4 SCHOOLS FOR WIE

Evaluation Report

Sumru Erkut & Fern Marx
External Evaluators
Wellesley Centers for Women

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Executive Summary

Evaluation of 4 Schools for Engineering

With funding from the National Science Foundation, engineering schools at Northeastern University, Tufts University, Worcester Polytechnic Institute, and Boston University joined forces in an effort to increase the number of girls who develop an interest in science, technology, engineering, and mathematics (STEM) fields during the middle school years, as well as in STEM careers. The 4 schools for Women in Engineering (WIE) strategy was to form all-female teams to train teachers and to serve as in-class resources for them. STEM Teams developed gender equitable engineering units to be used in 8th grade science classrooms and helped middle school teachers implement the new units for the engineering strand of the Massachusetts Frameworks. The strategy was implemented in eight public school districts in the greater Boston area.

Evaluation Components

The evaluation focused on how teachers and STEM team members experienced the program and what the impact of the intervention was on students. Teachers' and STEM Team members' perceptions were assessed through open-ended anonymous questionnaires completed after the implementation of the intervention. The impact of the intervention on students was assessed through comparing attitudes toward engineering, mathematics, science, and STEM fields and careers before and after the intervention.

1. Teacher Outcomes

In a paper and pencil survey with open-ended questions teachers were asked to reflect on the benefits of the project and the effectiveness of the STEM Teams, and for their recommendations for additional training, support, STEM Team composition and curricular changes. Integrating gender equity into their classroom teaching and activities was singled out as a highly effective component of the intervention. For the teachers participation in the STEM Teams involved exposure to expertise from actual engineers, graduate and undergraduate students, and industry representatives coupled with the training. Teachers reported that the training was an integral part of their participation and that it made a difference in both their understanding of engineering and in how to teach this subject effectively. For their students, the benefits teachers highlighted were exposure to role models, glimpses into the real world of work for engineers, and a curriculum that made it possible for all students to achieve up to a benchmark of proficiency rather than a competitive classroom environment where only a few students are engaged in the projects.

2. Impact on STEM Team Members

Each STEM Team was composed of a coordinator, teachers, faculty members, undergraduate and graduate students, and industry representatives. In group discussions and in response to an open-ended survey STEM Team members reported having enjoyed the regular meetings that kept the teams focused and remarked on the synergy generated by the diversity in team membership. The ability to expose middle school students to a wide variety of practicing engineers was also mentioned as a strength of the program. Several respondents recognized the value of having undergraduate students in the classroom, which not only made some projects possible but also was instrumental in establishing good rapport with the 8th grade students. Some team members also noted the challenges of recruiting and training undergraduates for the classroom.

All in all, the evaluation showed that it is feasible to bring together individuals from different domains to work together toward enhancing the teaching of STEM fields, with a specific emphasis on engineering.

3. Impact on Students

The student evaluation was carried out by comparing answers students gave to the same questionnaire administered in the beginning of the school year (pre-test) and then at the end of the school year (post-test). The outcome of the intervention is reported both in terms of general program impact averaged over all students and also in terms of its effect on individual students.

Program Level Outcomes

On the whole, students indicated that they found the classroom activities “somewhat” or “very interesting,” and this was true both for students who were not particularly interested in pursuing careers in math, science, and engineering as well as for those who did. Attitudes toward science were more positive after the intervention, attitudes toward engineering were less positive, while attitudes toward math did not change. The fact that the science attitudes showed a significant increase over the course of the semester speaks to the overall efficacy of the curriculum, which was presented in science classrooms.

Several explanations can address why the engineering attitudes were less positive following the intervention than before it. First, it may be that the use of attitudinal measures does not adequately reflect the actual learning that has taken place in math, science, and engineering and that testing actual knowledge might have resulted in more favorable findings. Another explanation is that for some students, a less favorable attitude toward engineering after the intervention may reflect a more *realistic* appraisal of their thinking about engineering after they became better acquainted with it through the intervention. Indeed, the individual level outcomes bear this out in that some students’ attitudes toward engineering, especially girls’, were more highly influenced by the intervention than their attitudes toward science or math.

Overall, when changes in girls’ attitudes toward STEM fields and careers were compared to those in boys, more girls reported a positive attitude change toward careers in engineering and chemistry than did boys. For girls, which school they attended (and thereby which teacher taught them, because only one teacher participated in most schools) was related to whether the intervention was associated with greater attitude changes toward both STEM fields and STEM careers, whereas it made no difference for boys. This finding is based on a small number of schools and needs to be viewed as tentative.

Individual Level Student Outcomes

In spite of the fact that students' overall scores on attitudes toward engineering did not become more positive after the intervention, there were a large number of individual students whose scores increased — that is, their attitudes toward STEM fields or careers became more positive — between pre- and post-test. We examined the impact of the intervention on individual students using regression analyses which yield information on what variables best predict whether a student's scores will increase or decrease. The results show that students who started out with lower positive attitudes toward both STEM fields and STEM careers made more gains after the intervention than students who started out with more positive attitudes. Moreover, the intervention had a greater impact on female students' attitudes toward engineering as a field of study as well as on choosing engineering as a career than it did on male students' attitudes.

We interpret the finding that the intervention had more influence on girls' attitudes (both positive and negative) toward engineering as a field and a career in terms of the possibility that girls were relatively less well informed about engineering hence had greater openness to new information on this topic. Indeed, girls' attitudes were influenced at the same level as boys' on biology and chemistry as fields of study and careers, which are better known fields. We believe that the intervention was able to influence girls more because, due to a lack of previous experience or knowledge, girls had fewer preconceived notions about engineering. This interpretation is bolstered by the finding that before the intervention fewer girls reported knowing engineers than did boys.

Conclusions

The evaluation shows that the 4 Schools for WIE project had the intended outcomes:

- Capacity building among 8th grade science teachers for increasing their confidence to teach engineering;
- Demonstration of the feasibility of forming well-functioning STEM teams that include middle school teachers, academics, graduate and undergraduate students, and industry representatives;
- Program level increase in positive attitudes toward science as a field of study (but not in engineering or mathematics);
- Individual level impact of the STEM Team strategy on girls' attitudes toward engineering both as a field of study and as a career to a greater extent than on boys' attitudes.

An unexpected but welcome finding was that the intervention was associated with greater improvement in the attitudes of students who started out with relatively low scores on attitudes toward STEM fields and careers than those who started out with more positive attitudes. The greater benefit of the intervention on students who showed the most positive change relative to where they started out in the beginning of the academic year and who had relatively less positive attitudes toward STEM fields and careers was a finding that was true for both girls and boys. This suggests that the intervention has the potential to benefit those who hold less positive views of STEM rather than merely making students who already hold positive attitudes even more positive.

All in all, the STEM team intervention succeeded in its goal to improve teachers' capacity to teach the new engineering strand in the 8th grade science curriculum. It succeeded partially in terms of improving students' attitudes toward STEM fields: all students' attitudes toward science as a field of study improved, but not toward engineering or mathematics. Perhaps most significantly, it resulted in more girls than boys coming to view engineering and chemistry as possible careers for themselves and had a larger impact on girls than it did on boys. Moreover, the context of school or teacher was related to changes in girls' attitudes toward engineering and mathematics as a field of study and engineering as a career but not that of boys.

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Evaluation Report

Background

With funding from the National Science Foundation, engineering schools at Northeastern University, Tufts University, Worcester Polytechnic Institute, and Boston University joined forces in an effort to increase the number of girls who develop an interest in science, technology, engineering, and mathematics (STEM) areas during the middle school years as well as in STEM careers. As an important step toward achieving this mission, the four schools designed a unique intervention system composed of trained STEM teams consisting of mostly female engineering faculty, students, teachers, and industry representatives as practitioners (with only a few males). Each engineering school developed its own STEM team to train middle school teachers about engineering and gender-inclusive practices and to serve as role models in the middle school classrooms. In addition to paying attention to gender equity, the STEM teams designed lesson plans that met the requirements of Science and Technology/Engineering Curriculum Frameworks in the Commonwealth of Massachusetts.[1] The 8th grade science classrooms in eight public schools in the greater Boston area used the engineering lesson units and benefited from the teams' help in implementation of the engineering strand of the Massachusetts Frameworks. For more information on the design of the project go to www.steamteams.org.

Evaluation Design

The evaluation focused on outcomes for teachers, STEM Team members and, more importantly, on the impact of the intervention on students. Teacher and STEM Team outcomes were assessed through an open-ended anonymous questionnaire. The impact of the intervention on students was assessed through comparing attitudes toward engineering, mathematics, science, and STEM careers before and after the intervention. All questionnaires were extensively field-tested in the first and second year of the program's operation.

Teacher Evaluation

Teacher Questionnaire

Teacher outcomes were assessed at the end of the 2003-2004 school year and again at the final feedback session held on September 30, 2005. The first survey asked teachers to reflect on the goals of the overall project and the effectiveness of the STEM Teams and to suggest recommendations for additional training, support, STEM Team composition and curricular changes (a copy of the Teacher Questionnaire and Report is in Appendix A).
The third-year survey asked teachers about what aspects of the STEM Team approach worked and didn't work for them.

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[1] Beginning in the fall of 2001, Massachusetts was the first state in the nation to introduce engineering as part of its mandated PreK-12 education frameworks.

Teacher Outcomes

Compared to the more extensive survey teachers completed at the end of the school year 2003-2004, only two questions were asked of the teachers implementing the curriculum at the conclusion of project. The teachers were asked to reflect about: 1) which aspects of the STEM Team approach worked for them; and 2) which aspects did not work for them. All six teachers responding to the survey had been involved in the project from its inception.

One of the ways in which the STEM Team approach appears to work effectively is by increasing access to expertise from faculty and undergraduate and graduate students plus the extra classroom support for 8th grade students and the teacher. Also mentioned was the support received through the provision of resources including equipment, supplies, access to information. One teacher also commented positively on the intensity and frequency of the university involvement.

For some teachers a key element in the success of the undertaking was the expertise contributed by each STEM Team member. For example, the engineers provided their expertise in science, the graduate and undergraduate students brought to the table the most current research findings, the industry representative provided real-life, fresh perspectives from their field experience, and middle school teachers provided knowledge of how to approach and teach young adolescents.

Some teachers commented on the positive effects of providing role models for students.

> Students benefited from positive role models… women as engineers in the classroom. Many young women in my class expressed a strong interest in pursuing careers in biotechnology.
>
> The sharing of current research by the undergrads gave my students a real sense of how biotechnology helps people… they wanted to pursue a career where they could help make someone else's life better.
>
> My students look forward to our projects and having engineers in the classroom. Many of my students do not have college role models, nor engineers in their lives. The exposure to engineering and what they do and who they are was wonderful.
>
> It also provided a mentor/mentee level to both myself and my students.

Several teachers commented on how enjoyable their involvement in the project was for them and how much it contributed to their own learning.

> I have been part of many partnerships with higher education institutions and this has been one of the most enjoyable and resulted in deep learning.

> I grew in my own confidence in terms of understanding molecular biology and biotechnology.
>
> Project based approach was effective and fun!
>
> This was the first time in my career that I have actually worked with “real” people in a career field. They increased my knowledge and ability to teach engineering.
>
> The collaboration among our team was probably the most influential development in all my education training. I had never been exposed to engineering and the old saying that “the teacher learns the most” was very true.
>
> I learned to think as an engineer and now it is simply a part of my planning.

One of the goals of the project was to address gender issues in math, science, technology and engineering in mixed-gender classrooms. According to the teacher comments, both the curriculum and the training succeeded in achieving positive outcomes in gender equity.

> This is of particular concern in the classroom where both boys and girls are present. Boys tend to grab the materials first, build first and test first, before their female counterparts have had sufficient time to consider the possibilities and make a plan of action. But long term design challenges required students to apply their understanding of science in a very explicit way. This is often not the case in engineering design challenges.
>
> It helped me as a teacher think about gender in the classroom and provided me with tools to help both genders succeed… projects where everyone has to reach a certain benchmark as opposed to competitive winning situations.

Additional comments indicated that students became knowledgeable and developed a deeper understanding of the design process as evidenced in their ability to apply it across contexts. The program also succeeded in avoiding many of the pitfalls of other currently used engineering curricula.

> Students saw themselves as scientists. They were in fact engineers and scientists. Their belief in themselves as smart and capable grew tremendously.
>
> The curriculum avoided many of the weaknesses in currently marketed engineering curricula, which while some experiments work, they do not result in a greater understanding or application of scientific content or principles.

Compared with the extensive accolades the six teachers gave the program, when asked what about the STEM Team approach did not work for them, they provided only very brief comments. One major concern voiced by two teachers was the issue of “timing.”

> Timing was tricky at times… in the classroom… to come to STEM team meetings. Lack of time is a huge constraint in all areas of life, especially in the classroom.
>
> The only negative that I found in the program was the scheduling. It is very difficult to align 8 people. Every professional was as flexible as they could be: for the students [graduate and undergraduate students] it was a major problem.

Another teacher voiced concern about the messages that were sent when there was a lack of growth in student attitudes. She felt that activities during the fall workshops were geared towards "fixing" teachers rather than a reevaluation of whether the structure of the program might not also be an effective strategy.

STEM Team Members' Evaluation

In addition to teachers, the third year survey also asked other STEM Team members about the efficacy of the STEM Team approach. Respondents ranged from STEM Team coordinators, college faculty members, graduate and undergraduate students to industry representatives.

One of the most positively perceived aspects of the approach was the diversity of the teams and the regular meetings that served to keep the teams focused. The ability to expose middle school students to a wide variety of practicing engineers was also mentioned as strength of the program. Several respondents recognized the value of having undergraduate students in the classroom, which not only made some projects possible but was also key in establishing good rapport with the 8th grade students. The challenges of recruiting and training undergraduates for the classroom were also noted.

Faculty members spoke to the value of full team training as did the industry representatives, who commented on the importance of the training in grounding everyone on the team, providing an opportunity to meet all the players and form relationships that would last beyond the program. One of the industry representatives commented on the freedom the teams had in developing their own projects, which increased the level of the team's commitment to the undertaking.

> I thought the most valuable part of the program was bringing in real engineers to speak to the students. …. We had an environmental engineer from Deer Island, a professor who works on solar cells, an engineer who works at a local biomedical (device) company, and a grad student who develops programs coming to speak to the students…. I think having a diverse group of speakers is really important. Maybe students will see a person they can identify with or a project that sound really cool and they will think, "I can do that." Especially if the student doesn't have a parent who is an engineer… they might never consider [engineering] as a career.

> Partnering university, middle schools and industry so that each could manage "part" of the program they are most capable of; it would have been very difficult for any one partner to coordinate and pull off [the] entire program.

> Allowing each STEM team to create and implement their own projects gave ownership and a higher level of commitment from the STEM teams.

> I learned a lot about thinking about gender in the classroom; inspiring discussions, ideas…. Working with the teachers was very good…so that the projects were at the appropriate level for the students.

Several comments related to the effect of the projects on the middle school students. One respondent commented on a specific project that provided the students, particularly the girls, with an opportunity to use real equipment and feel like real scientists. Another STEM Team member felt that the students were exposed to and learned about engineering principles that interested them, without necessarily realizing they were learning them.

> I think some of them [the girls] will now consider a career in engineering. …. The girls excelled at the project because it required taking precise measurements and carefully adding liquids, etc.

> I believe the students were enriched and inspired by the program.

In terms of what did not work in the STEM team approach, similar to the teachers, other team members had relatively few comments. One of the few frustrations mentioned was finding undergraduates who had the time to participate in the classrooms. A suggestion was made to pair an engineering student and an education student. These students would work in pairs and learn from each other how to teach science.

> We asked a lot of the [undergraduate and graduate] students and they were given no real training on how to act/interact with middle school students.

The other issue was one of time, a pressure felt by almost all team members. One of the industry representatives noted the need for extensive coordination in order to make the projects work and that while the lesson plans were delivered, the activities were not consistent across middle schools.

> Everyone felt very pressed for time. We (the non-teachers) wanted to be in the classrooms more, but we each had too many other responsibilities.

Letting students know in advance the amount of time expected of them was another recommendation.
One respondent raised concerns about the use of prizes and the idea of winning rather than learning.

> The part that did not work for me was the association with prizes or awards for each project we did. I think the students associated winning and prizes with being successful rather than learning and the knowledge and skills that they gained. I think if the awards were taken away, and [not] choosing students as the best or not the best, the students would appreciate the projects that they did more, rather than focusing on the prizes or the place they came in compared to other students.

A key component of the STEM Team's success was due to the work of the coordinator of each team who took responsibility for the organizational, administrative, and also curricular aspects of the strategy and worked closely with the teachers.

> We had fabulous teachers and that is what would make or break this approach. We also had a great coordinator who kept everything organized.

Student Evaluation

Evaluation Design

The evaluation was carried out by comparing answers students gave to the same questionnaire administered in the beginning of the school year (pre-test) and then at the end of the school year (post-test).[2] The pre-test survey was administered between 9/22/04 and 11/18/04; the post-test survey between 4/11/05 and 4/28/05. The retention rate between survey administrations was 88%.[3] Questionnaires were administered by the STEM Team coordinators during the science class period. Most students were able to complete the questionnaires within 20 minutes.

The impact of the intervention is reported in terms of a general program impact averaged over all students and also in terms of its effect on individual students. The former is important for understanding program level effects. The latter provides information on the ways in which individual students were influenced by the intervention. This dual focus in evaluating impact on students was implemented because, even if an intervention may not yield overall program level effects, its impact on individual students who improved as a result of the intervention can be examined to yield insights on "what works."

Demographic Characteristics of the Students

The students ranged in age from 11 to 16; the mean age was 13.41. All students were in the 8th grade. The overall distribution of gender was 51.4% male and 48.6% female. A total of 436 students on whom we had pre-tests completed the post-test survey and these students

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[2] Pre-test and post-test are used interchangeably with pre-intervention and post-intervention throughout the report.

[3] The retention rate was not a product of dropping out of the study. Rather, it reflected temporary absence on the day the pre-test was administered and students moving to another community.

form the basis of the study group for the final data analysis.[4] The number of pre- and post-test surveys received from each school can be seen in Figure 1.

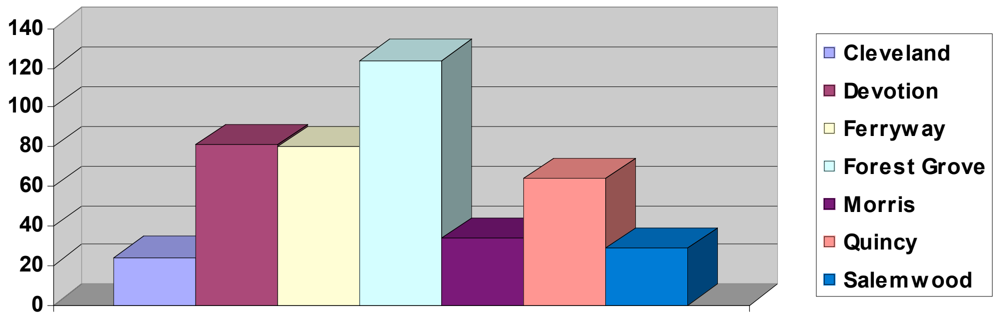

Figure 1: Distribution of Pre- and Post-test Surveys Received by School, N=436.

The largest racial/ethnic group of surveyed students was Caucasian, followed by Asian/Asian Descent, Black/African Descent, Hispanic, Other, and Biracial/Multi-ethnic (see Figure 2). The responses for Biracial/Multi-ethnic and Other included Chinese/Italian, African American/Asian, African American/Dutch/Italian, African American/Native American, African American/Caucasian, and Greek/Puerto Rican among others. It should be remembered that the racial/ethnic distribution is reflective of the schools from which the study group is drawn.

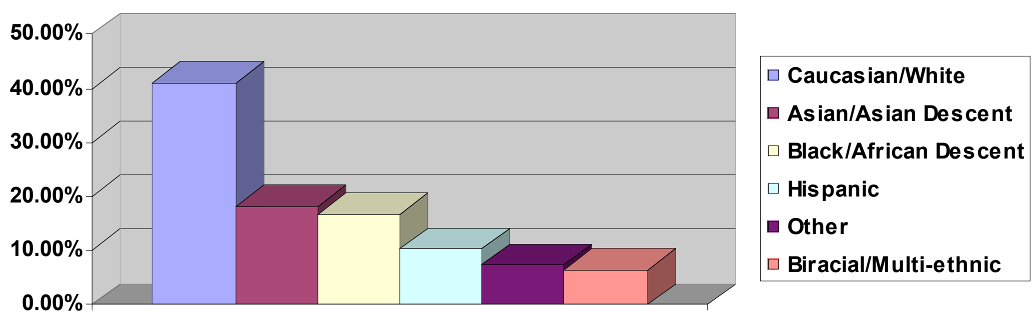

Figure 2: Racial/ Ethnic Distribution of Study Sample, N=435.

Characteristics of the intervention classrooms. Teachers provided the information on whether there was ability tracking in their school whereby students are placed in different classes based on some performance criteria. The study sample was almost equally divided between classrooms which did and did not track students (46.8% compared to 53.2%). These differences reflect school and/or school district policies.

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[4] For the purpose of analysis, one group is omitted from final study sample. The "Experimental Lego Group," which included 8 students on whom we had pre- and post-tests was omitted since they received a program with some variation from other experimental students in that school.

Discipline issues in the classroom were elicited either through self-reports by the classroom teacher or reported by the STEM Team coordinator, who had direct classroom experience or observed the classroom during survey administration. Discipline was seen as a problem in only 17% of the classrooms.

Academic level of classrooms was also estimated by classroom teachers and/or coordinators in consultation with classroom teachers. Class level ranged from Honors (AP class level) and Advanced (College Prep), Mid-level (basic level math & science), Standard (lowest level at the school) and Mixed (academic level in math and reading covered a wide range of skill and grade levels) (see Figure 3). It should be remembered that different school systems use different rankings and this information should be viewed as suggestive rather than definitive.

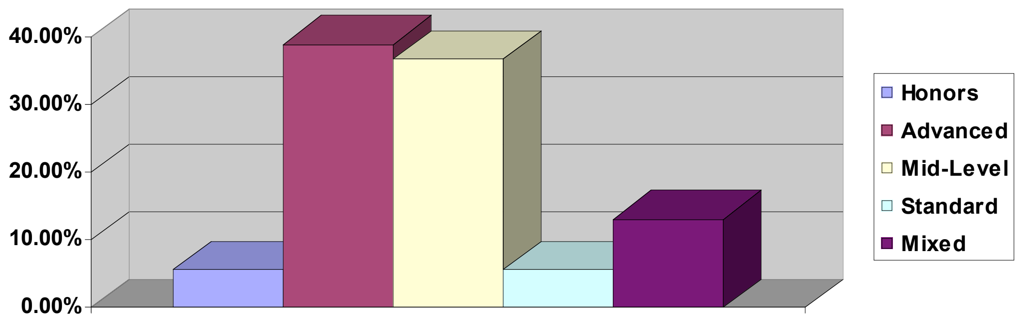

Figure 3: Class Level

Student Questionnaire

In addition to three attitude scales to be described later, the student questionnaire contained questions on educational goals, interest in a variety of careers related to STEM fields, and whether they knew any engineers. The post-test was identical to the pre-test and included an additional question on how interesting they found the activities on engineering in their science class and why. A copy of the Student Questionnaire can be found in Appendix B.

Student Characteristics

Future education goals. In response to the question, "Do you plan to go to college?" students could respond, "yes," "no" or "not sure." There was no statistically significant difference between pre- and post-test. At pre-test 91.0% replied affirmatively; at post-test 89.4% did so. The "not sure students" were 7.8% and 8.0% at pre-test and post-test, respectively. Differences by gender were not statistically significant at pre-test but almost reached significance at post-test ($p < .07$). At both times girls were more likely than boys to respond they planned to go to college (pre-test 92.9% compared to 89.3%; post-test 91.8% compared to 87.2%).

Knowing engineers. At both pre-test and post-test students were asked if they knew any engineers. At pre-test 35.7% indicated that they knew engineers. Given the classroom exposure to engineers over the school year, the proportion indicating that they knew engineers rose to 55.3% by post-test. The "not sure" group dropped from 34.3% to 24.7% between test administrations. This was a statistically significant pre-post difference ($p<.001$). Although not statistically significant, a slightly greater proportion of boys (36.8%) indicated they knew engineers at pre-test compared to girls (34.6%). By post-test, these proportions were reversed with 58.2% of girls indicating they knew engineers compared to 52.5% of boys, approaching statistical significance at $p<.07$. This finding suggests that exposure to female role models was somewhat more memorable to girls than to boys.

How interesting did students find the activities on engineering in this class. This question appeared on the post-intervention survey only.[5] A total of 411 students responded. Only 8.0% indicated that the activities were not at all interesting; 57.2% that activities were somewhat interesting and 34.8% found the activities very interesting. The average score was 2.27 (between somewhat interesting and very interesting). There were no differences in average scores by gender.

When asked to explain their answer, getting into the material, hands-on activities, specific modules, and the teams all were viewed as positive and even very positive aspects of their classroom experience. Among those who did <u>not</u> find the class at all interesting, many of the comments indicated that they found the class boring, redundant, and irrelevant because they were not interested in engineering, math, or science.

Typical statements among those who found the class very or somewhat interesting included,

> The things that can be done with engineering are very interesting. I think it's cool how we can make things out of everyday products that can be used all around the world.
>
> Because I love engineering…; building stuff out of nothing that will help everybody.

One group of students who felt positively about the class used the word "fun" to explain their response.

> I couldn't see myself as an engineer or even working with engineering, but after we did some of those projects in science, I realized that you could have a lot of fun with engineering, even though it wasn't one of the jobs I wanted to work in the future.
>
> Working on all the projects was very fun and it made me think about what I am doing and how to do it best instead of just having only one possible way of doing it.

Some of the students indicated that the class helped them learn or was educational, specifically mentioning the problem solving approach and hand-on activities used in the class.

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[5] The question was scored as 1=*not at all interesting,* 2=*somewhat interesting*, and 3=*very interesting*. It should be noted that students could provide as many explanatory responses as they wished. To get an estimate of the magnitude of the individual response category, the number of responses for each category was divided by the total number of valid responses.

> It's interesting because you can learn how different things work.
>
> [We use] many hands-on activities instead of reading out [of] the book. At the same time we learn a lot.

Several students mentioned specific projects or activity modules as reasons for their positive evaluation of the class.

> I enjoyed it when we created objects like shoes because they used creativity and imagination, however, I did not enjoy experiments like the chocolate factory because the materials and steps involved limited my flexibility. For example, the lamp had to be a specific height above the factory. The thermometer had to be a specific temperature before you began using it as well. Also, I found the baseboards difficult to work with because the wires kept popping out.
>
> Because I learned new things through this program and to me it was fun to work with different problems such as the cast project, candy project and the bridge project. They were all fun to me. My favorite project was the candy one because you got to eat the candy afterward.

Only 7% of respondents found the class boring and another 6% indicated that either they already had been exposed to similar activities in "kindergarten." Some felt that while the activities "looked cool" they had problems understanding what the activities were about. Others found a few activities interesting, such as the solar cooker, but found others pointless.

A few students mentioned role models, mentors, or teachers with particular reference to having the students and the engineers in the classroom. Several students noted that they enjoyed the teamwork and group work but were not sure they were interested in being an engineer.

Several students felt that the class would be helpful for their future.

> I think that some engineering is an interesting profession to choose and would help me be successful and happy. Some topics in engineering, I'm not as interested.
>
> We learned new things and it taught us that most of the time there is more than just one solution to solve a problem. It was fun thing and I know it will help me with my life in the future.

Attitudes toward Engineering, Math, and Science

The attitude scales[6] were derived from several sources and were evaluated in a series of pilot tests for both reliability and construct validity. (Information on the reliability and validity of the attitude scales can be found in Appendix C.)

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[6] Each attitude scales were scored as 1=*Strongly Disagree*, 3=*Not Sure*, and 5=*Strongly Agree*.

- *The Attitude towards Math and Science Scales* were adapted from Diane Doepken, Ellen Lawsky and Linda Padwa scales, which they had modified from the Fennema-Sherman Attitude Scales. The modification took place at the Gender Equity for Mathematics and Science Conference of Woodrow Wilson Leadership Program for Teachers in 1993. In our adaptation the original number of items pilot tested for the Attitude towards Math was 37 and for the Attitude towards Science was 27. Both scales were revised and successive versions were piloted in three communities. The final version for the 2003-2004 school year included 23 items for the Attitude towards Math scale and 21 items for the Attitude towards Science scale. Based on the 2004-2005 pre-test further revisions of the two scales were undertaken resulting in a 13-item Math scale and a 10-item Science scale. Both scales had Cronbach's alpha internal consistency reliabilities above .85.

- *The Attitude towards Engineering Scale* was adapted from the Survey of Attitudes towards Engineering scale developed by Robinson, Fadali, Carr, and Maddux (1999). The original number of items we pilot tested included 12 engineering and 24 activity interests. Successive revisions were based on pilot testing in four communities. The final 2003-2004 school year version contained 18 items. The scale was further reduced subsequent to the analysis of the pre-test data and resulted in a 12-item scale with Cronbach's alpha internal consistency reliabilities above .80.

Program Level Effect of Intervention

Comparison of pre- and post-intervention average attitude scores.

Table 1: Simple Comparison of Pre- and Post-Intervention Average Attitude Scores, Paired t-tests

	Pre-Average	***s.d.***	**Post-Average**	***s.d.***	**Paired *t*-test[a]**	**Significance (2-tailed)**
Engineering Attitudes Scores	**3.24**	**.723**	**3.15**	**.735**	**3.235**	**.001**
Math Attitudes Scores	**3.77**	**.790**	**3.76**	**.801**	**.492**	**.623**
Science Attitudes Scores	**3.44**	**.652**	**3.53**	**.756**	**-3.105**	**.001**

[a]Positive or negative sign of the *t*-test statistics reflect the difference between pre-test scores from the post-test scores. A positive *t* statistic shows that pre-test scores were higher.

A simple comparison of pre- and post-intervention scores using paired t-tests found a statistically significant difference between pre- and post-intervention scores for engineering and science. The engineering score was *lower* at post-test while the post-test science score was higher, and the attitudes toward math score did not change. Table 1 summarizes these findings.

Comparisons across schools. When these same scores were examined by school, at Ferryway, Forest Grove and Morris, post-test engineering attitude scores were statistically significantly lower (p<.05) as was the post-test math score at Quincy (p<.05). The only school in which the engineering attitude score increased between pre- and post-test was Salemwood, although it was not statistically significant. Even though math attitude scores did increase positively between pre- and post-tests at three schools — Devotion, Ferryway and Forrest Grove — the increases did not reach statistical significance. Science attitude scores increased significantly at two of these three schools between test administrations (Devotion, p<.01 and Forrest Grove, p<.05) and almost reached significance at Ferryway (p<.09). At the Morris and Quincy schools science attitude scores also increased between pre- and post-tests but did not reach significance.

Comparison of average pre- and post-intervention attitude scores by gender

In Table 2 we present the comparison of average pre- and post-intervention survey scores by gender. Boys' average scores began higher at the pre-intervention survey on all three scales and continued to be statistically significantly higher at post-intervention survey. The overall trends noted in Table 1 persisted when the average attitude scale scores were examined by gender.

Table 2. Simple Comparison of Average Pre- and Post-Intervention Attitude Scores by Gender

	Girls'		**Boys'**		
	Mean	***s.d.***	**Mean**	***s.d.***	***F*-test**
Pre-Intervention Engineering Attitudes Scores	**3.02**	**.658**	**3.43**	**.727**	**38.597*** **
Post-Intervention Engineering Attitudes Scores	**2.95**	**.721**	**3.35**	**.691**	**35.175*** **
Pre- Intervention Math Attitudes Scores	**3.63**	**.817**	**3.90**	**.742**	**13.338** **
Post- Intervention Math Attitudes Scores	**3.62**	**.847**	**3.90**	**.728**	**13.244*** **
Pre-Intervention Science Attitudes Scores	**3.34**	**.641**	**3.52**	**.654**	**8.523** **
Post-Intervention Science Attitudes Scores	**3.45**	**.782**	**3.60**	**.725**	**4.204* **

p<.05; ** p<.01; *** p<.001

Both boys and girls average scores on engineering attitudes decreased between administrations and remained essentially unchanged on the math attitudes. Science attitudes scores, on the other hand, increased for both genders between administrations with girls' scores increasing by a slightly greater amount than boys' scores (.11 and .08, respectively).

Attitudes toward STEM professions/occupations. On both the pre- and post-test students were asked to indicate their possible interest in a list of professions/occupations that use knowledge about math, science and/or engineering.[7] Students rated only one profession, Computer Technician, significantly differently ($p<.001$) between pre- and post-test but in a negative direction; the pre-test score was significantly higher than the score at post-test. While not reaching significance, post-test scores increased slightly for Nurse, Electrician, and Chemist but remained unchanged for Engineer.

When the professions/occupations were analyzed by gender, statistically significant differences were noted for Engineer ($p<.05$) and an almost significant difference was noted for Chemist ($p<.08$). In both professions, girls' scores increased between administrations by a small amount, while boys' scores decreased for each of these professions. Overall boys' scores increased between administrations for only two professions/occupations: Nurse and Electrician. Girls' scores increased and by a larger amount for Nurse and Electrician and also increased positively for Chemist, Engineer, and Biologist.

Discussion of Overall Program Effects Averaged over All Students

The results presented up to this point do not provide support for the intervention's impact on increasing girls' attitudes toward STEM fields. In terms of attitudes toward STEM *careers,* however, relative to boys, girls registered more positive attitudes toward STEM careers in engineering, chemistry, and biology. In the following section we discuss the impact of the intervention on individual students.

The fact that the attitudes toward science scores showed a significant increase over the course of the academic year speaks to the overall efficacy of the curriculum, which was presented in science classrooms. On the whole, students indicated that they found the classroom activities somewhat or very interesting and this was true even for those students who were not particularly interested in pursuing careers in math, science, or engineering.

Several explanations suggest themselves to explain these limited findings. First, it may well be that the use of attitudinal scores may not adequately reflect the actual learning that has taken place in math, science, and engineering and that testing actual knowledge may result in more favorable findings. Another explanation is that for some students, a less favorable attitude toward engineering after the intervention reflects a more *realistic* appraisal of their thinking about engineering after they became better acquainted with it through the intervention. Indeed, the individual level outcomes bear this out: some students' attitudes toward engineering were highly influenced by the intervention.

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[7] The four-point scale was ranked: 1= *Not At All Interested*, 2=*Not So Interested*, 3=*Somewhat Interested*, and 4=*Very Interested*. The list of professions/occupations included: Physicist, Nurse, Auto Mechanic, Medical Doctor, Electrician, Computer Technician, Welder, Chemist, Engineer, Accountant, Biologist, and Architect.

Perhaps a more important indicator of the positive nature of the classroom experience can be found in the statistically significant increases between administrations in girls' scores on two possible future careers, namely engineer and chemist. This finding stands in contrast to decreases in boys' attitudes toward both of these professions between pre- and post-intervention survey administrations.

Impact of School/Teacher on Program Outcomes

It is important for any evaluation to examine if unique and unmeasured qualities of schools or teachers make a difference in an intervention's outcome. These qualities can include the socioeconomic status of the school neighborhood, whether the school is in an urban or suburban community, teachers' age, teachers' educational level, years of service as a teacher. Eight middle schools participated in the implementation of the STEM Team strategy. In all but once case, only one teacher participated in the program from each school – one of the eight schools had three participating teachers. Because teachers and schools overlapped in most cases, any potential effect of the school is confounded by teacher effects. For that reason we refer to a joint school/teacher effect when comparing outcomes by school.

An examination of change between the pre- and post-intervention scores (using the one-way analysis of variance procedure) indicated that among boys there were no statistically significant differences across the eight schools. Only on pre-post difference scores on attitudes toward science and becoming a chemist were there school/teacher differences that *approached* statistical significance ($F = 1.895$, $df = 6, 207$; $p = .09$ and $F = 1$, $df = 6, 205$, $p = .07$, respectively). For girls, however, which school they attended (the STEM team and/or teacher they had) made a difference in their attitudes toward engineering as a field of study ($F = 2.169$, $df = 6, 202$, $p = .05$), mathematics as a field of study ($F = 3.197$, $df = 6,203$, $p = .01$), and attitudes toward becoming an engineer ($F = 2.161$, $df = 6, 192$, $p = .01$). These results suggest that girls were more likely to be influenced by contextual factors in the school or by their science teacher, especially regarding engineering both as a field and as a career. These results pertaining to the school and teacher context need to be viewed as tentative because of the small number of schools involved in the evaluation.

Impact of Intervention on Individual Students

Whether or not there were gains (e.g., in attitudes toward science) or losses (e.g., in attitudes toward engineering) at the program level, there were a large number of individual students whose scores increased – that is, their attitudes toward STEM fields or careers became more positive – between pre-and post-test. We examined the impact of the intervention on individual students using regression analysis which yields information on which variables best predict whether a student's attitudes will become more or less positive over the course of the intervention.

Impact on attitudes toward STEM fields

The impact of the intervention on individual students' attitudes toward STEM fields was analyzed in terms of difference scores. The difference scores capture the change in attitudes from the pre-test to the post-test, calculated by subtracting the pre-test scores from the post-test scores. Because a change from a score of 1 on the pre-test to 3 on the post-test is identical to a change from 3 to 5, the regression analysis included the pre-test score to control for each student's attitudes before the intervention. In this way we were able to examine if students who started out with less positive attitudes toward STEM fields or careers changed more, the same as, or less than students who already had relatively more positive attitudes before the intervention began.

In Table 3 the results of the regression analyses examining the difference scores on attitudes toward the STEM fields among *male* students is presented. The regression results are expressed in *beta* scores.[8] The predictor variables in this analysis are whether the student found the class interesting, the pre-intervention attitudes toward STEM fields, and the pre-post difference scores on attitudes toward STEM fields. Other predictors such as age, knowing engineers, and self-assessment of proficiency in the STEM subjects were examined but eliminated from the final regression analysis because they did not make a significant contribution to understanding change in attitudes from pre- to post-intervention for a given STEM field.

The results in Table 3 show that for each pre-post difference score in attitudes toward engineering, math, and science the most powerful predictor is a student's pre-intervention attitude toward the same STEM field before the project was implemented. The negative sign of the *beta* coefficient suggests that students who started out with more positive attitude scores ended up not changing much and students with less positive pre-intervention attitude scores had large difference scores, indicating greater change from the pre-test to the post-test.

There are two possible explanations for this finding. The first and the most optimistic is that students who initially had lower positive attitude toward a STEM field changed the most. The second interpretation is that the negative *beta* coefficient is a statistical artifact because students who initially had more positive scores did not change much because they were already positive. In methodological terms this second explanation would be referred to as a ceiling effect. Ceiling effects are considered to be an artifact of measurement, not substantive findings related to the impact of an intervention. We believe that the most likely interpretation is that the intervention was more successful with the students who did not have positive attitudes initially but that this relationship is not as strong as the *beta* coefficients would indicate.

[8] *Beta* scores reflect the strength of the relationship between a given predictor such as Interesting Class and the outcome variable, for example, Pre-Post Difference in Attitudes toward Engineering, in the context of all other predictor variables in the analysis.

Table 3. Regression Analyses Predicting Difference Scores in Attitudes toward STEM Fields among **Boys**, Expressed in Standardized Regression Coefficient, *beta*.

N=195 Predictor Variables	Pre-Post Difference In Attitudes toward Engineering *beta*	Pre-Post Difference In Attitudes toward Math *beta*	Pre-Post Difference In Attitudes toward Science *beta*
Interesting class	.139*	-.007	.141*
Pre Attitude toward Engineering	-.475***	.220*	.051
Pre Attitude toward Math	.155*	-.497***	.319***
Pre Attitude toward Science	.011	.049	-.454***
Pre-post Difference in Engineering	-	.238***	.139
Pre-post Difference In Math	.227**	-	.138
Pre-post Difference In Science	.137	.143	-
Variance Explained (R^2)	**27%**	**24%**	**27%**

*p<.05; ** p<.01; *** p<.001

It is of interest to note that among boys a positive pre-post difference score in attitudes toward engineering is additionally predicted by reports of finding the intervention classes interesting, having a positive attitude toward mathematics before the intervention, and coming to have more positive attitudes toward math after the intervention. These variables together explain 27% of the observed differences in male students' pre-post difference scores in attitudes toward engineering. A similar amount of variance is explained in the observed differences in male students' pre-post difference scores in attitudes toward math and science (24% and 27%, respectively). Finding the class interesting makes a difference for science but not for math. Having an initial positive attitude toward math before the intervention contributes to predicting the pre-post difference in attitudes toward science but an initial positive attitude toward science does not appear to be important for a larger positive difference score on math attitudes. This finding that an initial positive attitude toward mathematics making 8th grade boys more open to developing positive attitudes toward science but not the other way around suggests that mathematics is the more basic of the STEM fields. If you like math, you'll like science after the intervention, but if you like science initially, that initial positive attitude is not likely to generalize to liking math later.

Table 4. Regression Analyses Predicting Difference Scores in Attitudes toward STEM Fields among **Girls**, Expressed in Standardized Regression Coefficient, *beta*.

N=197 Predictor Variables	Pre-Post Difference In Attitudes toward Engineering *beta*	Pre-Post Difference In Attitudes toward Math *beta*	Pre-Post Difference In Attitudes toward Science *beta*
Interesting class	.312***	.002	.105
Pre Attitude toward Engineering	-.567***	.223*	.287***
Pre Attitude toward Math	.203*	-.384***	-.090
Pre Attitude toward Science	.109	-.059	-.294***
Pre-post Difference in Engineering	-	.289***	.330***
Pre-post Difference In Math	.214**	-	.057
Pre-post Difference In Science	.245***	.057	-
Variance Explained (R^2)	**41%**	**21%**	**20%**

*p<.05; **p<.01; *** p<.001

Predicting the girls' change in attitudes toward STEM careers from before to after the intervention follows a similar pattern of *beta* coefficients, with the initial attitude scores showing the largest but negative effects (see Table 4). Finding the intervention classes interesting appears to make a large difference in developing more positive attitudes toward engineering after the intervention but does not change the attitudes toward math or science. The most remarkable finding in the girls' results is that the predictor variables in the regression analysis explains fully 41% of the observed differences in female students' pre-post difference scores in attitudes toward engineering. The variance explained for difference scores in math and science is half of that. We interpret this finding to mean that the intervention had a more powerful effect on girls' attitudes toward engineering than it did on their attitudes toward math and science. Moreover, the intervention had a more powerful impact regarding changes in girls' than boys' attitudes toward engineering.

In Tables 5 and 6 the results of the regression analyses predicting changes in students' interest in STEM careers is presented. For both boys (Table 5) and girls (Table 6) the most influential predictor is having a less positive attitude toward the career in the pre-test, as indicated by high but negative *beta* coefficients. We believe that similar to the difference scores in attitudes toward STEM fields, this pattern of results is brought about by students starting out with low scores benefiting more from the intervention. Again, however, the impact of the intervention is not likely to be as strong as the magnitude of the *beta* coefficients would suggest because of the possibility of a ceiling effect.

Table 5. Regression Analyses Predicting Difference Scores in Attitudes toward STEM Careers among **Boys**, Expressed in Standardized Regression Coefficient, *beta*.

N=189 Predictor Variables	Pre-Post Difference In Engineer *beta*	Pre-Post Difference In Chemist *beta*	Pre-Post Difference In Biologist *beta*
Interesting class	.230***	.052	-.025
Pre-post Difference in Engineering	.196*	.065	.031
Pre-post Difference In Math	.140*	-.065	-.064
Pre-post Difference In Science	-.108	.145*	.261***
Pre-Engineer	-.495***		
Pre-Chemist		-.499***	
Pre-Biologist			-.403***
Variance Explained (R^2)	**32%**	**28%**	**28%**

* p<.05; ** p<.01; *** p<.001

Table 6. Regression Analyses Predicting Difference Scores in Attitudes toward STEM Careers among **Girls**, Expressed in Standardized Regression Coefficient, *beta*.

N=188 Predictor Variables	Pre-Post Difference In Engineer *beta*	Pre-Post Difference In Chemist *beta*	Pre-Post Difference In Biologist *beta*
Interesting class	.150*	.038	.019
Pre-post Difference in Engineering	.231***	.031	.009
Pre-post Difference In Math	.009	.012	
Pre-post Difference In Science	.233***	.303***	.153*
Pre-Engineer	-.561***		
Pre-Chemist		-.450***	
Pre-Biologist			-.482***
Variance Explained ($R^{2)}$	**41%**	**26%**	**27%**

*p<.05; ** p<.01; *** p<.001

In comparing variance explained in Tables 5 and 6 we see that similar to the finding regarding girls being more influenced by the intervention in their attitudes toward engineering as a field, they are more influenced toward engineering as a career. This is evidenced by the 41% of the observed differences in female students' pre-post difference scores in interest in becoming an engineer.

We interpreted the findings that the intervention had the most influence on girls' attitudes toward engineering as a field and engineering as a career in terms of girls' openness to new information on engineering. We believe that this openness is due to having less information on engineering before the intervention relative to boys rather than to a general openness. Indeed, girls' interests were influenced at the same level as boys' on biology and chemistry as fields of study and careers, which are better known fields. We believe that the intervention was able to influence girls to a greater extent because girls had fewer preconceived notions about engineering. This interpretation is bolstered by the finding that before the intervention slightly fewer girls reported knowing engineers than did boys.

Another finding that showed girls to be influenced more by the STEM Team strategy than boys can be seen in the comparison of the impact of school/teacher as a context for the impact of the intervention.[9] While boys' changes from the pre- to post-testing did not differ across schools or teachers, the comparisons for girls showed statistically significant changes, especially in attitudes toward engineering as a field of study and a career and also mathematics as a field of study. The hypothesis of school/teacher context having more of an influence on how girls respond to the intervention is open to interpretation. It could be a function of their lower levels of exposure to engineering, hence heightened sensitivity, as suggested above. It could also be that girls were more reactive to the conditions under which they were exposed to the intervention. Future research is needed to examine teacher and school effects separately using a larger sample.

Evaluation Summary

Teacher Outcomes

Teachers found the intervention highly valuable both for themselves and their students. For themselves one key element in the success of the undertaking is in developing a clearer understanding of engineering concepts, gender equity, and the expertise contributed by each STEM Team member to the classroom. Regarding STEM Team members' contributions, teachers reported that engineers provided their expertise in science; college faculty, graduate and undergraduate students brought in the most current research findings; the industry representative in providing real-life, fresh perspectives from their field experience, and the middle school teachers provided their knowledge and understanding of how to approach and teach young adolescents. Teachers reported that they benefited from having access to a curriculum that was not only of high quality but had built into it gender equitable practices and principles.

For their students, the benefits teachers highlighted were role models, glimpses into the real world of work for engineers, and a curriculum that made it possible for all students to achieve up to a benchmark of proficiency rather than a competitive classroom environment where only a few students are engaged in the projects.

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[9] We refer to the joint effect of school and teacher because in seven out of eight schools only one teacher participated in the program making it impossible to tease out school effects from teacher effects.

STEM Team outcomes

Each STEM Team was composed of a coordinator, teachers, faculty members, undergraduate and graduate students, and industry representatives. STEM Team members reported they enjoyed the regular meetings that served to keep the teams focused and remarked on the synergy generated by the diversity in team membership. The study showed that it is feasible to bring together individuals from different domains to work together toward enhancing the teaching of STEM fields, especially the new engineering strand.

Student Impact

Program level outcome. A simple comparison of pre- and post-intervention scores using paired t-tests found a statistically significant difference between pre-and post-intervention attitudes toward engineering and science as a field of study. Attitudes toward science became more favorable after the intervention than it was before. However, the attitudes toward engineering were less positive at post-test. Attitudes toward mathematics did not change. Analyses by gender showed that overall, girls' attitudes showed a greater increase than boys' attitudes in becoming engineers, biologists, or chemists after the intervention.

Individual level outcomes. In spite of the fact that students' overall scores on attitudes did not become more positive after the intervention, there were a large number of individual students whose scores increased — that is, their attitudes toward STEM fields or careers became more positive — after the intervention. We examined the impact of the intervention on individual students using regression analyses which yield information on what variables best predict whether a student's scores will increase or decrease. The results showed that students who started out with lower positive attitudes toward both STEM fields and STEM careers made more gains after the intervention than students who started out with more positive attitudes. Moreover, the intervention had a greater impact on female students' attitudes toward choosing engineering as a career than it did on male students' attitudes.

Conclusions

The evaluation shows that the 4 Schools for WIE project has had the intended effect on:

- Capacity building among 8th grade science teachers' confidence to teach engineering;
- Program level increase in attitudes toward science as a field of study but not in engineering or mathematics;
- While in absolute numbers more boys than girls reported they would consider engineering, biology, and chemistry as a career, the change in girls' interest in these careers was greater than the change in boys' interested in these careers after the intervention;
- Individual level impact of the intervention on girls' attitudes toward engineering both as a field of study and as a career.

The results show that in general, among both girls and boys, students who show the most positive change relative to where they started out in the beginning of the academic year are those who had relatively less positive attitudes toward STEM fields and careers. While some of this effect may be an artifact of a ceiling effect, this finding suggests that the intervention has the potential to benefit those in most need of help instead of merely making students who already hold positive attitudes hold even more positive views toward STEM fields and careers.

A shortcoming of the evaluation is that it did not allow for following up the students who appeared to benefit from the intervention. We cannot answer the question what happens to these students as they continue on to high school. Do they, in fact, take more courses in math, science, and technology and at higher levels (advanced placement)? How do their ideas regarding potential careers change over time? Without the ability to follow these young people beyond 8th grade, we cannot assess the full impact of the 4 Schools for WIE curriculum. In addition, without true control groups using random assignment, we cannot definitively attribute change to the efficacy of the curriculum. A further weakness of the present study is that it did not allow for an estimation of the school and teacher effects as separate contexts for the intervention. This is a particularly important point to examine in future studies because girls appeared to be more influenced by the school/teacher context regarding engineering than did boys.

What we do know, is that for the teachers the exposure to expertise from “real” engineers (as one teacher put it) — professors, graduate and undergraduate students and industry representatives coupled with the training that was such an integral part of this intervention — made a significant difference in both their understanding of engineering and how to teach this subject effectively. That may in fact be one of the most “significant” impacts of the project over time.

All in all, the STEM team intervention succeeded in its goal to improve teachers’ capacity to teach the new engineering strand in the 8th grade science curriculum that has been incorporated into the Massachusetts Science Frameworks. It succeeded partially in improving all students’ attitudes toward science as a field of study but not engineering or mathematics. It was more effective in fostering positive attitudes toward STEM fields and careers among male and female students who started out with less positive attitudes. Perhaps even more significantly, it resulted in more girls coming to view engineering and chemistry as possible careers for themselves and had a larger impact on girls than it did on boys.

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Appendix A

Teacher Survey and Report

Teacher Feedback form

4 Schools for WIE Report on Teacher Surveys, June 2004

TEACHER FEEDBACK FORM

School: ____________ Teacher: ____________ STEM Team: _________

The following questions concern your experience in implementing the 4 Schools for WIE activities in your classrooms during the 2003-2004 academic year. Thank you in advance for completing this survey, it will help us in planning for next year. You may fill this out on line and return it to: fmarx@wellesley.edu or to: Fern Marx, WCW, Wellesley College, 106 Central St., Wellesley, MA 02481.

1. The following are the five goals and anticipated outcomes for all 4 Schools for WIE Team Projects this year.

   Please rate how well you think the goals were met from "1= did not meet this goal at all" to "5=met this goal very successfully." Circle one number in each row. If you feel that the goal was only partially met, please explain your answer in a sentence below the goal.

	did not meet this goal at all				met this goal very successfully
a. Teach concepts about the practice and uses of engineering.	1	2	3	4	5
Please explain:					
b. Integrate engineering design process into classroom activities	1	2	3	4	5
Please explain:					
c. Apply gender-inclusive approaches in the classroom.	1	2	3	4	5
Please explain:					
d. Communicate the connection between classroom activities and the Massachusetts state frameworks	1	2	3	4	5
Please explain:					
e. Capitalize on school or district resources and local areas of interest	1	2	3	4	5
Please explain:					

2. To what extent do you feel that the training and support available to you from your STEM Team adequately prepared you for teaching the 4 Schools for WIE curriculum units and activities? Please circle one answer below and explain your response below.

   a. I felt the preparation/training from my STEM Team was:

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

   b. I felt the support available from my STEM Team was:

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

3. What, if any, additional training or support would you have liked to receive from your STEM Team?

4. How effective do you believe the curriculum and activities were in preparing students for the engineering strand of the MCAS exam?

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

5. What suggestions do you have for making the curriculum more effective for the next implementation?

6. A major part of the 4 Schools for Women in Engineering Project is the idea of providing STEM Teams consisting of practicing engineers in industry and academia, as well as engineering graduate and undergraduate students.

   a. In your opinion, how effective was having an all female STEM Team in providing role models for girls in science and engineering? Please explain your answer with specific examples, if possible.

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

   b. How effective was an all female STEM team for boys ? Please explain your answer with specific examples, if possible.

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

   c. Would the same results be possible if the visitors were only from companies, or only professors or only engineering students? Please explain your answer.

7. Thinking back over your experience this academic year with the 4 Schools for WIE, what stands out for you as the most significant experience(s)?

8. How effective do you feel the curriculum was in stimulating girls' interest in STEM, in taking addition math/science courses and thinking about future careers related to STEM? Please explain your answer with specific examples, if possible?

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

   Please explain:

9. Do you feel that having an all female STEM Team was successful in making the

math, science, and engineering curriculum more gender-neutral? Please explain your answer with specific examples, if possible?

Very Inadequate	Poor	Fair	Good	Excellent
1	2	3	4	5

Please explain:

10. Do you have any additional thoughts about this year's experience that you would like to share with us?

Thanks for your help!

4 Schools for WIE
Report on Teacher Surveys
June 2004

The findings from the 2004 Teacher Feedback surveys for the 4 Schools for Women in Engineering (WIE) program are discussed in the following report. Six teachers responded to the survey, two of whom taught at Forest Grove Middle School and one each taught at Cleveland, Ferryway, Josiah Quincy, and Salemwood Schools. The three teams represented include Northeastern, Tufts, and WPI.

Five Goals

Four Schools for WIE established five goals and anticipated outcomes for all of their programs this year. Results presented in Table 1 show that these goals were met to a large extent (although according to one respondent, with the exception of applying gender inclusive approaches in the classroom, the goals were rarely met). Overall the most successfully met goal was applying gender inclusive approaches in the classroom. Teachers wrote that they encouraged students to try taking a non-traditional gender role; one wrote that she "mixed groups up according to gender being careful to encourage girls and boys to try different roles." Others suggested that "success is due to awareness of gender equity goals"; one teacher wrote "I always feel the classroom was gender-inclusive but because of this initiative, I have evaluated my lesson plans more carefully especially when teaching simple machines and work/force concepts."

The goals of teaching concepts about the practice and uses of engineering and communicating the connection between classroom activities and the MCAS frameworks were met fairly successfully or very successfully. Regarding teaching the concepts of engineering, one teacher wrote, "Students had a very clear idea of the engineering steps involved by the end," and another, "I felt we met this goal by teaching through concepts and presentation/activities." As far as communicating the connection between classroom work and the state frameworks, teachers wrote that "students are very clear why they were learning engineering and how it connects to the frameworks/MCAS," and "we actually sat down and compared each goal to make sure it fit [within the framework]!"

The two goals with the lowest overall ratings were integrating engineering design processes into classroom activities and capitalizing on school or district resources and local areas of interest. One teacher wrote, "the process of integrating design engineering into classroom activities was evident during the planned activities, but I felt time constrained, personally, from further implementing more of the engineering design process." Another teacher commented that the team's orange juice project discovered the essence of integrating the engineering design process into the classroom activities, writing "the OJ module was just that!" Another teacher wrote, "I did this on my own with other activities, but not in connection with my STEM Team." In terms of capitalizing on school or district resources and local areas of interest, one teacher felt it did not happen at all. Another wrote, "I think that we may need to work a little bit on this goal."

Table 1: Meeting the Five Goals (n=6)

Goal	Mean Score[10]
Teach concepts about the practice & uses of engineering	4.33
Integrate engineering design process into classroom activities	3.83
Apply gender-inclusive approaches in the classroom	4.83
Communicate connection between classroom activities & MA state frameworks	4.17
Capitalize on school or district resources and local areas of interest	3.67

STEM Teams

The teachers were asked to rate the STEM Teams in a number of areas. Overall, the STEM Teams seem to have done an exceptional job (See Table 2). All six respondents rated the effectiveness of having an all-female STEM Team for both girls and boys as excellent. One teacher wrote, “The students worked well with the practicing engineers, instructors, and students,” and another, “girls felt more comfortable participating and asking questions.” As far as its effectiveness on the boys, one wrote, “All students were engaged in doing and understanding when the engineering student was in the classroom. I really don’t think they gave a lot of thought to the fact that the student was female,” and another wrote, “male students involved themselves in the activities without regard to the gender of presenter. The male students were also used to having female teachers. It might be interesting to have an all female STEM Team go into classrooms where males were the teachers.” Five out of the six teachers rated the teacher preparation and training and the available support provided by the STEM Teams as excellent. One teacher, reflecting the sentiment of the majority of the group’s responses, wrote,

[10] The responses were scored from 1=”did not meet goal at all”, 3=”met goal somewhat”, to 5=”met goal very successfully”.

> I stand completely amazed at the team support of time and energy which the team members put into designing the implementing the lessons which we developed. If teachers had the resources to invest in each lesson as we did the engineering lessons, what a wonderful world it would be. I am thankful for their unending support.

Another wrote that, "They were always willing to accommodate our schedules and come in to the class on a drop of a dime." Only one teacher felt that more time could have been spent in preparing for implementation. All six of the respondents indicated that the effectiveness of making the STEM curriculum more gender neutral was either good or excellent; "I think they understand that it is an easy option for males and [we are] exposing females to it."

Table 2: Regarding the STEM Team (n=6)

	Mean Score[11]
Teacher Preparation/Training	4.50
Available Support	4.83
Effectiveness of All-Female Team for Girls	5.00
Effectiveness of All-Female Team for Boys	5.00
Effectiveness of Making STEM More Gender-Neutral	4.50

Additional Training and Support: The teachers were asked for suggestions on what additional training and/or support they would like to have received from their STEM Team. One teacher wrote,

> I would like to work with WPI further on my own "knowledge" of the technology part of the science and technology MCAS frameworks – not only for content but also to work on creative ways to implement technology topics in the classroom.

Another wrote,

> I've never had the advantage of classroom support from a Team member familiar with the project's activities. In both 2003 and in 2004 I've attempted to guide my classes through certain activities either alone or with a STEM Team member who was just becoming familiar with the project. Most work with STEM Team member who knew the project was implemented in classes at the other school involved in the project.

Two teachers responded that plenty of training and support were provided. Another wrote, "Who could ask for anything more???? I am a 'happy camper' and felt this was a better year

[11] The responses were scored from 1="very inadequate", 3="fair" to 5="excellent".

than last. We were able to do more lessons and had better experiences with the ones that were developed last year."

Change in Teams?: Participants were asked whether the same results would be possible if the visitors were only from companies, only professors, or only engineering students. Four out of the six teachers responded, and they all thought the team setup was just right. One wrote, "No – the 'mix' worked well as it provided support and guidance for teachers which led to 'smooth' implementation." Others wrote, "I think the mix of all ranges of people involved in engineering is beneficial. But of course my students enjoyed having college students working with them. It gave them a positive role model of someone in college," "no – I think pulling from all fields is effective," and

> I think that the combination added greatly to the preparation but I do not think the students are completely cognizant of each presenter's actual role in the Team. They generalize that everyone was an engineer. We even use that general term in conversation with the students: "When the engineers return, we will have the presentations."

Effectiveness of Curriculum

Respondents were asked to what extent the new curriculum affected the students. Results show that the curricula and activities were quite effective in preparing students for the MCAS exam (See Table 3). All of the participants marked this item as either good or excellent. One teacher wrote, "After having seen the 2004 MCAS for Science Engineering and Technology, I am fairly confident that the curriculum designed by the STEM Team does a good job in addressing the Engineering strand." Another wrote, "My students actually said they knew that part of the MCAS best!" As far as stimulating girls' interests in STEM, half of the respondents indicated the program was excellent and the others marked "good" or "fair." Teachers' responses included, "Exposure and comfort level when working with any topic builds confidence. Student confidence is an important factor in course selection," "I think the curriculum stimulated girls' interests, but I feel it was a beginning, and to overcome the girls' initial refrain from these courses might take a longer initiative," "very good in stimulating girl's interest, not so sure about increasing their desire to take more math/science courses or about future careers," and "many students have approached me to talk about their career paths and options for high school courses."

Table 3: Effectiveness of Curriculum & Activities (n=6)

	Mean Score[12]
Preparation for MCAS Exam	4.33
Stimulating Girls' Interest in STEM	4.33

[12] The responses were scored from 1="very inadequate", 3="fair" to 5="excellent".

Suggestions for the Next Implementation: The teachers were asked for suggestions for making the curriculum more effective for the next implementation. Suggestions included:

- More communication between *all* teachers involved in the project, preferably via the Online Community Board
- A clearer sense of the time-line
- More frequent communication regarding *everything* needed to be done in order to complete all expectations by given deadline
- Change in the use of tools – "The MCAS test had many references to tools that are not used in my general science curriculum. In the activities we had designed in engineering, the tools are relatively simple and do not reflect the knowledge of tools that seems to be desired"

Additional Feedback
Significant Experiences: The teachers were asked to comment on what stood out for them as the most significant experience(s) during this past academic year with 4 Schools for WIE. One teacher wrote that her most significant experiences were "the support, content knowledge, and increase in teacher 'comfort' in working with the technology strand"; another wrote that "one of the best experiences was having college students come into the classroom" and another wrote that "taking students to Tufts to see first-hand what it is like to study engineering and meet the professors" was the most significant. Another wrote,

> The thing that stands out most for me is the difference between the expectations of the professional engineer involved versus the reality of how things actually play out in the classroom; the lack of flexibility of prerequisites for student understanding of certain ideas. Some engineers tend to have a fixed conception of how learning must proceed in order for understanding to occur.

A significant experience for one teacher was that her team was able to cover a lot of material related to engineering.

> We were able to do three times the amount of engineering related activities as we accomplished the first year. I was most grateful for the bridge introduction we added. The STEM Team asked the teachers what we deemed more useful in meeting the MCAS framework requirements and we all agreed that we needed more on bridges. The Team then went to work and put together a very nice, lively presentation and activity on bridges which we all developed together and which I, as a teacher, personally needed to augment my knowledge. That proved to be very fruitful as there were many bridge questions on the MCAS tests.

Additional Comments: A number of comments were offered when respondents were asked if there were any additional thoughts they would like to share about this year's experience. One wrote,

> The ending of this year has left me with the confidence that I need to enjoy implementation next year, from pre-test to implementation to post-test. It has taken

> me until now to actually see what really needs to happen in order for this to work as it is expected to unfold in the classroom.

Another wrote,

> The first year of the program I was happy with the results. The second year was even better as we were able to revise and refine for even better results. I hope to keep this going even beyond year #3, but I would like to continue with WPI support.

Another was delighted with the experience: “I enjoyed working with all the members of the Tufts staff and students,” and other offered their gratitude, “A big “Thank you” for everyone’s sincere efforts.”

Appendix B

Student Survey

STUDENT ASSENT FOR PARTICIPATION

Today I would like to ask you to complete a short survey on attitudes towards mathematics, science and engineering, and careers in these fields. Your participation is voluntary. If you decide you don't want to complete the survey at all or to stop at any time or to skip questions, you are free to do so.

If you would like to complete this survey, please check "Yes"

_____ Yes   _____ No

Your Name: ____

Your School's name:_____________________________________

Your Teacher's Name: ___________________________________

Today's Date: ____

The following questions are about engineering. Please read this paragraph before you answer the questions.

Engineering is a career that uses math and science to invent new products and solve problems that improve everyone's life. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, biomedical, and design. The word engineer comes from the Greek word for *imagine*. Engineers or "*imagineers*" not only build bridges and cars but also invent new fabrics, foods, and even virtual reality amusement parks. In fact, "*imagineers*" work with almost everything we eat, drink, wear, touch, see, smell, and hear in our daily lives.

On the following pages is a series of sentences. Please mark your answer sheets by indicating how you feel about them. Suppose a statement says:

Example 1:	**Strongly Disagree 1**	**Somewhat Disagree 2**	**Not Sure 3**	**Somewhat Agree 4**	**Strongly Agree 5**
I like engineering.	❍	❍	❍	❍	❍

As you read the sentence, you will know whether you agree or disagree. If you strongly agree, put an X in the circle under Number 5. If you agree, but not so strongly, or you only "sort of" agree, put an X in the circle under 4. If you disagree with the sentence very much, put an X in the circle under 1 for strongly disagree. If you disagree, but not so strongly, put an X in the circle under 2. If you are not sure about a question or you can't answer it, put an X in the circle under 3.

Even though some statements are very similar, please answer each statement. This is not timed; work fast, but carefully.

There are no "***right***" or "***wrong***" answers. The only correct responses are those that are true ***for you*.** Whenever possible, let the things that have happened to you help you make a choice.

PLEASE FILL IN ONLY ONE ANSWER PER QUESTION.

1. ATTITUDES TOWARD ENGINEERING

	Strongly Disagree 1	Somewhat Disagree 2	Not Sure 3	Somewha t Agree 4	Strongly Agree 5
1. A degree in engineering will allow me to obtain a well paying job	❍	❍	❍	❍	❍
2. I am not interested in any career that uses math and science.	❍	❍	❍	❍	❍
3. I like fixing broken appliances.	❍	❍	❍	❍	❍
4. At the science museum, I like the exhibits on robotics.	❍	❍	❍	❍	❍
5. A degree in engineering will allow me to obtain a job I like doing.	❍	❍	❍	❍	❍
6. I have no interest in helping design the space station.	❍	❍	❍	❍	❍
7. Engineering skills will allow me to better society.	❍	❍	❍	❍	❍
8. A degree in engineering will give me the kind of lifestyle I want.	❍	❍	❍	❍	❍
9. I am interested in designing better artificial limbs.	❍	❍	❍	❍	❍
10. I would like to learn how to make safer cosmetics.	❍	❍	❍	❍	❍
11. Engineering interests me because I like to think about solving technical problems.	❍	❍	❍	❍	❍
12. I am not interested in what makes machines work.	❍	❍	❍	❍	❍

2. Attitudes toward Math

Please use the same instructions you used for completing the Attitudes toward Engineering.

	Strongly Disagree 1	Somewhat Disagree 2	Not Sure 3	Somewhat Agree 4	Strongly Agree 5
1. Math is a worthwhile, necessary subject.	❍	❍	❍	❍	❍
2. Math is not important for my life.	❍	❍	❍	❍	❍
3. Math has been my worst subject.	❍	❍	❍	❍	❍
4. I see math as something I won't use very often when I get out of high school.	❍	❍	❍	❍	❍
5. I would consider choosing a career that uses math.	❍	❍	❍	❍	❍
6. I study math because I know how useful it is.	❍	❍	❍	❍	❍
7. Math is hard for me.	❍	❍	❍	❍	❍
8. I'll need a good understanding of science for my future work.	❍	❍	❍	❍	❍
9. I'm not the type to do well in math.	❍	❍	❍	❍	❍
10. Most subjects I can handle OK, but I just can't do a good job with math.	❍	❍	❍	❍	❍
11. I am sure I could do advanced work in math.	❍	❍	❍	❍	❍
12. I can get good grades in math.	❍	❍	❍	❍	❍
13. I'm no good in math.	❍	❍	❍	❍	❍

3. Attitudes toward Science

Please use the same instructions you used for completing the Attitudes toward Math.

	Strongly Disagree 1	Somewhat Disagree 2	Not Sure 3	Somewhat Agree 4	Strongly Agree 5
1. I am sure of myself when I do science.	❍	❍	❍	❍	❍
2. I would consider a career in science.	❍	❍	❍	❍	❍
3. I don’t expect to use much science when I get out of school.	❍	❍	❍	❍	❍
4. Knowing science will help me earn a living.	❍	❍	❍	❍	❍
5. I’ll need science for my future work.	❍	❍	❍	❍	❍
6. I know I can do well in science.	❍	❍	❍	❍	❍
7. Science will not be important to me in my life’s work.	❍	❍	❍	❍	❍
8. Science is a worthwhile, necessary subject.	❍	❍	❍	❍	❍
9. Most subjects I can handle OK, but I just can’t do a good job with science.	❍	❍	❍	❍	❍
10. I am sure I could do advanced work in science.	❍	❍	❍	❍	❍

4. YOUR FUTURE

Here is list of jobs that use knowledge about math, science and/or engineering. How interested are you in these kinds of jobs? If you are *Very Interested*, put an X in the circle under Number 4. If you are *Somewhat Interested*, put an X in the circle under 3. If you are *Not So Interested*, put an X in the circle under 2. If you are *Not At All Interested*, put an X in the circle under 1.

There are no "*right*" or "*wrong*" answers. The only correct responses are those that *are true for you*.

	Not At All Interested 1	Not So Interested 2	Somewhat Interested 3	Very Interested 4
1. Physicist	❍	❍	❍	❍
2. Nurse	❍	❍	❍	❍
3. Auto Mechanic	❍	❍	❍	❍
4. Medical Doctor	❍	❍	❍	❍
5. Electrician	❍	❍	❍	❍
6. Computer Technician	❍	❍	❍	❍
7. Welder	❍	❍	❍	❍
8. Chemist	❍	❍	❍	❍
9. Engineer	❍	❍	❍	❍
10. Accountant	❍	❍	❍	❍
11. Biologist	❍	❍	❍	❍
12. Architect	❍	❍	❍	❍

5. About Yourself

How well do you expect to do this year in your:

	Not very well 1	OK/Pretty well 2	Very well 3
English class?	❍	❍	❍
Math class?	❍	❍	❍
Science class?	❍	❍	❍

Year of Birth: ______________

Boy ❍ **Girl** ❍

My family is: (CHECK ONE ONLY)

❍ **African American**

❍ **Caucasian/ White**

❍ **Asian (Please Specify): ______________________________**

❍ **Hispanic (Please Specify): ___________________________**

❍ **Biracial/ Multiracial (Please Specify): __________________**

❍ **Other (Please Specify): ______________________________**

Do you plan to go to college? Yes ❍ No ❍ Not sure ❍

Do you know any engineers? Yes ❍ No ❍ Not sure ❍

THANKS FOR YOUR HELP!

POST-TEST

The Post-test Questionnaire was identical to the pre-test except for the addition of the following question, the answers to which required having participated in the intervention.

Please tell us how interesting you found the activities on engineering in this class:

Not at all interesting ❍ Somewhat interesting ❍ Very interesting ❍

Please explain your answer.

THANKS FOR YOUR HELP!

Appendix C

Psychometric Analysis of the Attitude Scales

Reliability (Cronbach's alpha)

Internal consistency scores of scales indicate the degree to which all items in the scale are measuring the same phenomenon, in this case, self-esteem. The internal consistency score is often reported as Chronbach's alpha, which varies from .00 to .99. In general, the more items that measure the same phenomenon, the closer the scales internal consistency will be to .99. As can be seen in Table 1, the scales have adequate internal consistency; they are all above .80.

Table 1: Unstandardized Cronbach's alpha internal consistency scores for each scale at both pre- and post-test for the data set used in the current analyses.

Scale	Number of Items	Number of Subjects	Pre-Test Cronbach's Alpha	Number Of Subjects	Post-Test Cronbach's Alpha
Engineering	12	396	.829	409	.842
Math	13	394	.866	392	.880
Science	10	400	.865	406	.858

Validity

The set of correlations in Table 5 below provides information related to the *construct validity* of the attitude surveys. If the items in each of the surveys measure the underlying constructs adequately, we would expect that the three surveys would be moderately correlated with each other (***r*** =.25 - .50) range but that the pre-post-intervention administrations of each subject would be strongly correlated with each other (***r***=.60 and above range). As predicted, the results show that the highlighted correlation coefficients *between* the pre- and post-intervention scores are all above r=.50. The correlations *among* the surveys are weaker. The fact that the prediction was supported suggests that the measures are very likely measuring the underlying constructs they were designed to measure; hence they have construct validity.

The only exceptions are the high correlations between pre-intervention engineering and pre-intervention science scores (***r***=.552). This can be viewed as an indicator of the closer association of engineering and science at pre-tests, as the engineering curriculum was being implemented in science classes.

Table 2: Correlations (*Pearson r*) among average pre- and post-intervention attitude survey scores.

	Pre Eng.	Post Eng.	Pre Math	Post Math	Pre Science
Pre-intervention engineering attitude scores	**1**				
Post-intervention engineering attitude scores	**.699**	**1**			
Pre-intervention math attitude scores	**.411**	**.363**	**1**		
Post-intervention math attitude scores	**.347**	**.452**	**.703**	**1**	
Pre-intervention science attitude scores	**.552**	**.434**	**.339**	**.249**	**1**
Post-intervention science attitude scores	**.490**	**.490**	**.320**	**.328**	**.637**