AC 2008-665: ENGINEERING OUR FUTURE NJ: PROMOTING ENGINEERING IN K-12 SCHOOLS THROUGH PROFESSIONAL DEVELOPMENT, POLICY INITIATIVES, AND PARTNERSHIPS

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Engineering Our Future NJ: Promoting Engineering in K-12 Schools through Professional Development, Policy Initiatives, and Partnerships

Abstract

This paper describes the statewide scale-up phase of an initiative whose goal is to ensure all students in New Jersey experience engineering as an integral component of their K-12 education, not merely as an extracurricular activity or elective course. Building on a pilot effort and supported by several corporate and competitive federal and state grants, the program aims to: reach a critical mass of 2,000 teachers with professional development in exemplary K-12 engineering curricula; influence policy to strengthen educational standards and assessments; and create a statewide network of partner organizations who deliver or host professional development and provide technical support to neighboring schools. This paper describes the professional development and curricular programs they support; the policy landscape and efforts; and the strategies, including catalyst grants, used to engage community colleges, institutions of teacher education, and other organizations, in outreach and programming. In addition to these activities, the EOFNJ initiative has launched an awareness-building effort to disseminate critical messages to various stakeholder groups, including school administrators, and the parent community. A research effort, in its early stages, is underway to understand the impact of EOFNJ activities statewide and in several school districts.

Background

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. The *Engineering Our Future New Jersey (EOFNJ)* initiative, led by the Center for Innovation in Engineering and Science Education (CIESE) at Stevens Institute of Technology, is focused on strengthening New Jersey's Core Curriculum Content Standards to ensure that all students, elementary through high school, experience engineering as an integral component of their education, not merely as an elective course or extra-curricular activity. The Stevens initiative represents one program of those offered by some 18 institutions which provide K-12 outreach in pre-college engineering programming in New Jersey, including Rutgers and New Jersey Institute of Technology, which have offered such programs for nearly 30 years. Other engineering universities, community colleges, and at least one college of teacher education, Montclair State University have also been involved in K-12 engineering outreach. [1]

Engineering Our Future NJ Overview

The EOFNJ initiative is a multi-pronged effort launched in 2005 that includes: pre- and in-service teacher professional development; policy initiatives; partnerships and capacity-building efforts; promotion; and a research component. Its stated goal is to ensure all

students experience engineering, with a focus on innovation, in the context of required, regular classroom coursework in elementary through high school by 2010. Notable is that New Jersey Core Curriculum Content Standards in science are being revised in 2009. It is hypothesized that by exposing *all* students to hands-on design and problem-solving and the application of science and mathematics principles toward the solution of relevant, real-world design problems in the context of *required* courses, that more students will be motivated to enroll and succeed in gatekeeper courses in middle and high school and pursue engineering and other STEM careers.

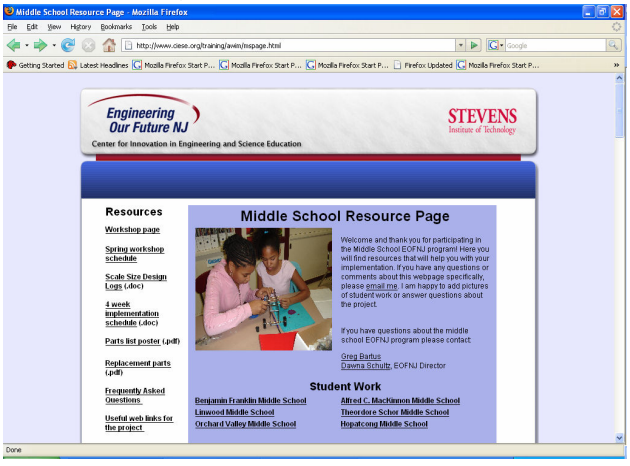
EOFNJ has pursued a two-phased approach to providing engineering in K-12 schools in NJ. Phase 1, the pilot phase, has been discussed in previous papers[1,2]. This paper describes activities, impact, and preliminary professional development evaluation data of Phase 2. The goal of Phase 2 is to create a critical mass of teachers and administrators who will demonstrate the efficacy and feasibility of embedding engineering into existing curricula and frameworks in science, mathematics, and technology courses. A key objective is to impact 2,000 educators in New Jersey with professional development and related programming such that schools have the capability to select, adopt, and effectively implement exemplary engineering curricula in required science, mathematics, and technology courses.

The major thrusts of Phase 2 include: professional development, partnerships, policy initiatives, and promotion. A research effort is also currently underway and will be reported upon in future papers. Preliminary evaluation data of professional development programs are included in later sections of this paper.

Professional Development

As has been documented through a pilot study, EOFNJ teacher professional development programs are providing teachers with a thorough understanding of selected, exemplary engineering curricula and underlying science and engineering concepts through a hands-on experience that frequently results in effective classroom implementation and occasionally in district-wide adoption of the curriculum[2].

Figure 1: EOFNJ Middle School Resource Web Page



Educators who attend EOFNJ professional development continue to be supported after the training through the resource web pages maintained on the CIESE web site (www.stevens.edu/ciese/eofnj) for each of the EOFNJ curricula. Figure 1 shows the EOFNJ middle school resource page.

EOFNJ is providing professional development on exemplary engineering curricula originally used in the 2006 pilot program, but additional curricula are now being supported as well. Current curricula which teachers may learn about and experience through hands-on professional development workshops are identified in Table 1.

Table1: EOFNJ Curricula and Software

Curriculum/Software	Grade Level	Developer	Publisher
Engineering is Elementary www.mos.org/eie	3-5	Museum of Science, Boston	Museum of Science, Boston www.eiestore.com
A World in Motion www.awim.org	6-8	Society of Automotive Engineers	Society of Automotive Engineers www.sae.org/exdomains/awim/teachers/requestkit.htm
Building Math www.engineering.tufts.edu/buildingmath/index.html	6-8	Museum of Science, Boston	Walch Publishing www.walch.com/search.php?title=building+math
Engineering The Future www.mos.org/etf	9-12	Museum of Science, Boston	Key Curriculum Press www.keypress.com/x19890.xml
CIESE Engineering Lessons www.ciese.org/engineeringproj.html	3-12	CIESE	CIESE www.ciese.org/engineeringproj.html
Pro/Engineer Wildfire Software (Schools Edition) www.ptc.com/for/education/schools_program_faq.htm	6-12	Parametric Technology Corporation	Parametric Technology Corporation www.ptc.com

To reach a critical mass of 2,000 teachers, professional development takes place in a variety of venues and durations. Through a corporate grant from the Verizon Foundation, we are providing one- and two-day hands-on workshops to introduce engineering curricula and alignments with science and mathematics standards and curricula. These workshops are held both at Stevens and at school districts and other locations around the state and are offered at no or nominal cost to participants. Educators are eligible for professional development credit after completing the workshops. In addition to these introductory workshops, two other programs, sponsored by the National Science Foundation and the New Jersey Department of Education, are providing long-term,

intensive professional development for cohorts of between 50 and 75 of elementary, middle, and high school teachers, with accompanying classroom and online support[3,4].

These NSF and state-supported initiatives are conducting rigorous evaluation studies of teacher and student learning and changes in classroom behavior, which are being reported in separate papers.

Middle school teachers designing thermometers from *The International Boiling Point Water Projec*t.

As of January 2008, the EOFNJ partners have provided professional development to 1,000 K-12 teachers and administrators from 250 school districts and related organizations in all of New Jersey's 21 counties. Through partnerships with school districts, other institutions of higher education and associated engineering, technology, science and research organizations, the EOFNJ initiative has achieved the halfway mark of its near-term goal, to reach 2,000 K-12 educators through professional development on exemplary engineering curricula. Figure 2 illustrates the sources of teacher professional development participants.

Elementary teachers designing water filters from the Engineering is Elementary module-Water, Water, Everywhere

Figure 2: Total Teachers Impacted per EOFNJ Capacity-Building

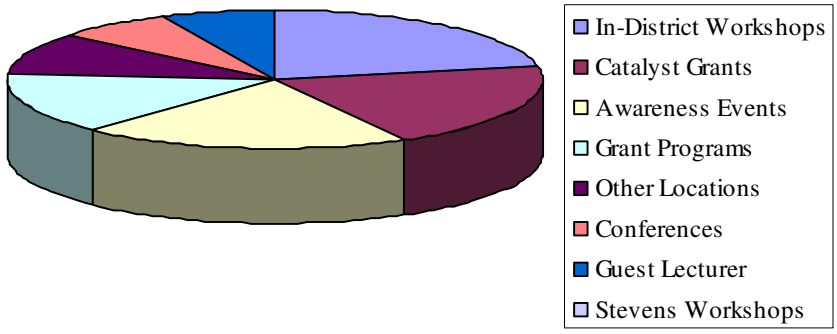


Figure 2 Legend Descriptions

In-district Workshops	Workshops held in schools and districts across the state.
Catalyst Grants	Teachers impacted via partner institutions who received catalyst grants for expansion programs.
Awareness Events	Conferences held for administrators and guidance counselors.
Grant Programs	State and federally-sponsored programs that have expanded EOFNJ efforts.
Other locations	Workshops hosted at colleges, museums and other sites.
Conferences	EOFNJ presentations given at various conferences.
Guest Lecturer	Classes taught to pre-service teachers as part of a science methods or other undergraduate or graduate-level course
Stevens Workshop	Workshops held at Stevens.

Evaluation of Engineering Workshops

At the end of each workshop, teachers complete an evaluation, in the form of a Likert Scale, and assess the content and quality of the workshop, using a scale from "strongly agree" to "strongly disagree." Below is a summary of all evaluations received for *Engineering is Elementary*, *A World in Motion*, and *Engineering the Future* workshops held on the Stevens campus.

***Engineering is Elementary* (EiE)- Total evaluations 75**	% in Top Two Rating Categories
1. The overall rating of the training	91%
2. The course purpose and objectives were clearly stated	83%
3. The handout materials were clear	92%
3. The trainer was well prepared	95%
4. The training met my expectations	92%
5. The material is useful and relevant for my classroom	89%

Some of teachers who had completed the EiE evaluation wrote about what aspects of the training were valuable to them:

- "The lessons were diverse and could be used in many subjects making them great interdisciplinary modules."
- "Having quick easy lessons at my fingertips that I could take back and immediately implement into my classroom."
- "Showing how students can be taught to problem solve."

A World in Motion **(AWIM)- Total evaluations 38**	% in Top Two Rating Categories
1. The overall rating of the training	82%
2. The course purpose and objectives were clearly stated	71%
3. The handout materials were clear	82%
4. The trainer was well prepared	79%
5. The training met my expectations	76%
6. The material is useful and relevant for my classroom	79%

Some of teachers who had completed the AWIM evaluation wrote about what aspects of the training were valuable to them:

- "Hands on discovery method leads to an understanding of how gears are used for various functions."
- "Having a fellow teacher speak to our group was helpful. It was good to hear about the experiences of another teacher with the program."
- "The tips and resources given."

Engineering the Future **(ETF)- Total evaluations 27**	% in Top Two Rating Categories
1. The overall rating of the training	90%
2. The course purpose and objectives were clearly stated	93%
3. The handout materials were clear	93%
4. The trainer was well prepared	97%
5. The training met my expectations	93%
6. The material is useful and relevant for my classroom	86%

Some of teachers who had completed the ETF evaluation wrote about what aspects of the training were valuable to them:

- "Our curriculum is in need of serious updating and this workshop has opened my eyes to the possibilities and direction which our district needs to move."
- "Many varied examples of projects that are relative to daily student experiences."
- "Practical experiments are easy to do and are done with materials easy to find."

Future papers will report on the impact of professional development on classroom implementation.

Partnerships

In order to meet its goals, CIESE has cultivated a strong set of alliances and institutional partnerships that, as a network, are delivering professional development throughout the state and working together to influence educational policy. Figure 3 shows the variety of institutional and school partners involved in the EOFNJ effort.

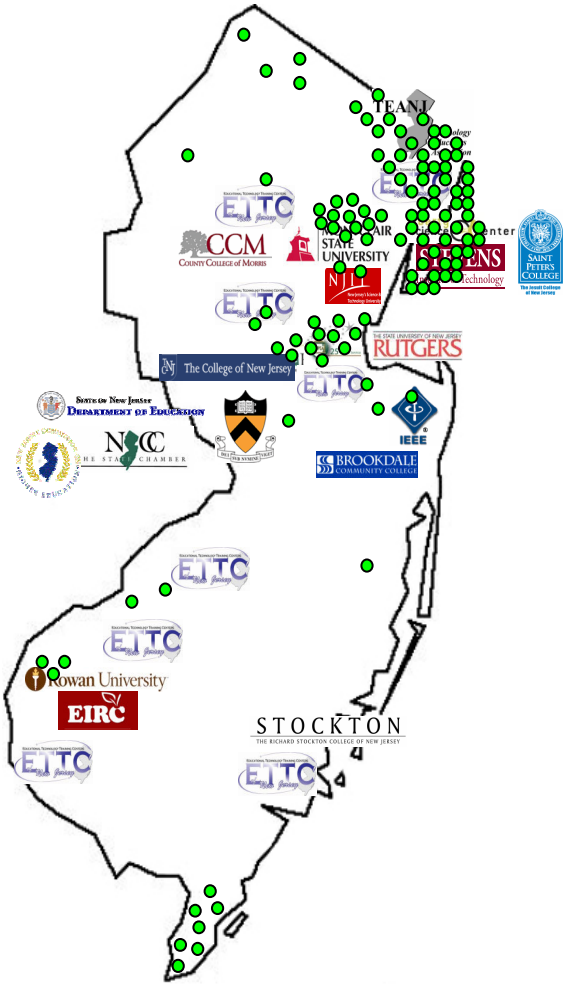


FIGURE 3: EOFNJ Partners

At the most fundamental level, meeting the goal of reaching 2,000 teachers requires partnering with other, geographically-distant organizations. Conducting meaningful teacher training for large groups of teachers within three years is a significant challenge without a statewide infrastructure. Adding to this challenge are new constraints on teacher release time, particularly for workshops related to subjects not included on mandatory statewide tests. Through a combination of models, EOFNJ is benefiting from partnerships with two- and four-year institutions to reach the goal of training 2,000 teachers as well as the desired changes in standards, assessment, and classroom practice. Several strategies have been particularly effective to engage partners and expand programming:

- Catalyst grants of to initiate new or expand existing programs to reach pre- or in-service teachers with engineering professional development. Grantees receive funding of $5,000, plus training and materials to launch new programs.

- In-school and district-based workshops, offered as part of districts' professional development plans.

- Guest-lecturer and workshops offered at host sites such as colleges of teacher education to reach both pre- and in-service teachers.

Partners include two- and four-year colleges, industry, government, education associations, schools and school districts, and other stakeholder groups. Together, these organizations are working to engage in the delivery of engineering programming for teachers and students; sharing of curricula and effective models; and coalition-based lobbying efforts. These partnerships are an essential component of large-scale change efforts and a critical vehicle for statewide scale-up[5].

Promotion

A key objective in achieving the goal of infusing engineering into mainstream K-12 education in New Jersey involves building awareness of engineering, its importance to U.S. economic health, and reducing negative perceptions of engineering held by important constituencies. 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, a major awareness-building event in May 2007 was held, in partnership with a corporate sponsor, the NJ Department of Education, and the NJ Principals and Supervisors Association, for school administrators. This one-day conference addressed "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. Approximately 250 school leaders participated in this one-day conference. Another event, targeted for guidance counselors, is scheduled for April 2008.

Below is a summary of all the evaluations received for the May *Engineering Our Future NJ* 2007 Conference held on the Stevens campus.

EOFNJ May 2007 Conference- Total evaluations 76	%Very Good or Above*
Overall rating of the conference	88%
Keynote Presentations	
Innovation as a Learning Objective	65%
Why K-12 Engineering?	100%
Business Role and Stake in Growing the Next Generation of Engineers	66%
Preparing Our Children for Success and Citizenship in a Global Economy	56%
Building Strategic Engineering Design Capacity in NJ	78%
Session 1	
Engineering is Elementary Engineering and Science Curriculum	84%
Research on the Impact of K-12 Engineering on Student Learning	56%
Engineering Clinics for Middle School Teachers and Guidance Counselors	45%
Design and Global Engineering: What Does The Modern Engineer Look Like?	72%
Engineering Resources for Educators, Students, Parents, and Counselors	80%
How Business is Convincing High School Students to Learn More Now, Do More Now, Earn More Later	80%
Dual Degree Engineering Programs	100%
Session 2	
Curriculum Standards: Where Does Engineering Fit in NJ?	46%
A World in Motion Curriculum: Middle School Engineering Curricula	36%
Technology Education: A Critical Piece to the Pre-Engineering Puzzle	82%
Using Princeton University Materials Academy (PUMA) Activities & Modules	75%
Pre-K to 5th Grade Children's Engineering Initiative	90%
Engineering the Future Curriculum: High School Implementation Model	89%
Why Are There Still Underrepresented Groups in Engineering?	75%
Session 3	
The Academy at Rutgers for Girls in Engineering and Technology (TARGET)	78%
Science and Engineering Connections: Unique and Compelling K-12 Curriculum Offerings	79%
Engineering Experiences for Pre-service Elementary Teacher	50%

The K-12 Engineering Pipeline: A 30-plus History of Success	33%
Engineering Programs that Work for Middle School Students	21%
Funding Stem Initiatives	88%
High School Engineering Program: Implementing Project Lead the Way	17%

*% of respondents in the top 2 categories ("very good" and "excellent").

Some of teachers and administrators who had completed the EOFNJ May 2007 conference evaluation wrote about what aspects of the event that were valuable to them:

- "Speaker was very well prepared and willing to answer questions and offer resources. I gained new knowledge and information that I will be able to use right away."
- "Thank you for your effort in promoting engineering in education, as a science supervisor I am motivated to initiate this in the school."
- "Personable well prepared presenters."

Further, presentations at state and national teacher conferences, such as the New Jersey Technology Educators Association (NJTEA) and New Jesery Science Teachers Association (NJSTA), have built visibility within the state with key audiences.

Policy Initiatives

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. 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 that will start with biology. Further, it is anticipated that New Jersey will adopt the recommendations and standards of the American Diploma Project (ADP) which will require three years of prescribed science courses: biology, chemistry, and physics[6]. 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[7]. 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.

Research Activities

A research study, currently in the preliminary stages, is underway to better assess the impact of EOFNJ activities on classroom activities, student motivation and learning, and to better understand the conditions under which a school or districts adopts and institutionalizes engineering curricula and programs. The program evaluation consists of three parts, each with a different focus and method of collecting data.

The first section will characterize the overall impact of the EOFNJ program by summarizing the number of teachers involved and the programs through which their involvement occurred.

The goal of the second section of the evaluation is to determine the impact of the program on classroom practices, student achievement and attitudes, and to collect information that might inform further development of the program. Teachers who have participated in the EOFNJ program and their respective students will complete questionnaires addressing their knowledge of program content, e.g. the engineering design process; the types of activities that are being used in the classroom to teach science and math, with engineering as the vehicle of instruction; obstacles encountered when implementing the activities; and attitudes about science and engineering. Data will be analyzed to determine strengths of the program and areas in which improvements should be made and the nature of those improvements.

The third section of the evaluation is a series of case studies with the goal being to collect information that may be beneficial to other teachers, school districts, or program providers in the early stages of or contemplating participation in EOFNJ or similar programs. Through interviews and focus groups, the evaluation team will speak with administrators, faculty, and parents in two school districts that have participated in EOFNJ and one post-secondary partner institution. The discussion in these interviews and focus groups will be centered on characterizing the initial involvement, describing how program participation spread throughout the school/district, describing obstacles that have been faced and how these obstacles were overcome. The emphasis in the focus group discussions with the parents will be the impact on student achievement and attitudes toward science and math instruction.

The results of this evaluation will be reported in future papers.

Challenges, Lessons Learned, and Next Steps in EOFNJ

Through the experience of implementing EOFNJ over three years, EOFNJ planners have identified challenges, lessons learned, and next steps in the program.

Time available for professional development and teacher shortages in technology education represent two challenges to the goals of EOFNJ. The New Jersey Technology Educators Association of NJ (NJTEA) 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[7,8]. 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.

De-mystifying engineering as a discipline and persuading policymakers and school administrators that engineering design and design-based problem-solving are important 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. 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.

Summary

Reaching the goal of benefiting all K-12 students with engineering experiences as an integral part of their K-12 education requires a systemic and holistic approach that involves many different sectors of education, government, and business. The EOFNJ initiative is pursuing this goal by developing capacity and partnerships throughout the state to: deliver effective professional development; strengthen educational policy, particularly curriculum standards and assessments; and provide support to schools for integration of engineering into mainstream curricula. Through a portfolio of programs that span from introductory, one-day workshops, to three-year intensive professional development efforts with associated evaluation and research on student learning, EOFNJ is building the evidence necessary to convince policymakers and educational stakeholders of the merits of including engineering in K-12 education. This paper presents a snapshot of a dynamic and evolving set of circumstances.

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