

Lessons Learned in a University-Public School Partnership for Teaching Engineering in Grades 2-6

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Abstract

Worcester Polytechnic Institute is conducting an NSF-funded GK-12 program titled "K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)." The goals include (1) assisting the Worcester Public School System to implement curricula in engineering and technology at the elementary level, and (2) providing in-depth involvement with K-6 education to WPI graduate and undergraduate students as they pursue their own technical education. At the mid-point of the project, this paper reports the lessons learned in managing this rather large and complex project which brings together two quite different educational institutions. The results to date have been quite positive.

Introduction

In 2003 WPI began a three-year project, "K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)." This project is funded by the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program, the goal of which is to involve engineering graduate students with K-12 science and engineering education. Some small number of these graduate students will decide to pursue careers in K-12 education, but for most, the intense exposure provided by the Fellowship program should lead to increased involvement with K-12 education throughout their careers. This paper summarizes lessons that the program directors and participants have learned after one and one half years of experience with the program, and provides recommendations to others considering such activities. Feedback from all involved (fellows, WPI faculty, elementary principals and teachers, and public school administrators) has been overwhelmingly positive. Quantitative assessment work is underway, and will be reported separately.

Project Background and Current Status

The overall goal of the NSF GK-12 program is to prepare engineering graduate students who are informed about K-12 education and who have the interest and knowledge to enable them to remain engaged in K-12 education in some manner throughout their professional careers. This represents a new approach to the pipeline issues in technical education with which NSF has long been involved. In addition to the positive impact on the graduate fellows (who are the major target of the NSF program), there will also be the direct impacts on the students and teachers with whom the fellows interact. Our project has three primary objectives:

1. To develop partnerships between the Worcester Public School (WPS) system and WPI;

2. To implement the technology/engineering portion of the Massachusetts Science and Technology/Engineering Curriculum Frameworks (MSTECF)[1] in grades K-6; and
3. To develop curricular materials and prepare teachers so that the project is self-sustaining after the NSF grant expires.

Massachusetts is one of the few states to have mandatory curriculum standards in engineering and technology at the K-12 levels and appears to be the only state with such standards in the K-6 grades) which specifically incorporate engineering and technology topics. Hence, Massachusetts is an ideal venue for the extension of NSF's previous science and mathematics initiatives to the engineering disciplines.

More details on project objectives, overall organization, and budget aspects are presented in [2]. Organizationally, this project is complex, involving WPI faculty, graduate and undergraduate students, WPS elementary teachers and principals, and five grade levels in three schools in academic year 2004-05. The graduate fellows in the program devote full time in the summer and half time in the academic year to their K-6 activities, which include substantial time in the elementary classrooms as well as development (and often delivery) of lesson plans on engineering topics.

Undergraduate students may participate in two ways: as fellows with duties similar to the graduate fellows, but with a reduced time commitment, or as part of their regular academic program for academic credit. This latter possibility represents a distinctive feature of WPI's undergraduate program which is the requirement for all students to complete a major project (generally team-based) on some aspect of the interface between technology and society. These projects carry credit equivalent to nine semester hours and may address any of an extremely wide range of topics. Wherever possible they include a "real world" aspect and may be conducted off campus in the local community or at any of twelve residential project sites around the world. The goals of the PIEE project provide a good fit to these activities, so teams of undergraduate students have been incorporated into the PIEE program.

The current (2004-05) academic year is the second of the three project years. Following is a summary of the project activities in the current year:

- Three elementary schools in the city of Worcester are involved, representing a broad range of ethnic and income demographics;
- Grades two through six are included;
- A total of 18 classrooms with over 350 students are involved;
- Twelve fellows (8 graduate and 4 undergraduate) are participating;
- Twenty undergraduate project students in 9 teams are participating;
- Five WPI faculty are actively involved (the PI, a co-PI, and three grade level project advisors); these faculty represent the departments of Biology and Biotechnology, Biomedical Engineering, Mathematics, Electrical and Computer Engineering, and Chemical Engineering
- The research advisors of the fellows are kept informed and are asked to participate as appropriate.

Figure 1 illustrates the deployment of project personnel in project years 1 and 2. Note the substantial gain in complexity from year 1 to year 2. The role of the “Initiating Team” is to introduce the engineering/technology curriculum to particular classrooms and the teachers in those classrooms. The role of the “Adaptation Team” is to expand the reach of that curriculum at a particular grade level to new classrooms and new schools. The expectation is that fewer personnel resources are needed at the adaptation level, but in the current year we were not particularly successful in this regard. Figure 2 illustrates our plan for the final project year where “Sustainability Teams” assist experienced teachers in mentoring other teachers in expanding and institutionalizing the program. Here the ratio of WPI personnel to WPS personnel is lowered further. Figure 3 summarizes the roles of each team: to **Design**, then to **Implement**, and finally to **Disseminate** the engineering/technology curricular materials and teaching approach.

With the rest of the paper devoted to the operational and pedagogic problems and difficulties which we have observed, it is appropriate to summarize some of the major accomplishments of the project here:

- A large number of high-quality lessons (available at <http://www.wpi.edu/Academics/PIEE/Resources/Lessons/>) on engineering and technology have been delivered to WPS students through the WPS teacher – WPI fellow partnership;
- The database of lesson plans is large and growing;
- Everyone, particularly including fellows and WPS teachers, report high satisfaction with the project;
- Recruiting of fellows and undergraduate students has been easy;
- The performance of the fellows has been outstanding in general, with very few significant problems;
- Fellows appear to be entering the programs for the “right” reasons (i.e. an interest in teaching, in children, and/or a desire to contribute to the community);
- Beyond the specific accomplishments of the PIEE project, strong personal and professional bonds between WPI and the WPS personnel are being developed, which can only foster further enhancement of engineering and technology education in grades K-6.

Operational Issues and Lessons Learned

Although this paper reports some problems and issues which are worthy of attention, it is important to note that all reports to date indicate that the PIEE project is quite successful. In fact, the most persistent problem has been the difficulty of keeping the magnitude of the program under control, as principals, teachers, and parents clamor to add additional classrooms to the project. As the program increases its reach, we are learning sometimes painful lessons about how to manage our limited resources.

Year 1

Elm Park, Midland Schools

Grades 4, 5, 6

Initiating Teams (one for each grade level)

<p>Grade 4 Initiating Team 2 WPS teachers (1+1) 2 WPI grad fellows 2 IQP teams 1 WPI faculty member</p>	<p>Grade 5 Initiating Team 2 WPS teachers (1+1) 2 WPI grad fellows 2 IQP teams 1 WPI faculty member</p>	<p>Grade 6 Initiating Team 2 WPS teachers (1+1) 2 WPI grad fellows 2 IQP teams 1 WPI faculty member</p>
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Year 2

Flagg St.

Grades 2, 3

Midland

Grade 3

Initiating Teams (one for each grade level)

<p>Grade 2 Initiating Team 3 WPS teachers 2 WPI grad fellows (G, UG) 1 IQP team 1 WPI faculty member</p>	<p>Grade 3 Initiating Team 2 WPS teachers (1+1) 2 WPI grad fellows 2 IQP teams 1 WPI faculty member</p>
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Elm Park, Midland Schools

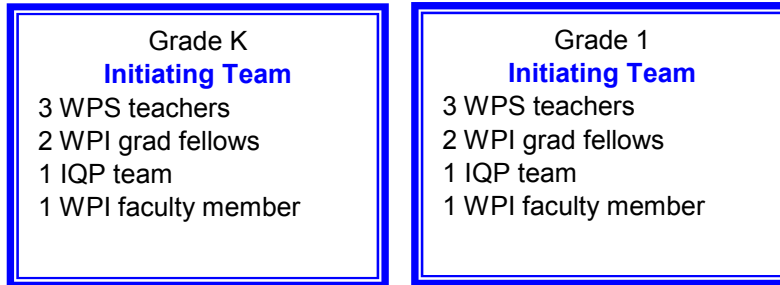
Grades 4, 5, 6

Adaptation Teams (one for each grade level)

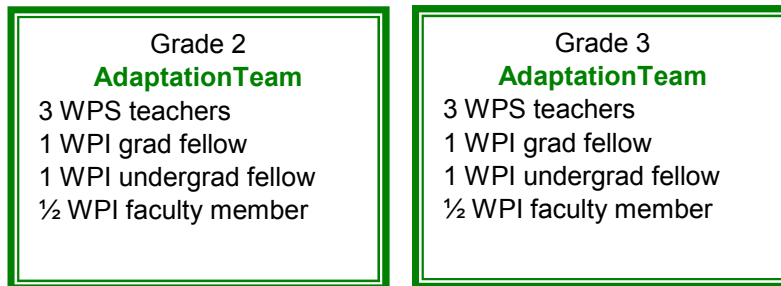
<p>Grade 4 Adaptation Team 5 WPS teachers (3+1) 2 WPI grad fellows 1 WPI undergrad fellow 2 IQP teams 1 WPI faculty member</p>	<p>Grade 5 Adaptation Team 4 WPS teachers (2+2) 1 WPI grad fellows 1 WPI undergrad fellow 2 IQP teams 1 WPI faculty member</p>	<p>Grade 6 Adaptation Team 3 WPS teachers (2+1) 2 WPI grad fellows 1 WPI undergrad fellow 2 IQP teams 1 WPI faculty member</p>
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Fig. 1. Personnel configuration in the first two project years.

School 1
Grades K, 1
2 Initiating Teams



School 2
Grades 2, 3
2 Adaptation Teams



School 3
Grades 4, 5, 6
3 Sustainability Teams

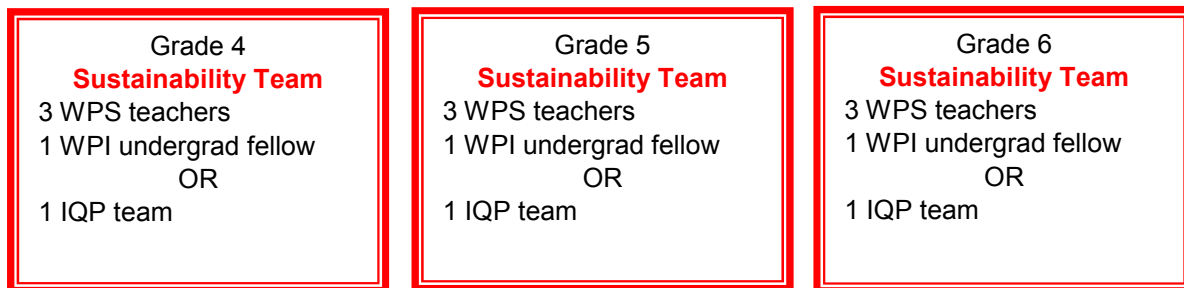


Fig. 2. Arrangement of personnel in year 3 of project.

Following is a summary of the major issues (fortunately, a short list), based on the experience of the PI, co-PI, and other WPI faculty involved in the project, followed by elaboration on some of the aspects:

- The project definitely does not “run itself.” Pro-active, day to day management is essential. This is due to at least two factors: the complexity of the project, and the relative inexperience of most of the participants. This inexperience is obvious for the undergraduate and graduate students, but it is also true in some sense for both the WPS and WPI faculty. The WPI faculty’s engagement in K-6 activities is new for us, as is the WPS teachers’ involvement with engineering and with working with fellows and undergraduate WPI students.
- Occasional difficulty in accomplishing the transfer of responsibility for delivery of engineering/technology lessons from the fellows to the teachers.
- Occasional difficulty in establishing the desired “partner” status between WPS teacher and WPI fellow, rather than “teacher” and “teacher’s aide” status. This is understandable because in the elementary classroom, the WPS teacher is definitely the expert and the WPI fellow is the novice. However, with respect to the engineering/technology lesson content, the roles are reversed.
- Potential time commitments for all participants generally exceed the time that is available.

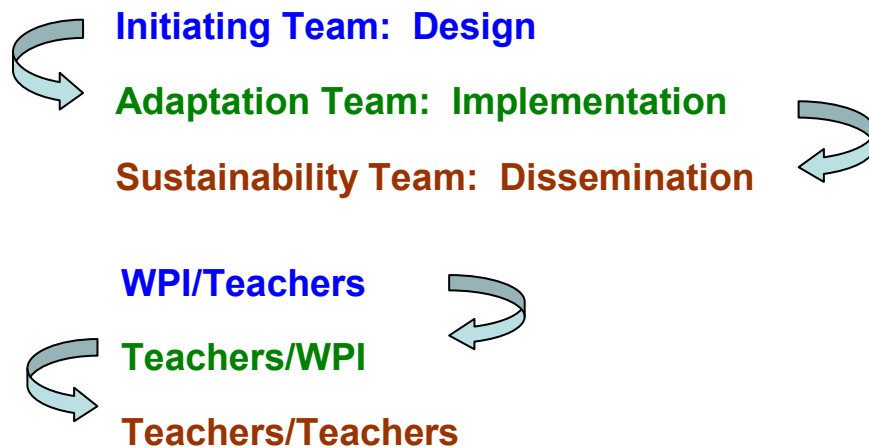


Fig. 3. Progression from year to year as engineering/technology curricula are developed and institutionalized.

Project Management

Until now, the project PI (Judith Miller) has provided most of the administrative and management oversight, including details such as scheduling meetings and following up on small problems. In the near future, some of these duties will be transferred to a non-faculty administrative person. The following points may seem obvious, but must not be overlooked:

- The university and elementary education systems are so different that nothing (such as easy access to a telephone) may be taken for granted;
- The differing academic calendars between the public school system and the university must be taken into account
- A substantial amount of scheduling and record keeping must be carried out on a regular basis.

Time Management

For the fellows, this project is a major activity in their professional lives: nearly full-time during the summer and half time (shared with their graduate studies) during the academic year. For the WPS teachers, on the other hand, this project represents an additional activity in their existing teaching responsibilities. On the one hand, the fellows and undergraduate students provide assistance and support in the classroom which is much appreciated by the teachers. On the other hand, there is inevitably some disruption to the pre-existing academic schedule and some need for the teachers to mentor the WPI students, which leads to new time commitments for the teachers. Also, it must be noted that a fundamental goal of the project is to transfer the engineering/technology lesson plans and background information to the teachers so that the curriculum can be delivered solely by the teachers after the fellows leave. Given the demands on the teachers' time, it is not surprising that a fellow is sometimes asked to deliver the engineering lessons while the teacher takes care of other matters, but this does not accomplish the goals of the PIEE project.

Large time demands have been reported as an issue by the fellows. Both they and their teachers desire them to be in the classroom as much as possible, but this must be balanced with the fellows' other responsibilities both outside the PIEE project (their own studies) and within the project but outside the classroom (developing lesson plans, meeting with undergraduate project students, etc.).

The only solution to these problems of which the authors are aware is active communication among everyone involved, together with the setting of clear expectations by the PIs and school principals and timely response to any incipient problems as they arise.

Organizational Structure and Communications Paths

All of the participants in this project are "part time." While the amounts of time which each person devotes to the project vary greatly, everyone is substantially involved in other activities. This in itself is not unusual, but when combined with the numbers of people involved in this project, the different roles of each, and the differing experience levels, the stage is set for problems of misunderstanding, miscommunication, and lack of communication. In our opinion, the lack of communication is as serious as miscommunication because it will lead to missed opportunities for program success. We address these problems in three ways:

- Clearly defined roles for each person. See the project web site (<http://www.wpi.edu/Academics/PIEE/>) for this and other documents.
- A well-defined, but non-rigid, reporting structure

- Explicit communications requirements, including journals, presentations, evaluations, and scheduled meetings.

Following is a summary of the scheduled meetings:

- General meetings, to which everyone is invited (and schedules permitting, expected to attend). This includes PI's, fellows, teachers, principals, WPS administrators, undergraduate project students, and WPI faculty who are project advisors. These meetings provide an opportunity for overall updates, for the project personnel to get to know one another, and for breakout groups at each grade level (Fig. 4). Four meetings are held per year.
- Fellows with their teachers. These meetings are integrated with the fellows' classroom participation and are obviously vital. It is important that time be set aside for these meetings, rather than just relying on quick exchanges between teachers and fellows.
- Undergraduate project students with the associated fellows and faculty advisors. These meetings are scheduled weekly.
- PI and co-PIs with school principals and other WPI administrators. Four such meetings are held per year, rotating among the schools involved.
- Spring Fair. This event is open to parents and students as well as project personnel per year and is held on the WPI campus annually. It includes classroom displays of engineering projects.



Fig. 4. Informal meetings among WPI faculty, graduate fellows, and Worcester Public School teachers are vital to the program's success.

Pedagogic Issues

The obvious question in this project is: "How do you teach engineering to a second (or third, fourth, fifth, or sixth) grader?" Engineering is a process, not a body of knowledge. Hence, it is quite different from much of the elementary-level science content. However, the scientific method is also a process, so engineering can grow naturally from the laboratory and exploration-based aspects of the science curriculum. Also, science provides the knowledge base for engineering. There does seem to be a tendency to slip back from "engineering" to "science" since the latter is more familiar to most of the participants. The comments from fellows in the next section address this important issue to some extent. The formal engineering design process (proceeding from definition of the problem through the brainstorming phase to construction and test, and then improvement), is frequently referred to. The process and its description is adapted as appropriate to each grade level.

The Fellows' Perspective

The following summary of candid and anonymous comments from current fellows should provide a good insight into the project. Fellows were asked to respond to the indicated questions or statements.

Briefly explain your reasons for choosing this fellowship.

Most of the responses cite a personal interest in working with children, often in the context of interesting them in science and engineering. Aspects specifically mentioned included "giving back" to the community and working with low income children. Only one fellow specifically mentioned the monetary aspect (the fellows are provided with stipends and tuition support).

Has the Fellowship influenced your interest in teaching at any level? Please explain briefly.

Two thirds of the respondents replied in the affirmative, with comments such as "Yes, I am more interested in teaching, but see how difficult it is," and "Yes, I enjoy making a difference in a child's life." The others replied negatively, with a variety of explanations including "No, I don't intend to teach at any level but it has been a good experience and a break from the monotony of WPI classes," and "No, I enjoyed the teaching and working with kids, but I realize that this is not what I want to do for the rest of my life"

Please comment on what has worked and has not worked in the lessons that you have delivered

The responses here were essentially unanimous: hands-on activities, particularly involving something with which the students are familiar, work well, and abstract lessons and those which do not involve building something work much less well. Comments also mentioned the need to use vocabulary that is appropriate to the grade level; even words such as "accurate" and "precise" may not be understood at the lower levels.

To what extent do you believe the PIEE program has improved the teachers' abilities in the engineering/technology area?

On a numerical scale of 1 (not at all), 2 (somewhat), 3 (reasonably), 4 (very), to 5 (extremely), the fellow's responses ranged from 2 to 5 with an average score of 3.33. This is encouraging. The fellows commented that some teachers have enthusiastically

embraced the program, delivering the engineering lessons themselves, while others have been less involved, with the fellows delivering most of the content.

What changes should be made to improve the operation of the PIEE program?

Two types of responses appeared here:

1. Increase the communications among all the participants, and be sure to actively manage the project.
2. Find a way to involve some of the teachers more in the project.

The first response essentially represents a capsule summary of this paper. The second response is perhaps inevitable: when a new set of expectations is introduced, some participants will respond more rapidly than others.

Summary and Conclusions

At the half-way point of the project, the investigators are confident in the validity of this approach to addressing the need to include engineering and technology in the elementary school classroom. Significant impacts have already been made on over 500 elementary students, teachers, and WPI graduate and undergraduate students. The authors hope that the insights provided in this paper will help others in conceiving and implementing similar programs in other school systems.

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