Efforts to Promote Engineering in K-12 Schools in New Jersey: A Case Study of Recent Professional Development, Capacity-Building, Awareness-Building and Policy Initiatives

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***Abstract* - A number of organizations have well-established programs to promote the teaching of engineering in K-12 classrooms in New Jersey. The adoption of new state K-12 curriculum content standards in 2004 raised awareness of the possible role of engineering in K-12 education in the state; however the resulting policy documents created ambiguity regarding the requirements for all students to study technology education and engineering and the associated methods of assessment. In recent years, several major programs aimed at increasing awareness and participation in K-12 engineering have been launched throughout New Jersey. This paper describes the background, policy context, and major initiatives being implemented in New Jersey, with an emphasis on a program of Stevens Institute of Technology, known as *Engineering Our Future NJ* (EOFNJ), whose goal is an engineering requirement for all elementary through secondary students in New Jersey.**

INTRODUCTION

For as many as 30 years, a number of organizations in New Jersey have conducted outreach programs to interest, engage and prepare students and teachers in engineering and STEM. The New Jersey Institute of Technology (NJIT) and Rutgers University report conducting engineering outreach activities for approximately 30 years [1, 2]. Other research universities, as well as community colleges, professional societies, corporations, and informal science education providers have and continue to deliver a range of programming from graduate-level teacher preparation coursework to single-day workshops to after-school enrichment activities, competitions, and focused efforts to increase awareness and participation in engineering of girls and underrepresented minorities. Many of these programs have raised awareness among education decision makers about the benefits to students of participation in team-based, problem-based engineering design activities. This paper seeks to describe those efforts that have focused primarily on K-12 engineering programs in New Jersey that deliver content or instruction during the regular school day and school year.

CONTEXT OF STANDARDS

After a lengthy public comment process from 2001 through 2004, new New Jersey Core Curriculum Content Standards (NJCCCS) were recommended to the New Jersey State Board of Education [3]. Science standards were formally adopted in July 2002 [4] and Technological Literacy standards were adopted in April of 2004 [5]. The Technological Literacy Standard is comprised of 8.1, Computer and Information Literacy (educational technology) and 8.2 technology education [6].

In crafting the language of Science standards and Technological Literacy standards, policymakers considered the input of various stakeholders who lobbied for a spectrum of positions regarding where and to what extent technology, technological literacy and engineering design should be included. The debate illustrated the confusion that existed in clearly distinguishing the differences, unique benefits, and particular learning objectives in the domains of educational technology (use of computers and information technology) from

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those of technology education, as defined in the National Science Education Standards (the design, engineering, and technological issues related to conceiving, building, and maintaining useful objects and/or processes in the human-built world) [7]. Further, some in the science education community opposed inclusion of technology in the science standards and advocated for a separate strand for technology. Many in the vocational-technical high school community argued against including engineering/engineering design as a general requirement for all students, maintaining that engineering fit only within their distinctive mission. The technology education teacher community in New Jersey was divided regarding the shift toward engineering. Some believed that embracing engineering would result in the exclusion of many of the traditional technology education students who benefited from hands-on courses but did not have college preparatory science and mathematics coursework, while other technology educators advocated for a broader and more inclusive definition of their field. Most discussants agreed that a lack of qualified teachers would preclude effective system-wide implementation of more rigorous standards that required engineering or engineering design.

After much debate and compromise, the New Jersey Core Curriculum Content Standards passed by New Jersey State Board of Education included a technological design strand in Science Standard 5.4 (Nature and Process of Technology) [8] and a separate Technology Education Standard (8.2) [6]. Learning expectations for students in Grades K-2, 3-4, 5-6, 7-8, and 9-12 were identified through Cumulative Progress Indicators (CPI) that described what students should know and be able to do to demonstrate their learning.

For example, Science Standard 5.4 (Nature and Process of Technology) states: “All students will understand the interrelationships between science and technology and develop a conceptual understanding of the nature and process of technology.” The relevant CPIs for Grades 3-4 require students to:

1. Describe a product or device in terms of the problem it solves or the need it meets.
2. Choose materials most suitable to make simple mechanical constructions.
3. Use the design process to identify a problem, look for ideas, and develop and share solutions with others. [9]

One of the Grade 9-12 CPIs for Science Standard 5.4 mandates that students be able to “Plan, develop, and implement a proposal to solve an authentic, technological problem [10].”

Technology Education Standard 8.2, adopted nearly two years later, states, “All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world as they relate to the individual, society, and the environment” and is further explained:

Descriptive Statement: The following indicators are based on the Standards for Technological Literacy (STL, 2000) and support the National Academy of Engineering’s (2002) call for students to gain technological literacy. Students will be expected to understand the various facets of technology and the design process. They will analyze and evaluate design options and then apply the design process to solve problems. A systems perspective is employed to emphasize the interconnectedness of all knowledge and the impact of technology and technological change. Students will be expected to use technology as it applies to physical systems, biological systems, and information and communication systems. The intent at the elementary and middle school levels is that all students develop technological literacy and are prepared for the option of further study in the field of technology education. At the elementary level, the foundation for technology education is found in the science standards, particularly standards 5.2 and 5.4 [11].

CPIs described more sophisticated levels of technological design understanding and skills required of students in grades 5-8 and 9-12, such as “by Grade 12 students should be able to use a computer assisted design (CAD) system in the development of an appropriate design solution and create a technological product, system, or environment using given design specifications and constraints by applying design and engineering principles [12].”

Clearly, ambiguity was introduced regarding the interpretation of how Standard 8.2 applied to required learning outcomes for all students, both because it referenced Science Standard 5.2 and

5.4 for Grades K-4 as well as the language in the descriptive statement that allows for "*the option* of further study in the field of technology education."

This ambiguity has led to uneven and under-emphasis of teaching of the specific competencies outlined in Standards 5.4 and 8.2 throughout New Jersey schools.

POST-8.2 ADOPTION

Since the adoption of Standards 8.1 and 8.2 in 2004, a number of additional challenges to its widespread and effective classroom implementation have been observed:

- Confusion over terminology: Differentiating technology education from computer and information literacy continues to be a source of confusion for various levels of education stakeholders, which vexes providers of technology education programming.

- Who is responsible for teaching technology education? Science teachers are often challenged to cover required material in the science curriculum and are unable or unwilling to include material which they may view as supplemental and "covered elsewhere (Standard 8.2). In addition, the Technology Educators Association of New Jersey (TEANJ) estimates that half of New Jersey's technology educators will retire by 2015 and the state will need more than 900 new technology teachers by the same year [13], suggesting a dire shortage of teachers capable of teaching technology education and engineering.

- Lack of instructional time, materials, teacher confidence: Where does technological design, engineering design "fit" in the curriculum and school day? How do existing teachers (science or general classroom teachers) prepare to teach these new skills and competencies? What curricula or materials are needed and how do teachers make judgments of the value of such curricula?

- Will and how will 8.2 be assessed? High stakes testing and pressures from No Child Left Behind legislation have put more emphasis on mathematics and literacy testing while other subjects, even science, receive less instructional time, less emphasis, and less assessment.

Despite these challenges, it is important to note that many beacons and model programs of exemplary technology education programs exist throughout New Jersey which are effectively exposing students to technological design and engineering at varying grade bands and levels of complexity.

SERENDIPITOUS EVENTS AND STRATEGIC PLANNING

As these scenarios were occurring throughout New Jersey following the adoption of new Science Standards and new Technological Literacy Standards, the Stevens Center for Innovation in Engineering and Science Education (CIESE) in 2004 expanded its mission and programming to encompass K-12 engineering education, the result of an internal reorganization within the Institute. For 15 years prior, CIESE had focused on K-12 science and mathematics education, conducting teacher professional development programs, developing curricula, and engaging in educational research primarily in the use of software and Internet-based resources to improve teaching and learning. The Center's largest body of work resulted from a National Science Foundation grant (RED-9454719) from 1994-98 to explore applications of the Internet for K-12 science and mathematics education, which impacted 3,000 teachers from 700 New Jersey schools, through partnerships and turnkey training programs [14]. A five-year, $9.3 million U.S. Department of Education (USED) capacity-building grant to replicate in three other states the work of this NSF grant followed, resulting in partnerships with three of the United States' leading community colleges, Maricopa, Miami-Dade, and Cuyahoga Community Colleges to provide teacher professional development to nearly 8,000 K-12 teachers over a five-year period [15]. The models implemented in these two programs have informed the approach used in the Stevens K-12 engineering initiative, known as *Engineering Our Future NJ* (EOFNJ).

ENGINEERING OUR FUTURE NJ

Through EOFNJ, Stevens CIESE has embarked upon the development of a statewide program to influence policy to strengthen existing standards;

ensure that all students experience age-appropriate, exemplary engineering curricula as an integral part of their K-12 education; build capacity on a statewide level to deliver teacher professional development; increase awareness of engineering, its benefits to student learning, and its importance in the 21st century global economy; and develop a research agenda to gather evidence of impact on student learning.

Phase 1 of EOFNJ was characterized as a pilot/demonstration project and began with a grant from the New Jersey legislature in July 2005. The grant was part of a larger grant program, falling under the auspices of a workforce development initiative to prepare K-12 teachers and community college STEM faculty. Funding sponsored a statewide pilot program designed to demonstrate the benefits on student learning of participation in research-based, age-appropriate engineering curricula among elementary, middle school, and secondary students. A further objective of the pilot study was to understand teacher implementation issues that facilitated or impeded use of engineering curricula at elementary, middle, and high school levels.

An accelerated effort to conduct the pilot during the 2005-06 school year was launched, with school recruitment, curriculum selection, teacher professional development, and development of the assessment instruments taking place in the summer and fall of 2005. Two units of the Museum of Science, Boston's *Engineering is Elementary* curriculum [16, 17] were selected for their coherence with common spring topics in the typical elementary science curriculum and the NJ CCCS, while the Society of Automotive Engineers' *A World in Motion* "Toy Car" unit was selected for implementation at the middle school level [18]. Two modules of the full-year the Museum of Science, Boston's *Engineering the Future: Science, Technology, and the Design Process* curriculum for implementation in both physics and technology education classrooms at the high school level [19].

A statewide application process was promoted and assisted through efforts of the New Jersey Department of Education. Incentives for participation included two days of professional development; classroom materials; a $300 stipend; and local recognition by school administration and media. From approximately 70 applications, 12 elementary schools, 12 middle schools and 11 high schools were selected. Care was taken to ensure a broad cross-section of New Jersey schools among the 35 study participants; schools represented a range of geographic, socio-economic, and academic characteristics [20-23].

Curriculum development partners from the Museum of Science, Boston and the Society of Automotive Engineers were engaged to conduct two full days of professional development at Stevens to kick off the pilot study in December 2005. Enlisting the participation of curriculum developers as workshop leaders added a higher level of prestige and importance to the study among participating schools and teachers, and ensured that teachers would be learning the curriculum and implementation scenarios that had been widely field-tested.

External evaluators were engaged to conduct the study, design assessments to measure student learning in the selected units at all levels, and to capture teacher implementation feedback. The National Center for Technological Literacy at the Museum of Science, Boston was contracted to provide evaluation for the elementary and high school programs, while the Institute for Learning Technologies at Teachers College, Columbia University conducted the middle school study.

Approximately 1,200 students in Grades 3-12 participated in the study. Gains in student understanding of core science, mathematics, technology/engineering concepts were seen at all levels. Teacher feedback was collected from elementary, middle, and high school teachers regarding their preparedness and experiences implementing the curriculum, and their recommendations for improvement [20-23].

The results of this pilot study have informed the Phase 2, or statewide scale-up effort, now underway.

GRASSROOTS AND LEGISLATIVE AWARENESS CAMPAIGN

In order to generate support and recognition for participating teachers and schools and to build momentum for the program, CIESE engaged in a statewide and local publicity effort. Press releases highlighting the schools, the teachers, and the programs were sent to every pilot school's community and regional newspapers, as well as the home town newspapers of each participating teacher. In addition, project briefings were held with many legislators in whose districts were participating schools. These briefings highlighted EOFNJ goals in the context of economic and workforce development issues, an overview of the pilot study, and the pioneering work of the schools in their district. Legislators and other opinion leaders from the business community and science education community were also provided with a position paper that outlined the program's goals, strategy, progress, and participants. An advisory board, representing education, business, informal science education, and other stakeholders, was also convened.

EOFNJ PHASE 2

Phase 2, the statewide scale-up effort, received a major boost when Verizon Communications became interested in the EOFNJ initiative and provided a $500,000 grant to support statewide scale-up. With the stated objective to reach 2,000 teachers with age-appropriate engineering curricula before the New Jersey Core Curriculum Content Standards revision in 2009, CIESE hired a full-time project director for the EOFNJ effort, promoted and offered numerous professional development opportunities for teachers, and began to develop a network of other professional development providers with similar aims.

Phase 2 efforts have focused on:

- Demonstrating efficacy of K-12 engineering on student interest, achievement
- Creating a critical mass of teacher-advocates who will participate in the standards revision process through committees and public comment
- Influencing policy and school adoption through legislative, corporate, media, and grassroots efforts
- Supporting schools with training, curriculum, technical, and financial needs
- Broadening participation in K-12 engineering among girls and underrepresented minorities

Key initiatives of Phase 2 include:

- Teacher professional development aimed at reaching 2,000 teachers in New Jersey
- Infrastructure/capacity-building/partnerships
- Awareness campaign
- Increasing curricular offerings to engage additional subject area (e.g., mathematics) teachers
- Expanding research agenda and conducting program/participant evaluation studies
- Monitor statewide developments with standards revisions and student testing changes

The aim of EOFNJ teacher professional development programs is to provide teachers with a thorough understanding of selected, exemplary engineering curricula and underlying science and engineering concepts through a hands-on experience that will result in effective classroom implementation. In addition to curricula used in the pilot, CIESE now provides professional development on the new *Building Math* [24], on Pro/Engineer software and a variety of new engineering lessons that supplement existing CIESE online science curricula [25]. The curricular approach is to both infuse engineering into science and mathematics curricula where alignments with the NJCCCS allow, and to promote engineering and technology as standalone curricula where such implementation is possible.

Professional development takes place in a variety of venues, at Stevens, in the northern, metropolitan end of the state, and in partnership with other institutions in other locations. Thanks to the Verizon grant, workshops are offered for a nominal fee that covers the cost of hospitality and materials. Instructor time is paid for by the grant. In-school and in-district training is available to organizations that recruit 15 or more teachers. In addition, CIESE staff deliver workshops as part of other organizations' pre-service or in-service teacher development programs, as described in the next section.

In addition to these brief one- and two-day workshops, the momentum of the EOFNJ initiative has helped garner several other longer-term, intensive grants that blend engineering and science professional development:

1. BUILD IT: A $1.2 million National Science Foundation Information Technology Experiences for Students and Teachers (ITEST) project in which 36 middle and high schools are engaged in an underwater robotics project using LEGO and NXT programming devices, to learn engineering, science, and information technology concepts and skills [26].

2. Partnership to Improve Student Achievement (PISA): A $2.0 million New Jersey Department of Education Math-Science Partnership grant for 60 Grade 3-5 teachers from six urban northern New Jersey school districts [27].

3. Teachers for the 21st Century: A $50,000 pilot program sponsored by Honeywell with 15 Jersey City middle school teachers [28].

INFRASTRUCTURE/NETWORK AND CAPACITY-BUILDING CTIVITIES

A number of significant and longstanding K-12 engineering programs are being implemented throughout the state, led by other universities and other organizations. Recognizing that broad support and participation will be necessary to achieve desired changes in standards, assessment, and classroom practice, several efforts have been launched to create a statewide coalition of organizations interested in similar outcomes:

1. "Catalyst grants" of $5,000 to institutions who conduct teacher professional development on exemplary engineering curricula for elementary, middle, and high school teachers. Grant recipients receive training from Stevens in the curriculum they select for their program, recruit teachers, conduct training, and provide Stevens with contact and evaluation data about participants. An estimated 450 teachers will be trained in engineering curricula during the term of this program.

2. "Guest lecturer" workshops for preservice teachers at colleges of teacher education.

3. In-service workshops at partner sites, offered at no cost at partner colleges and other professional development providers.

4. In-school/district-based workshops, offered at no or nominal cost to districts.

5. Community college K-12 engineering outreach event: CIESE is also planning an event for all 19 community colleges in New Jersey in December 2007 to acquaint them with the goals, curricular resources, and outreach models available to promote K-12 engineering. Participants will be provided with a materials voucher to order curriculum materials, and will be supported with turnkey training if they begin to offer teacher workshops.

AWARENESS CAMPAIGN

An awareness campaign, consisting of media outreach to the public, communications to key educator and sponsor constituencies, and targeted mailings and presentations has reached approximately 500,000 readers in New Jersey over the last two years. A major aim of the awareness campaign is to de-mystify engineering and engineers; to showcase girls and underrepresented groups in engineering; and to highlight and acknowledge the work of participating schools and teachers in their local communities. Among the vehicles used to increase awareness are:

- Press releases/local newspaper stories recognizing teachers, schools
- Regional stories about programs, curricula, innovations
- Op-ed and issues articles about globalization, innovation, and workforce/education connections
- Legislator meetings highlighting initiative, participants
- Engineer visits in the classroom and media coverage
- EOFNJ newsletter (online and hard copy)
- EOFNJ web site
- National, regional conferences, presentations, papers

In addition, Stevens sponsored a major awareness-building event in May 2006 for New Jersey principals and supervisors. This one-day conference was co-sponsored by the New Jersey Department of Education, the New Jersey Principals and Supervisors Association, and Verizon Communications. Keynote and luncheon speakers discussed "Why K-12 Engineering?" and business and government's position on and role in preparing students for success in the 21st century. In addition, all of New Jersey's engineering institutions and many of the state's professional development providers presented workshops on current programs, offerings, and research. More than 250 school leaders participated in this one-day conference. Another event, targeted for guidance counselors, is scheduled for April 2008.

ESTABLISHED K-12 ENGINEERING PROGRAMS THROUGHOUT NJ

A brief survey was sent to a number of organizations involved in K-12 engineering outreach to elicit the scope, scale, funding sources, and major activities currently underway. Ten responses were received: seven from engineering universities; one from a teacher education institution; one from a teacher association; and one from an international engineering society. It is difficult to compare and categorize results from this survey, partly due to the diversity of organizations responding and their differing missions and audiences, and partly because of an inability to distinguish some technology education programming from engineering programming. That distinction continues to be a blurry one for reporting and analysis contained herein. Despite these challenges, some observations can be made from the responses.

Focused programming to equip K-12 teachers to teach engineering has been conducted in New Jersey for nearly 30 years. Based on estimates provided by respondents, more than 15,000 teachers have been impacted over this period with face-to-face workshops or other professional development services [29]. Many thousands of other teachers, both in New Jersey and elsewhere, have been impacted by online resources, such as those contained in the Institute of Electrical and Electronics Engineers (IEEE) resource, TryEngineering.org.

The most mature programs are those at NJIT and Rutgers University, while Montclair State University a leading college of teacher education, has emphasized technology education and “children’s engineering” as part of its preservice teacher programs for nearly 15 years. Other programs, including those offered by Rowan and Princeton Universities, and that of Stevens Institute of Technology, are more recent, resulting from major grants (as at Princeton and Stevens) and catalyzed by the creation of the School of Engineering at Rowan University. The College of New Jersey reports working in the field of K-12 engineering for more than 10 years, with undergraduate and graduate as well as in-service teacher programs. IEEE, based in New Jersey, but with an international mission, has promoted K-12 engineering for six years primarily through the TryEngineering.org web site. The Technology Educators Association of New Jersey also estimates having promoted engineering to approximately 1,500 teachers over 15 [29]. The NJ Department of Education affiliate, Education and Information Resource Center, through collaborations with NASA, has impacted approximately 150 teachers with engineering-focused workshops and outreach in southern New Jersey during the last three years.

Program providers are working with teachers throughout the K-12 spectrum, with efforts fairly evenly spread between elementary, middle, and high school teachers. Program activities have been sponsored by a range of agencies and organizations, including the National Science Foundation, the New Jersey Commission on Higher Education, the New Jersey Department of Education, as well as corporate and private foundations, and, as at The College of New Jersey and Montclair State University’s preservice teacher education programs, by tuition. TCNJ’s Department of Technological Studies is producing the only certified technology education teachers in the state forhigh school and middle school teachers) and is also the only university in the state that has a Math-Science-Technology degree for elementary education majors in which the technology portion is pre-engineering. TCNJ also leads the NJ Technology Student Association (NJTSA), which has grown from 1,464 students in 21 chapters in 2002 to 6,700 students in 44 chapters 2007. While TSA was originally a technology education movement, it also now includes engineering, incorporating many engineering design problems in its competitions. Just recently, NJIT, in collaboration with Rutgers University-Newark, has submitted a proposal to the NJ Department of Education to implement a teacher preparation program in Technology Education/Engineering Technology which is expected to begin in September 2008.

In addition to those organizations that responded to the survey, a number of others, most notably community colleges and U.S. Department of Education-sponsored GEAR-UP programs (Gaining Early Awareness and Readiness for Undergraduate Programs), are sponsoring various forms of teacher professional development and student programming in engineering and technology.

In addition to these well-established programs, a new organization, the NJ

Engineering Education Consortium, was formed in December 2006 with three strategic goals:

- Establish engineering education in all New Jersey elementary, middle and high schools.
- Prepare New Jersey teachers to deliver appropriate engineering content to their students.
- Strengthen and expand New Jersey's higher education engineering infrastructure

With participation from the New Jersey Commission on Higher Education, the state's Chamber of Commerce, as well as the four- and two-year colleges that offer engineering programs, this group will seek to influence state policy, heighten awareness of engineering and engineering careers, and expand current programming.

CURRENT POLICY LANDSCAPE

With the planned revision of New Jersey's Core Curriculum Content Standards in 2009, the 2007/2008 period is critical to influence opinion leaders and policymakers. Based on input from the New Jersey Department of Education, major revisions to the standards and Cumulative Progress Indicators are not expected. Revision to language to clarify standards will be the primary goal.

As the impact of No Child Left Behind legislation and its reauthorization continues to shape the body of knowledge on which students are assessed, it will be important for engineering and technology education to position its learning outcomes to align with subjects that are tested. This is critical to ensure that these subjects and specific learning outcomes are not viewed as optional and therefore, not uniformly taught. At the Grade 3-8 level, New Jersey is implementing new student assessments, and a new series of statewide tests in science. As the assessments are designed, the engineering and technology education community must focus on ensuring that some portion of the content includes engineering and technological design.

At the secondary level, New Jersey is in a transition stage with regard to graduation requirements and assessments. New Jersey has just moved away from a cumulative test of science content given in Grade 11 (the High School Proficiency Assessment in science), toward an end-of-course model for science will start with biology. Further, it is anticipated that New Jersey will be adopting the recommendations and standards of the American Diploma Project (ADP) which will require three years of prescribed science courses: biology, chemistry, and physics [30]. The opportunity, therefore, to mandate engineering or technology education coursework for all students at the high school level becomes a daunting challenge. One approach, described by Kimmel et al. is to integrate engineering into high school science curricula, through standards, and associated assessments [31]. Preliminary discussions of new end-of-course assessments in science have emphasized the benefits of a performance assessment, which could lend itself to an engineering problem. With this opportunity, however, comes the challenge of convincing the science education community and stakeholders who provide input to the assessments that this would be a worthwhile approach. Requiring a course for high school students in technology education or engineering seems unrealistic, given the mandates of the American Diploma Project. Integrating engineering and technology into the science curriculum and assessments appears to be a more practical, though not assured, approach of reaching all high school students with an engineering experience.

CHALLENGES AND NEXT STEPS

Looking beyond these challenges to the possible near future that would codify standards requiring all students to experience engineering in the elementary, middle, and secondary levels, with an associated assessment of their learning, an even greater challenge looms. How will schools meet these requirements?

The Technology Educators Association of NJ (TEANJ) has documented a shortage of technology educators, while Kimmel et al. note that the proliferation of middle and high school technology and pre-engineering courses have created a shortage of qualified teachers to teach such courses [31, 13]. Further, the limited time schools have available for professional development will likely continue to be focused on mathematics, language arts, and now science, those subjects that are assessed as part of No Child Left Behind.

Convincing policymakers, who fund programs such as the Math-Science Partnership, and school administrators, who choose which curricula to adopt, that engineering deserves "a place on the bus" of subjects that are critical competencies for 21st century citizens, will require both evidence of student impact as well as a clearer understanding by such constituencies of what engineering is (and is not); what its contributions to society and the economy are and will be in the future; and why engineering careers are suitable for females and minorities. Connecting engineering to pervasive themes of our times, such as innovation as a driver of the economy, globalization and workforce issues, homeland security and the need for technological solutions, is one important tool in this campaign. A communications plan that targets key messages to key constituencies is needed. For example, EOFNJ has held briefing meetings with a number of state and federal legislators to discuss the overall aims, strategy, and program activities, focusing on "big picture" goals, then followed up by inviting the legislator to a school in his or her district that is implementing an engineering lesson. For those policymakers who are unfamiliar with what engineering is and how it can be applied in an elementary or middle school setting, this has been a powerful combination.

Figure 1

Audience	**Message**
Policymakers and funding agencies	Economic prosperity; innovation; homeland security
Industry	Investment in future workforce
School boards and administrators	21st century workforce skills; critical competencies
Parents	Career opportunities, examples of success
Girls and minorities	Social contributions of engineering; accessibility; career opportunities; support; role models
Guidance counselors	Careers, accessibility, downplaying "geek" stereotype
Science teachers	Linkages with existing curricula; similar to scientific process; evidence of improved student learning of science through *application* (Piaget)
Elementary teachers	Training and support available; fun and hands-on; student-motivator
Technology teachers	Reward innovation, rigor, exemplars of program success
Students	Fun! Creative! Hands-on; teamwork, can make a difference to society

However, it will be necessary for a wide range of constituencies to be involved and convinced that engineering should become a universal requirement for K-12 students. Examples of key stakeholders and messages that can help justify this position appear in Figure 1.

While not an exhaustive list, these examples show how misconceptions or lack of understanding of engineering and engineers can be overcome to stakeholders who are important to this effort.

In addition to targeting specific stakeholder groups with key messages, several other strategies are recommended to raise the level of visibility and support for K-12 engineering such that all schools are able to participate:

- Dedicated funding and high visibility from agencies such as the National Science Foundation, the U.S. Department of Education and state departments of education for K-12 engineering programs, including curriculum development, teacher professional development, and research on student learning

- Ensuring that a component of high stakes national and statewide tests include an engineering/technological design component

- Broadly disseminating to policymakers, parents, and K-12 decision-makers who make curricular choices research that demonstrates efficacy and benefits of K-12 engineering on student learning of science, mathematics, and on skills such as problem-solving, and the ability to be creative and innovative.

- Humanizing engineering through popular media so that the general public's conceptions of engineering and engineers are updated.

Reaching the goal of benefiting all K-12 students with engineering experiences as an integral part of their K-12 education will require a systemic and holistic approach that involves many different sectors of education, government, and business. This case study, a snapshot of a dynamic and evolving set of circumstances, is presented as an effort to spur further discussion and participation by these critical stakeholders.

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