineering, and Technology



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Although the term *technology* is often used by itself to describe the educational application of computers in a classroom, instructional technology is a subset of the much broader field of technology. While important, computers and instructional tools that use computers are only a few of the many technological innovations in use today.

Technologies developed through engineering include the systems that provide our houses with water and heat; roads, bridges, tunnels, and the cars that we drive; airplanes and spacecraft; cellular phones, televisions, and computers; many of today's children's toys; and systems that create special effects in movies. Each of these came about as the result of recognizing a need or problem and creating a technological solution. Figure 1 on page 53 shows the steps of the engineering design process. Beginning in the early grades and continuing through high school, students carry out this design process in ever more sophisticated ways. As they gain more experience and knowledge, they are able to draw on other disciplines, especially mathematics and science, to understand and solve problems.

Students are experienced technology users before they enter school. Their natural curiosity about how things work is clear to any adult who has ever watched a child doggedly work to improve the design of a paper airplane, or to take apart a toy to explore its insides. They are also natural engineers and inventors, builders of sandcastles at the beach and forts under furniture. Most students in grades PreK-2 are fascinated with technology. While learning the safe use of tools and materials that underlie engineering solutions, they are encouraged to manipulate materials that enhance their three-dimensional visualization skills–an essential component of the ability to design. They identify and describe characteristics of natural and manmade materials and their possible uses and identify the use of basic tools and materials, e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, and spools. In addition, students at this level learn to identify tools and simple machines used for a specific purpose (e.g., ramp, wheel, pulley, lever) and describe how human beings use parts of the body as tools.

Students in grades 3-5 learn how appropriate materials, tools, and machines extend our ability to solve problems and invent. They identify materials used to accomplish a design task based on a specific property and explain which materials and tools are appropriate to construct a given prototype. They achieve a higher level of engineering design skill by recognizing a need or problem, learn different ways that the problem can be represented, and work with a variety of materials and tools to create a product or system to address it.

In grades 6-8, students pursue engineering questions and technological solutions that emphasize research and problem solving. They identify and understand the five elements of a technology system (goal, inputs, processes, outputs, and feedback). They acquire basic skills in the safe use of hand tools, power tools, and machines. They explore engineering design; materials, tools, and machines; and communication, manufacturing, construction, transportation, and bioengineering technologies. Starting in these grades and extending through grade 10, the topics of power and energy are incorporated into the study of most areas of technology. Students integrate knowledge they acquired in their mathematics and science curricula to understand the links to engineering. They achieve a more advanced level of skill in engineering design by learning to conceptualize a problem, design prototypes in three dimensions, and use hand and power tools to construct their prototypes, test their prototypes, and make modifications as necessary. The culmination of the engineering design experience is the development and delivery of an engineering presentation.

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Students in grades 9 and 10 learn to apply scientific and mathematical knowledge in a full-year, comprehensive technology/engineering course. The topics addressed include engineering design; construction technologies; power and energy technologies in fluid, thermal, and electrical systems; communication technologies; and manufacturing technologies. Students engage in experiences that enhance their skills in designing, building, and testing prototypes. The culmination of this level of design experience is also the development and delivery of an engineering presentation.

Technology/engineering curricula in grades 11 and 12 follow the approaches used for the previous two grades but expand in a variety of areas based on available school expertise and student interest. Students may explore advanced technology/engineering curricula such as automation and robotics, multimedia, architecture and planning, biotechnology, and computer information systems. They may continue building on their background in engineering design by working on inventions. Course offerings in the high school grades should engage students who are interested in:

- expanding their studies in the area of engineering and technology because they are interested in a college-level engineering program,
- pursuing career pathways in relevant technology fields, or
- learning about certain areas of technology/engineering to expand their general educational background, but who will not necessarily follow a technical career.

All areas of study should be taught by teachers who are certified in that discipline. Because of the hands-on, active nature of the technology/engineering environment, it is strongly recommended that it be taught in the middle and high school by teachers who are certified in technology education, and who are very familiar with the safe use of tools and machines.

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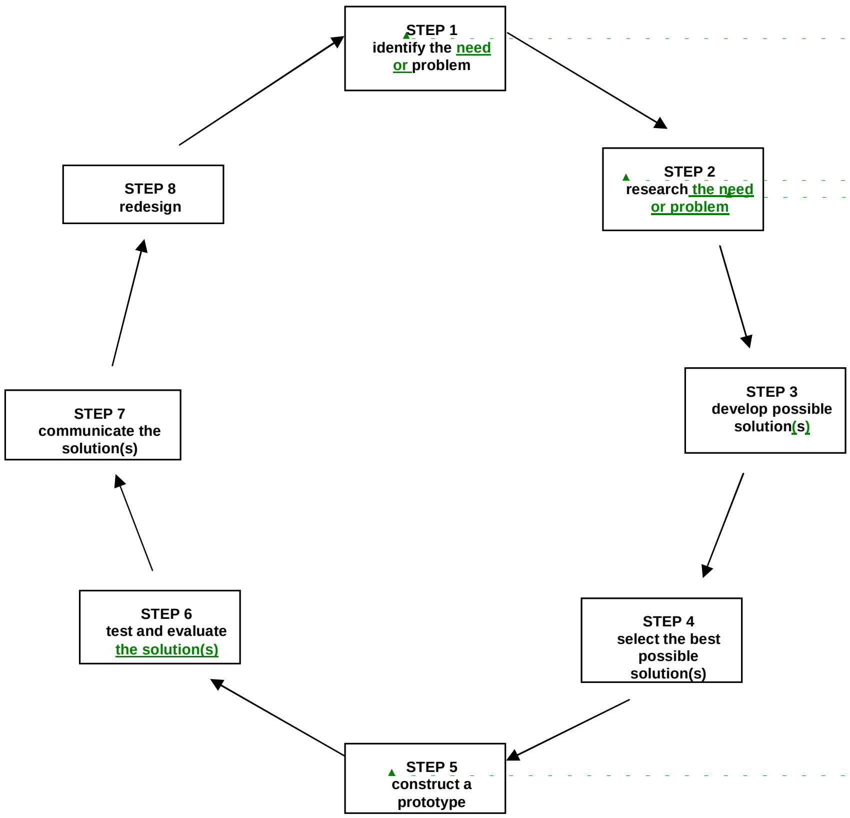
Figure 1
Steps of the Engineering Design Process



1. Identify the need or problem
2. Research the need or problem
    - Examine current state of the issue and current solutions
    - Explore other options via the internet, library, interviews, etc.
3. Develop possible solution(s)
    - Brainstorm possible solutions
    - Draw on mathematics and science
    - Articulate the possible solutions in two and three dimensions
    - Refine the possible solutions
4. Select the best possible solution(s)
    - Determine which solution(s) best meet(s) the original requirements
5. Construct a prototype

- Model the selected solution(s) in two and three dimensions
6. Test and evaluate the solution(s)
   - Does it work?
   - Does it meet the original design constraints?
7. Communicate the solution(s)
   - Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
   - Discuss societal impact and tradeoffs of the solution(s)
8. Redesign
   - Overhaul the solution(s) based on information gathered during the tests and presentation

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Technology/Engineering Learning Standards

Please note: Suggested extensions to learning in technology/engineering for grades PreK -5 are listed with the science learning standards. See pages 12-21 (earth and space science), 31-38 (life science), and 46-51 (physical sciences).

Grades PreK-2

1. Materials and Tools

Broad Concept: Materials both natural and human-made have specific characteristics that determine how they will be used.

1.1 Identify and describe characteristics of natural materials (e.g., wood, cotton, fur, wool) and human-made materials (e.g., plastic, Styrofoam).

1.2 Identify and explain some possible uses for natural materials (e.g., wood, cotton, fur, wool) and human-made materials (e.g., plastic, Styrofoam).

1.3 Identify and describe the safe and proper use of tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structures.

2. Engineering Design

Broad Concept: Engineering design requires creative thinking and consideration of a variety of ideas to solve practical problems.

2.1 Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever.

2.2 Describe how human beings use parts of the body as tools (e.g., teeth for cutting, hands for grasping and catching), and compare their use with the ways in which animals use those parts of their bodies.

Grades 3-5

1. Materials and Tools

Broad Concept: Appropriate materials, tools, and machines extend our ability to solve problems and invent.

1.1 Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.

1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.

1.3 Identify and explain the difference between simple and complex machines, e.g., hand can opener that includes multiple gears, wheel, wedge gear, and lever.

2. Engineering Design

Broad Concept: Engineering design requires creative thinking and strategies to solve practical problems generated by needs and wants.

2.1 Identify a problem that reflects the need for shelter, storage, or convenience.

2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.

2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.

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2.4 Compare natural systems with mechanical systems that are designed to serve similar purposes, e.g., a bird's wings as compared to an airplane's wings.

Grades 6-8

Please note: For grades 6-high school, there are suggested learning activities after each set of learning standards. The number(s) in parentheses after each activity refer to the related technology/engineering learning standard(s).

1. Materials, Tools, and Machines

Broad Concept: Appropriate materials, tools, and machines enable us to solve problems, invent, and construct.

1.1 Given a design task, identify appropriate materials (e.g., wood, paper, plastic, aggregates, ceramics, metals, solvents, adhesives) based on specific properties and characteristics (e.g., weight, strength, hardness, and flexibility).

1.2 Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.

1.3 Identify and explain the safe and proper use of measuring tools, hand tools, and machines (e.g., band saw, drill press, sanders, hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) needed to construct a prototype of an engineering design.

Suggested Learning Activities

- Conduct tests for weight, strength, hardness, and flexibility of various materials, e.g., wood, paper, plastic, ceramics, metals. (1.1)
- Design and build a catapult that will toss a marshmallow the farthest. (1.1, 1.2, 1.3)
- Use a variety of hand tools and machines to change materials into new forms through forming, separating, and combining processes, and processes that cause internal change to occur. (1.2)

2. Engineering Design

Broad Concept: Engineering design is an iterative process involving modeling and optimizing for developing technological solutions to problems within given constraints.

2.1 Identify and explain the steps of the engineering design process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multiview drawings.

2.3 Describe and explain the purpose of a given prototype.

2.4 Identify appropriate materials, tools, and machines needed to construct a prototype of a given engineering design.

2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

2.6 Identify the five elements of a universal systems model: goal, inputs, processes, outputs, and feedback.

Suggested Learning Activities

- Given a prototype, design a test to evaluate whether it meets the design specifications. (2.1)

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- Using test results, modify the prototype to optimize the solution, i.e., bring the design closer to meeting the design constraints. (2.1)
- Communicate the results of an engineering design through a coherent written, oral, or visual presentation. (2.1)
- Develop plans, including drawings with measurements and details of construction, and construct a model of the solution, exhibiting a degree of craftsmanship. (2.2)

3. Communication Technologies

Broad Concept: Ideas can be communicated though engineering drawings, written reports, and pictures.

3.1 Identify and explain the components of a communication system, i.e., source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.

3.2 Identify and explain the appropriate tools, machines, and electronic devices (e.g., drawing tools, computer-aided design, and cameras) used to produce and/or reproduce design solutions (e.g., engineering drawings, prototypes, and reports).

3.3 Identify and compare communication technologies and systems, i.e., audio, visual, printed, and mass communication.

3.4 Identify and explain how symbols and icons (e.g., international symbols and graphics) are used to communicate a message.

4. Manufacturing Technologies

Broad Concept: Manufacturing is the process of converting raw materials (primary process) into physical goods (secondary process), involving multiple industrial processes, e.g., assembly, multiple stages of production, quality control.

4.1 Describe and explain the manufacturing systems of custom and mass production.

4.2 Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

4.3 Describe a manufacturing organization, e.g., corporate structure, research and development, production, marketing, quality control, distribution.

4.4 Explain basic processes in manufacturing systems, e.g., cutting, shaping, assembling, joining, finishing, quality control, and safety.

5. Construction Technologies

Broad Concept: Construction technology involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.

5.1 Describe and explain parts of a structure, e.g., foundation, flooring, decking, wall, roofing systems.

5.2 Identify and describe three major types of bridges (e.g., arch, beam, and suspension) and their appropriate uses (e.g., site, span, resources, and load).

5.3 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.

5.4 Describe and explain the effects of loads and structural shapes on bridges.

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Suggested Learning Activities

- Design and construct a bridge following specified design criteria, e.g., size, materials used. Test the design for durability and structural stability. (5.3)

6. Transportation Technologies

Broad Concept: Transportation technologies are systems and devices that move goods and people from one place to another across or through land, air, water, or space.

6.1 Identify and compare examples of transportation systems and devices that operate on each of the following: land, air, water, and space.

6.2 Given a transportation problem, explain a possible solution using the universal systems model.

6.3 Identify and describe three subsystems of a transportation vehicle or device, i.e., structural, propulsion, guidance, suspension, control, and support.

6.4 Identify and explain lift, drag, friction, thrust, and gravity in a vehicle or device, e.g., cars, boats, airplanes, rockets.

Suggested Learning Activities

- Design a model vehicle (with a safety belt restraint system and crush zones to absorb impact) to carry a raw egg as a passenger. (6.1)
  - Design and construct a magnetic levitation vehicle as used in the monorail system. Discuss the vehicle's benefits and trade-offs. (6.2)
  - Conduct a group discussion of the major technologies in transportation. Divide the class into small groups and discuss how the major technologies might affect future design of a transportation mode. After the group discussions, the students draw a design of a future transportation mode (car, bus, train, plane, etc.). The students present their vehicle design to the class, including a discussion of the subsystems used. (6.1, 6.3)

7. Bioengineering Technologies

Broad Concept: Bioengineering technologies explore the production of mechanical devices, products, biological substances, and organisms to improve health and/or contribute improvement to our daily lives.

7.1 Explain examples of adaptive or assistive devices, e.g., prosthetic devices, wheelchairs, eyeglasses, grab bars, hearing aids, lifts, braces.

7.2 Describe and explain adaptive and assistive bioengineered products, e.g., food, bio-fuels, irradiation, integrated pest management.

Suggested Learning Activities

- Brainstorm and evaluate alternative ideas for an adaptive device that will make life easier for a person with a disability, such as a device to pick up objects from the floor. (7.1)

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WHAT IT LOOKS LIKE IN THE CLASSROOM

Local Wonders

Adapted from the Building Big Activity Guide, pp. 36-37

Technology/Engineering Grades 6-8

Your community may not have an Eiffel Tower or a Hoover Dam, but you can choose any structure in your community that is significant because of its appearance, uniqueness, or historical or social impact. Consider local bridges, tunnels, skyscrapers or other buildings, domes, dams, and other constructions. You can e-mail the American Society of Civil Engineers at buildingbig@asce.org to connect with a volunteer civil engineer for this activity. To help select your local wonder, have the class brainstorm a list, take a bus tour around town for ideas, or collect some photographs for discussion.

After building newspaper towers and talking about structures and foundations, fifth and sixth graders at the Watertown, Massachusetts Boys and Girls Club brainstormed a list of interesting structures in their town. They selected St. Patrick's, an elaborate church across the street from the clubhouse. The children brainstormed questions about their local wonder. Those with an engineering focus included: When was it built? How long did the construction take? Who built it? What is it made of? Why did the builders choose that material? What is underneath the building? What holds it up? What keeps it from falling down? How was it built? Were there any problems during construction and how were they solved? Questions with a social/environmental focus included: Why was it built? What did the area look like before it was built?

Next, the students investigated their local wonder with some hands-on activities that explore basic engineering principles such as forces, compression, tension, shape, and torsion. They toured the structure, took photographs, researched the structure, interviewed long-time community members about their memories about the structure, and interviewed engineers, architects, and contractors who worked on the project. They conducted research at the library, the Historical Society, and the Watertown Building Inspector's office, where they acquired the building's plans and copies of various permits. They used this information to develop a timeline of the building's history.

Students can use the following method to estimate the size of a large structure. First, measure a friend's height. Have your friend stand next to the structure, while you stand a distance away (across the street, for instance). Close one eye and use your fingers to "stack" your friend's height until you reach the top of the structure. Multiply the number of times you stacked your friend by his/her height to find the total estimated height of the structure.

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The outline of the final report may look like this:

I. Name of group submitting report
II. Name and description of structure (identify the type of structure, e.g., bridge, skyscraper, and decribe and explain its parts)
III. Location
IV. Approximate date structure was completed
V. Approximate size
VI. Why we chose this particular local wonder
VII. What's important about our local wonder
VIII. Things we learned about our local wonder (include information such as type of construction, engineering design concepts, and forces acting on the structure)
IX. Interesting facts about our local wonder

Any group that completes this project can submit its investigation to pbs.org/buildingbig. Send them your complete report, including photographs or original drawings of your local wonder. Students should be encouraged to draw the structure from a variety of different perspectives. Students can also share their reports with other classes in their schoolor at a local town meeting.

Assessment Strategies

- Share examples of other groups' completed investigations with the students at the beginning of the project. Discuss and develop criteria for effective write-ups, and identify what constitutes quality work.
- Students can record their learning in an engineering journal. Students can write down each day what they have learned, questions that they may have, resources they found helpful, and resources they need to find. The teacher should read the journals to monitor students' progress and level of participation, and to identify what topics the students have mastered and which areas of learning need to be reinforced by additional instruction.
- Post your local wonder report on your school district website, on the town website, or on a town agency's website, e.g., the Chamber of Commerce. Include an e-mail address and encourage feedback.
- At the end of the unit, provide the students with a photograph of a similar structure from another town or area. Ask them to write a final paper that compares this structure to the local wonder they just studied. How are they alike? Different? Compare the materials, design, and purpose of these structures.

Note: The applicable standards may vary depending upon the type of structure selected.

Engineering Design Learning Standards

2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multi-view drawings.

2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

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Construction Technologies Learning Standards

5.1 Describe and explain parts of a structure, e.g., foundation, flooring, decking, wall, roofing systems.
5.2 Identify and describe three major types of bridges (e.g., arch, beam, and suspension) and their appropriate uses (e.g., site, span, resources, and load).
5.3 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.
5.4 Describe and explain the effects of loads and structural shapes on bridges.

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James A. Caradonio, Ed.D.
Superintendent

May 29, 2002

Denise W. Nicoletti, Ph.D.
Assoc. Professor of Electrical and Computer Engineering
WPI
100 Institute Road
Worcester MA 01609

Dear Prof. Nicoletti,

The Worcester Public Schools (WPS) wholeheartedly endorses "K-6 Gets a Piece of the P.I.E.E.," WPI's grant proposal to the National Science Foundation for GK-12 Teaching Fellows. Our enthusiasm for this current initiative comes from a long and very fruitful relationship with WPI. As WPS Superintendent, I am especially pleased that you will be a PI in this initiative, given your ongoing success with our middle school girls in the field of engineering. The opportunity now to bring engineering to elementary school teachers is both timely and exciting.

We have selected two schools to begin the program, Elm Park Community School, a long-time neighborhood partner to WPI, and Midland Street School, just a short walk from the WPI campus. The principals of both schools are eager to get their teachers involved and to see their students gain from this experience.

Demographic information for these two schools is fairly representative of our school district, which totals 26,000 students:

School	Enrollment	Male	Female	Minority	African American	Latino	FRL*
Elm Park	468	270	198	58.8%	17.0%	28.8%	87.8%
Midland St.	297	151	146	39.4%	11.0%	20.0%	42.4%

*Free and Reduced Price Lunch

Even before the State adopted its new Science and Technology/Engineering Curriculum Framework (2001), the Worcester Public Schools took the lead in Massachusetts by creating the first K-12 Engineering Pipeline Collaborative (EPiC). Now starting its third year in the WPS Doherty Quadrant, EPiC has developed an "Academy of Engineering" at Doherty High School, a "Pre-Engineering Cluster" at Forest Grove Middle School, and professional development for the elementary level focused on using engineering-type activities to enhance the science curriculum.

The major goal of this massive undertaking is to increase the academic achievement of our large, diverse student population by addressing the content in the "Science and Technology/Engineering" Curriculum Framework through access to more challenging courses, academic support in the areas of mathematics and science, exciting applications and curriculum units, and more exposure to careers in the engineering field.

We have already committed significant resources for building rehabilitation, technology, curriculum and professional development. This has been accomplished through the coordination of various funding streams, including our foundation budget, a "career majors" grant from the Massachusetts Department of Education, initial funding from the UMass/Raytheon K-16 Engineering Pipeline Collaborative, and a recent gift from Verizon to provide engineering mentors for middle school girls. These funds total in excess of $800,000, allowing us to put the following structures in place:

"EPiC" The Engineering Pipeline Collaborative	Board of Directors
"Academy of Engineering Doherty High School	Grades 9, 10, 11
"Pre-Engineering Cluster" Forest Grove Middle School	Grade 8

It is at the elementary level that we are sorely lacking. K-6 teachers are trained as generalists, and few have concentrations in math or science. They would have their content knowledge increased and their confidence boosted if they could share their teaching with WPI Fellows. Teaching Fellows would benefit from WPS teachers' experience in the classroom, and might choose to become K-12 teachers themselves, at a time when school systems nationwide are hungry for them.

The Worcester Public Schools is truly committed to expanding "EPiC" in the Doherty Quadrant. To accomplish that end, we will need to build capacity in our elementary "feeder" schools. This NSF grant will be a major factor in helping us to reach this goal.

Sincerely,

James A. Caradonio

James A. Caradonio, Ed.D.
Superintendent, Worcester Public Schools

WPI

Electrical and Computer Engineering Department
100 Institute Road • Worcester, MA 01609-2280
Phone 508-831-5231 • Fax 508-831-5491 • http://www.wpi.edu/

June 3, 2002

To Whom It May Concern:

As Associate Department Head and Graduate Coordinator for the Electrical and Computer Engineering (ECE) Department at WPI, I fully support the initiatives described in the proposal to the NSF Graduate Teaching Fellows in K-12 Education program. It would be appropriate and welcome for ECE graduate students to receive support through this program while pursuing their degree.

I know from conversations with current ECE graduate students that at least one to two students each year have expressed interest in developing their skills in teaching while attaining their degree. Because of this, I am optimistic that we would find good candidates for this fellowship.

Sincerely,

F. Looft

Fred Looft, Ph.D.
Professor

WPI

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WORCESTER POLYTECHNIC INSTITUTE
WORCESTER, MA 01609 – 2280

Homer F. Walker, Professor and Department Head 508-831-5241 walker@wpi.edu Fax: 508-831-5824

May 30, 2002

To whom it may concern:

I am delighted to lend my strong support to the initiatives described in the proposal to the NSF Graduate Teaching Fellows in K-12 Education program. Support through this program for Mathematical Sciences graduate students would be most appropriate and welcome.

We should be able to find easily several well-qualified students who would be very worthy of support. I am especially enthusiastic about the possibility of supporting students in our Master of Mathematics for Educators program. This program, which currently has about 20 students in it, is a *mathematics* degree (not an education degree) especially oriented toward students who intend to pursue careers in K-12 teaching.

This support would also enable an exciting opportunity for students to become involved in our new Mathematics in Industry Workshop for High School Teachers. This will bring about 80 high school teachers to campus for one week in each of the next three summers. During their stay, they will work with faculty, industrial mathematicians and students to find effective ways to use real-world problems to motivate high school students, in particular women and underrepresented minorities, to pursue careers in mathematics, engineering, information technology or finance/economics.

Sincerely,

Homer F. Walker
Mathematical Sciences Department Head