

# **Engineering Connections for Middle School Science Teachers**

**Debra Brockway, Stevens Institute of Technology**  
**Greg Bartus, Stevens Institute of Technology**  
**Beth McGrath, Stevens Institute of Technology**

## **Abstract**

In its second year of existence, a continuing partnership between a university and a global technology and innovation corporation is providing middle school science teachers in primarily urban districts with professional development and follow-up support to introduce students to engineering concepts, to improve students' problem-solving skills, and to increase student interest and engagement in science. The vehicle for this professional development is a variety of science and engineering lessons that align with district curricula and make use of compelling web-based resources and hands-on engineering design activities. This paper describes the program, with an emphasis on the summer workshop and preliminary evidence of its impact on teachers.

## **Introduction**

National reports and policy papers abound on the need to encourage more students to pursue and succeed in science, technology, engineering, and math (STEM) study and careers, however most K-12 science teachers do not have a good understanding of what engineering is or how to teach it. Many science teachers, especially at the middle school level, also lack a strong foundation and certification in the science subjects they teach.<sup>1</sup> Although only 1.3% of all public school classes in New Jersey are taught by teachers who are not considered highly qualified by federal government standards, almost five times as many high poverty middle school science classes, 6.3%, are taught by teachers who are not highly qualified.<sup>2</sup> Aside from special education classes, middle school science classes in high poverty schools have the largest percentage of classes throughout K-12 New Jersey schools taught by teachers who are not highly qualified.

Whether students can be adequately prepared to succeed in STEM subjects if they are taught science by teachers who lack science certification or a strong background in science is an empirical question beyond the scope of this paper. It is clear, however, that students from urban areas and low income households have significantly lower science achievement than the national average. Results on the 2005 National Assessment of Educational Progress (NAEP) Trial Urban District Assessment (TUDA) in science, for example, show significantly lower average scores for Grade 8 students in urban areas compared to the national average.<sup>3</sup> There is still a difference, although not as great, when scores of students from low-income households in urban areas are compared to those of low-income households nationwide.

A second, equally important, concern is the insufficient enrollment of students at the post-secondary level in engineering programs. Although enrollments in science and engineering (S&E) programs are up, they have not yet reached the level of enrollments in 1983 and increasing numbers of students in S&E programs are requiring remediation and dropping out of the programs before completing their studies.<sup>4</sup> Attracting enough students, and particularly a

diverse group of students, to the engineering profession is especially difficult since students and society at large do not have an accurate perception of the field of engineering.<sup>5</sup> Design-based activities have been shown to engage students with widely varying achievement levels and result in significant acquisition of science content<sup>6</sup> and may increase student awareness of and interest in engineering.

In an attempt to address the relatively large number of middle school science teachers lacking highly qualified status and relatively low student achievement in science in urban areas, Honeywell Hometown Solutions and the Center for Innovation in Engineering and Science Education have targeted urban districts in New Jersey for the Honeywell Teachers for the 21<sup>st</sup> Century Program. In this program, professional development is provided to teachers, regardless of their highly qualified status, with the goal being to provide teachers with additional educational tools to engage their students in the learning of science and engineering concepts.

### **Overview of the Program**

In 2007, Honeywell Hometown Solutions and the Center for Innovation in Engineering and Science Education (CIESE) at Stevens Institute of Technology joined forces to create the Honeywell Teachers for the 21st Century Program. This program is designed to strengthen science content knowledge, develop engineering design process (EDP) experience and skills, and enhance pedagogy by preparing participating teachers to use online, award-winning curriculum resources developed by CIESE. These standards-aligned projects utilize real time data and global telecollaboration among students on authentic science investigations, to engage students in science inquiry, quantitative analysis, and investigation of natural phenomena.

Teachers participate in a week-long summer workshop which is comprised of hands-on science investigations and team-based engineering design activities in life, Earth, and physical sciences. Activities reinforce topics measured by the NJ ASK8, a statewide assessment, and are centered on the CIESE online projects. In addition, teachers are given a solid foundation in the underlying science content that is important to the project as well as some new technological tools and skills that can be used to highlight relevant emerging technologies. Finally, teachers are provided a brief introduction to action research and are expected to outline an action research plan to effectively assess the impact on students of the CIESE project that is implemented.

Following completion of the workshop, program participants receive equipment and supplies valued at \$250 to implement the projects in their classrooms. Each participant also receives at least one classroom visit from CIESE staff to support implementation. Our visit can take the form of mentoring, team teaching, or planning, with the goal of providing some feedback and support for their improvement in the classroom.

Program participants are selected from middle school teacher applicants in northeastern New Jersey with priority given to teachers in urban districts in Hudson County. Thirty-nine middle school teachers participated in the program at Stevens Institute of Technology during the summer of 2008. Selection was made based on educational background as well as matching the goals of the teacher with the goals of the program.

## **Description of the Summer Workshop**

The focus of the week long summer workshop is the CIESE online projects. Participating teachers conduct real-world science experiments and participate in engineering design activities related to four projects appearing on the CIESE website: International Boiling Point Project, Human Genetics, Musical Plates, and Weather Scope. Each project is modeled during the workshop, complete directions for experiments are provided, underlying science content is explained, and an array of engineering and technology activities designed to enhance understanding is included. Some examples and a brief description of the projects are as follows:

- International Boiling Point Project – a global, collaborative experiment to determine which variable has the greatest impact on the temperature at which water boils. Teachers observe a demonstration highlighting the key variable affecting boiling and gain skill using Excel to create x-y scatter plots with best fit lines with their students.
- Human Genetics – a collaborative data collection and analysis activity to understand dominant and recessive genetic traits and their prevalence in the population. Teachers learn new activities designed to simulate heredity and gain skill using Excel to generate pie and bar charts to analyze genetic data collected from students around the world.
- Musical Plates – an exploration of the relationship among earthquakes, volcanoes, and plate tectonics using real-time earthquake and volcano data from dynamic databases such as the U.S. Geological Survey. Teachers learn how Google Earth can be a useful technology tool for creating earthquake maps and explore liquefaction and the engineering design process to develop a stable structure.
- Weather Scope – an activity involving the design and construction of instruments that meteorologists use and creation of a weather learning log to record weather observations. Teachers develop a rubric and assess a professional weather forecast, learn to develop and evaluate their own weather forecast, and build and reengineer basic weather instruments using the EDP.

While the focus of the week-long workshop is on performing activities that relate to these four projects, the workshop also includes a review of relevant science content, an introduction to the engineering design process, and an introduction or review of the software incorporated in the projects: Excel, PowerPoint, and Google Earth.

Toward the end of the workshop, teachers work in pairs or independently to develop implementation plans for one or more of the projects. As part of the implementation plan, teachers create an action research plan which focuses on a question or goal for their implementation and a strategy for assessing the success of the project.

## **Methods**

This second year of the program saw a significant increase in teacher participation, primarily due to the opportunity to recruit teachers earlier in the academic year. This earlier start also allowed

an opportunity to consider how we might determine whether the program was having the desired impact on teacher content knowledge and classroom practices. Therefore, this year a larger amount of data is being collected in a systematic way in an attempt to evaluate the impact of the program.

Teachers were asked to complete an Internet-based survey on the morning of the first day of the workshop and the afternoon of the last day. The pre-workshop survey consisted of 15 items, several of which were multipart items. This first survey focused on the following topics:

- Teachers' sense of self-efficacy with respect to three areas:
  - Content knowledge,
  - Technology/computers in classroom applications, and
  - Engineering concepts and applications to teaching science
- Teacher and student activities in the classroom, and
- Demographics.

The post-workshop survey repeated the items related to self-efficacy and asked questions regarding teachers' experiences with the workshop including:

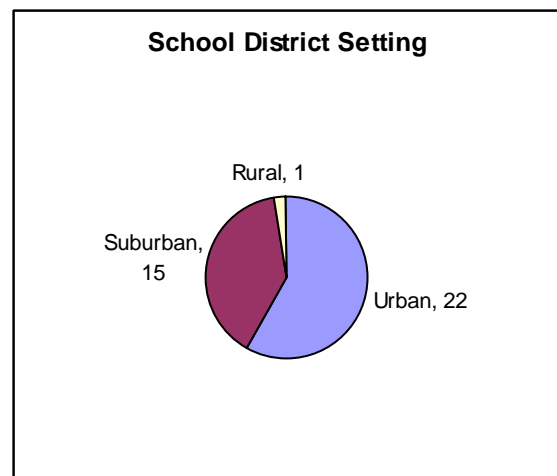
- The value they placed on specific workshop activities,
- The effect the workshop had on their knowledge of specified content and pedagogy, and
- Recommendations for making the workshop more relevant for their needs.

The self-efficacy items were repeated at the conclusion of the workshop in an attempt to determine what effect, if any, the workshop had on teachers' level of confidence in implementing certain content areas and a range of activities in the classroom. These items will be presented to teachers again at the conclusion of the current academic year along with the items relating to teacher and student activities in the classroom. The objective of this third survey is to determine whether the workshop and classroom support they receive during the academic year have an effect on teacher practices and, again, self-efficacy.

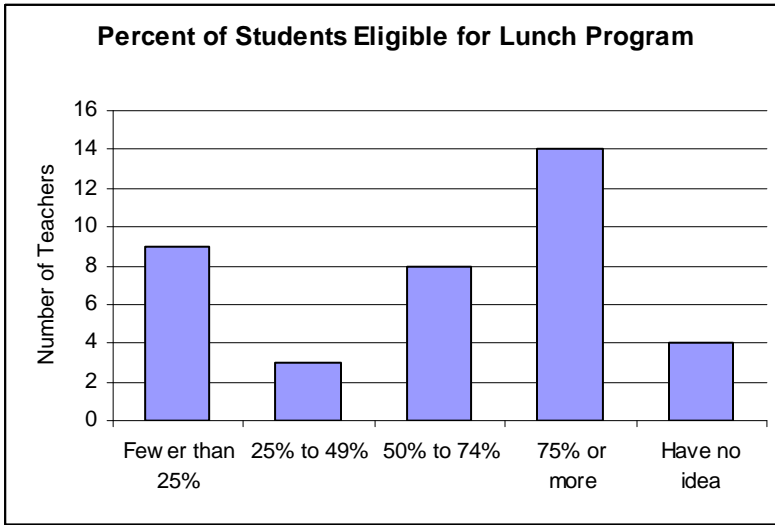
### Teacher Demographics

Thirty-eight of the 39 participating teachers responded to the pre-workshop survey and 31 responded to the post-workshop survey, although not all teachers answered every question. As mentioned previously, teachers in urban districts were being targeted for participation in this program. Figure 1 shows that more than half of the participating teachers are from urban districts.

Approximately 65% of the participating teachers who could estimate the percentage of students in their district who are eligible for the National School Lunch Program (NSLP) stated that at least half of the students in their districts are eligible as shown in Figure 2. Four teachers could not make an estimate of this value. While we have some demographic information about teacher



**Figure 1:** Setting of the school districts where program participants teach. (N=38)

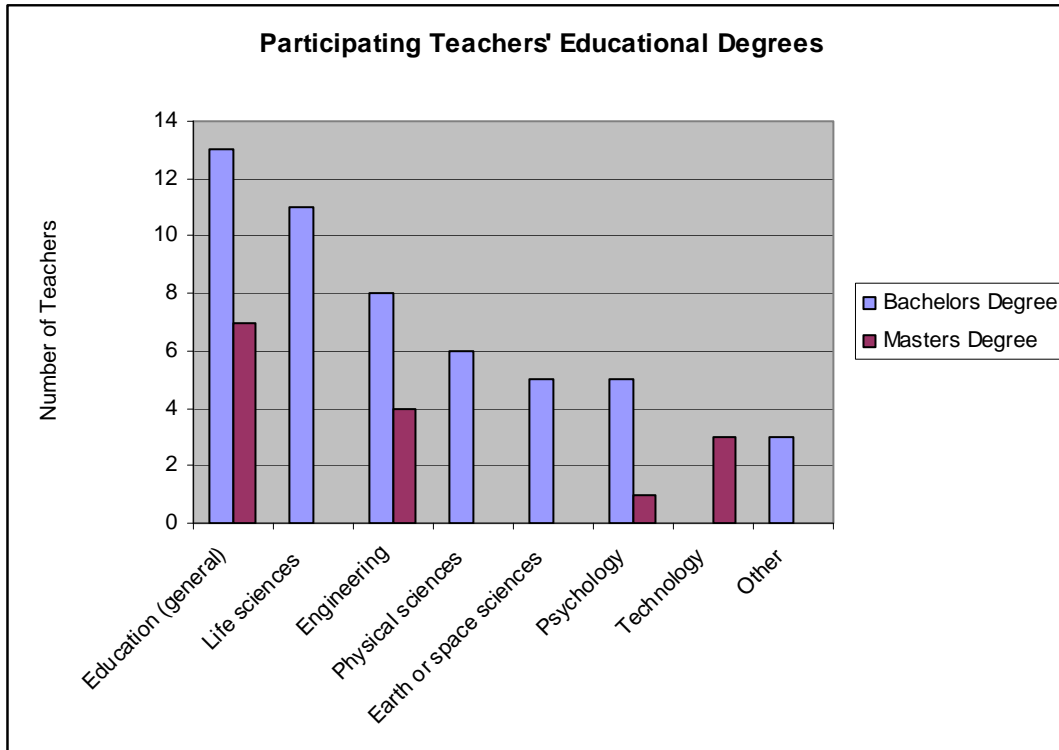


**Figure 2:** The percentage of students in the participating teachers' school who are eligible for the National School Lunch Program (NSLP) as reported by teachers. (N=38)

participants, including their school districts, from their applications to the program and could characterize the socioeconomic status of the participating teachers' districts with greater reliability, this data would not be able to be correlated with teachers' responses to other information collected in the survey. Due to the desire to maintain anonymity in the survey, respondents were not asked to identify themselves or the districts in which they teach. The missing data on items such as the lunch program item,

however, will limit the possibilities for data analysis as the program progresses.

As mentioned previously, middle school science teachers were targeted for this program because they are more likely than teachers at other levels to be teaching science exclusively while lacking an educational degree in science or otherwise being highly qualified in science. Figure 3 shows



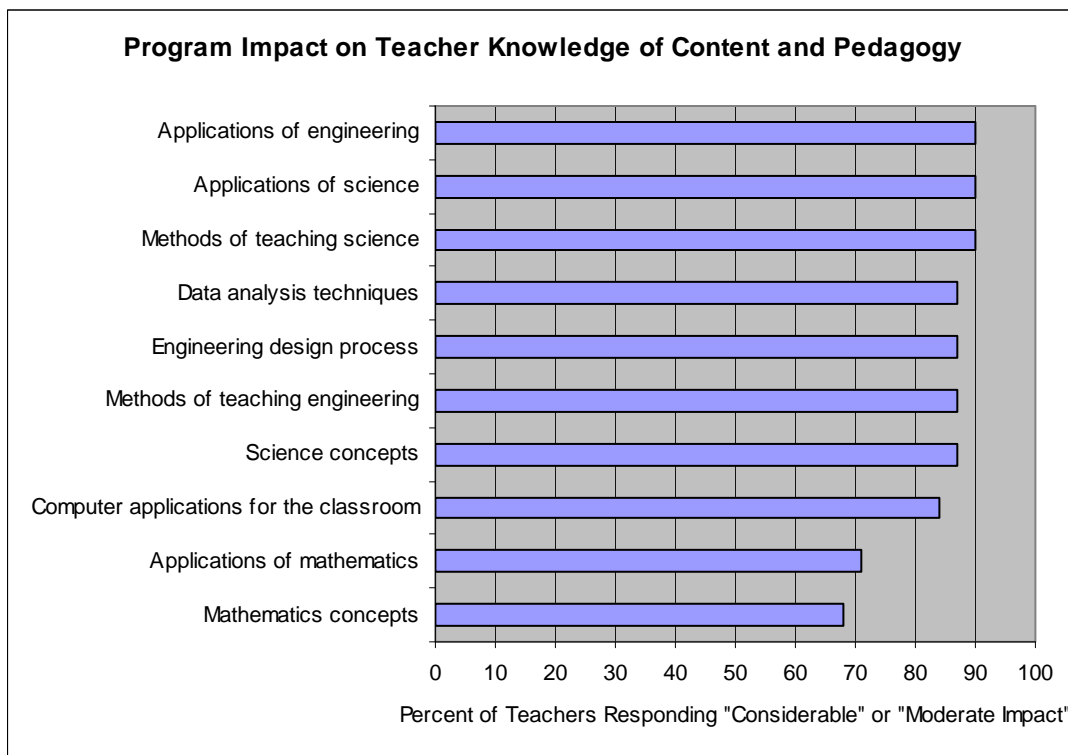
**Figure 3:** Response of teachers when asked in which field(s) they have received degree(s). Total number of bachelor's degrees is greater than the number of participating teachers because some teachers had double majors. (N=36)

that the most common degree area for both bachelors and masters degrees is general education and a significant number, 14%, have undergraduate degrees in psychology. Information regarding teacher certifications was not collected but might be beneficial in interpreting the data

### Impact of Professional Development

More than 90% of the teachers responding stated that the workshop activities were very relevant to the classes they teach. This result might be expected since teachers applied to participate in the program and were aware of the major topics that would be addressed in the workshop. It would not be expected that this level of positive response would be generated, however, when teachers are asked about specific workshop topics and activities because of the variation in the teachers' backgrounds and the courses they teach. Nevertheless, the responses regarding specific topics and activities were still overwhelmingly positive.

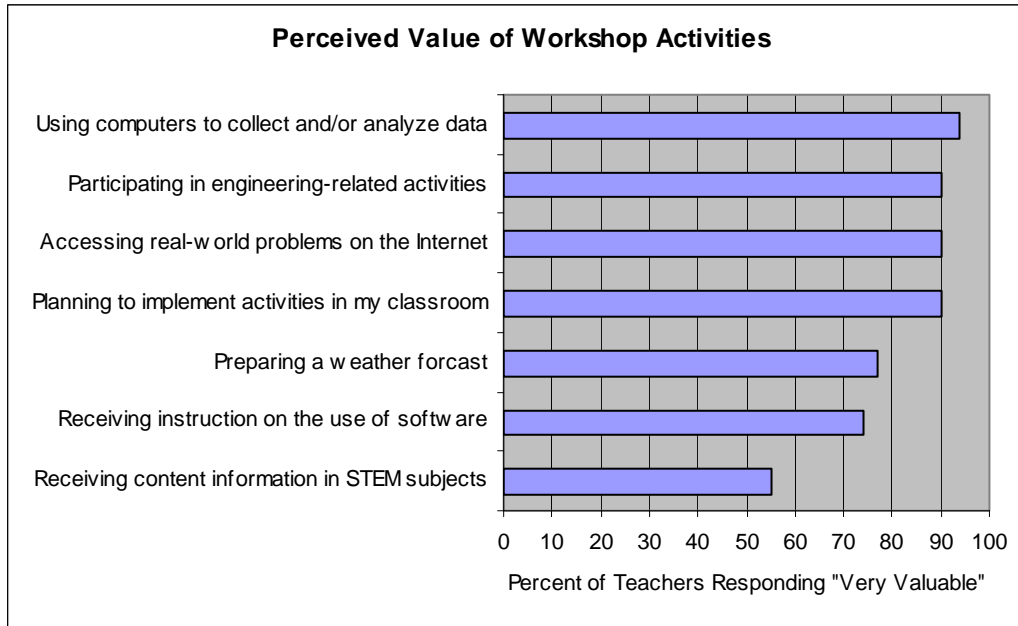
More than 80% of teachers reported that workshop topics relating to science, engineering, computer applications, and data analysis increased their knowledge either considerably or moderately as shown in Figure 4. Even the mathematics-related topics, a minor part of the workshop, were reported to have a considerable or moderate impact on teacher knowledge for approximately 70% of the teachers.



**Figure 4:** Percent of teachers who responded that the summer workshop increased their knowledge of the listed topics a considerable or moderate amount.

Likewise, when asked about specific workshop activities, teachers overwhelmingly responded that the activities were very valuable. More than half of the activities were perceived by at least

90% of the participating teachers to be very valuable and all were considered very valuable by at least half of the teachers as shown in Figure 5. Teachers' varied backgrounds played a significant role in their responses to this item as some of the teachers have advanced degrees in science and were therefore less likely to find the science content incorporated into the activities valuable.



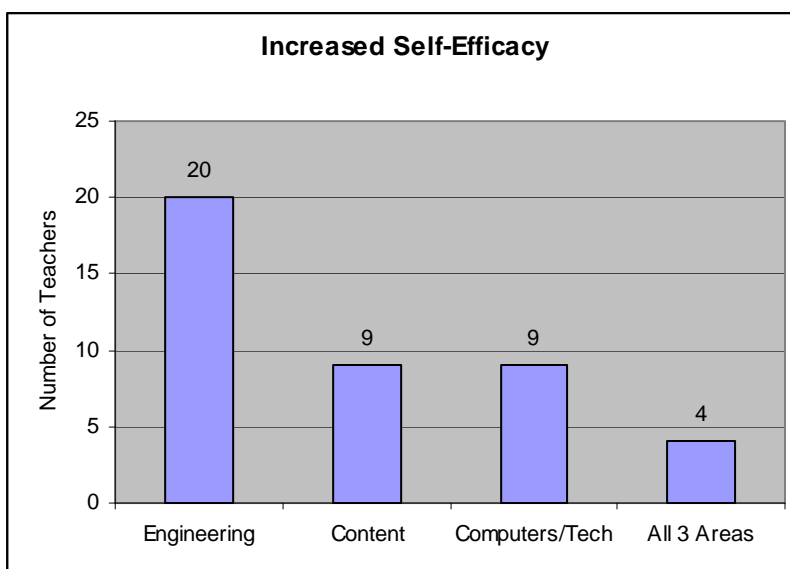
**Figure 5:** Percent of teachers who stated that each of the listed workshop activities was very valuable. (N=31)

While teachers' perceptions of workshop activities and their self-reported impact on teacher knowledge of content and pedagogy were overwhelmingly positive, an efficacy scale score was used as a more reliable measure of workshop impact. At the beginning and at the end of the workshop, teachers were presented 14 statements regarding their confidence in the classroom with respect to specific content areas and pedagogical methods and they responded as to their level of agreement. Each statement is related to one of three focal areas in the workshop:

- Content knowledge (6 statements)
- Engineering (4 statements)
- Technology/Computers (4 statements)

An efficacy scale score was calculated for each teacher in each of the three focal areas for both the pre- and post-workshop surveys.

As would be expected, most individual teachers' level of confidence increased in one or more of the focal areas as a factor of their prior educational background, employment experiences, and personal interests. Figure 6 shows the number of teachers whose sense of self-efficacy increased in each focal area based on their sub-scores for each area. Complete results for these scores were obtained for 28 of the 39 participating teachers. Most teachers' scores indicate an increased self-efficacy in at least one area, based on the mean self-efficacy scores for the group in each of the focal areas, however, only one area showed a statistically significant increase in self-efficacy: engineering ( $t = 3.915$ ;  $p = .001$ ).



**Figure 6:** Teachers with increased self-efficacy in each of three focal areas based on a composite score. (N=28)

## Conclusions and Future Work

Middle school science students in New Jersey are more likely than high school science students and elementary students to have teachers who are not highly qualified in the classes they are teaching. When we consider middle school science students in high poverty school districts, the problem is magnified almost five-fold. The Honeywell Teachers for the 21<sup>st</sup> Century Program has been established to provide teachers, regardless of their highly qualified status, additional tools in the form of hands-on science investigations and team-based engineering design activities as well as content knowledge and technology applications to increase student engagement and achievement in science and to introduce students to engineering concepts.

Preliminary results from participating teacher responses to Internet-based surveys indicate that there have been some positive impacts on individual teachers' perceptions of their preparedness for teaching science and engineering concepts and statistically significant effects on their self-efficacy with respect to engineering. Teachers have reported that the workshop activities increased their knowledge of content and pedagogy considerably or moderately. Additional analyses of the data collected thus far will be performed to determine whether teachers from the urban and high-poverty districts were impacted differently than those from other districts.

Data collection will continue through the end of the academic year to determine what impact, if any, the program has had on teacher practices in the classroom. CIESE staff will be observing classes and teachers will complete an additional online survey regarding self-efficacy and teacher practices. These data will be compared to the data collected during the workshop to obtain a clearer picture of the impact of the program. Also, although the program has not specifically included provisions for collecting student data to determine the impact on student achievement or engagement, some teachers have agreed to provide results from their action research plans. These data will provide anecdotal evidence as to the impact of the program on students.



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