K-12 Engineering Outreach
Impact on University Teaching Fellows

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Abstract

Graduate and undergraduate Engineering Teaching Fellows develop important skills through participation in K-12 engineering outreach programs. The K-12 teaching experience augments the traditional university educational experience of the Fellows in several ways including improvement of communication skills through oral explanations of complex subjects to K-12 students and improvement of their ability to function on multidisciplinary teams through team-teaching content with Fellows from other engineering disciplines. These value-added impacts are affected significantly by the amount and type of training provided for the Fellows and their partnership teachers. Training in teaching methodologies including inquiry-based instruction and classroom management are necessary for effective classroom intervention. This paper examines self-reported evidence that demonstrates significant positive impact of participation in engineering outreach on Fellows' ability to communicate effectively and function on multidisciplinary teams.

Introduction

Outreach programs placing graduate and undergraduate engineering students in K-12 classrooms as Engineering Teaching Fellows have demonstrated the ability to positively impact K-12 students.[1-5] The National Science Foundation (NSF) Graduate Teaching Fellows in K-12 Education (GK-12) program has provided funding for such Fellows programs at more than 20 engineering colleges. These programs generally utilize graduate level Engineering Teaching Fellows to create and implement project-based curricula using engineering to teach math and science concepts in the K-12 classroom.

Three such programs have been implemented by the Duke University Pratt School of Engineering's K-Ph.D. Program: Duke-NCSU Engineering Teaching Fellows in Elementary Education sponsored by an NSF GK-12 Track 1 grant[6], MUSCLE: Math Understanding through the Science of Life sponsored by the GE Foundation Math Excellence Program [7, 8], and Techtronics: Hands-on Exploration of Technology in Everyday Life sponsored by the Burroughs Wellcome Fund's Student Science Enrichment Program[9-11]. This paper examines the impacts on Engineering Teaching Fellows of participating in these three programs.

From 1999-2003, the Duke-NCSU GK-12 Engineering Teaching Fellows Program placed graduate and undergraduate teaching Fellows in 7 schools in 4 counties. Fellows provided

assistance and expertise for teachers in the design and delivery of hands-on activities integrating science and engineering into the NC Standard Course of Study. Fellows also developed "Science Boxes" to collect and answer student questions, "Science Nights," "Discovery Days," and "Win a Day at Duke" contests. Eight annual Fellow training workshops, taught by partnership teachers, covered Bloom's Taxonomy, learning styles of special-needs children and behavior management. Teachers participated in monthly training sessions on integrating technology into classrooms and received Duke Continuing Education credit. The Duke-NCSU GK-12 Engineering Teaching Fellows program was recognized by Microsoft Research University Programs as a national K-12 outreach model.

From 2001-2004, MUSCLE provided a curriculum enhancement program designed to increase the number of students who choose science and technology related careers. The program focused on the integration of mathematics into all areas of the North Carolina Standard Course of Study with particular emphasis on life sciences. Engineering Teaching Fellows designed and implemented hands-on projects to inspire student excitement for learning math, science and technology concepts. MUSCLE partnered Duke University's Pratt School of Engineering with Lakewood Elementary School and Rogers-Herr Middle School in Durham, NC, by placing undergraduate Engineering Teaching Fellows in these partnership schools to help teachers develop and execute hands-on activities that integrate meaningful math exercises into life sciences. MUSCLE Fellows provided expertise in science, math, and engineering, and functioned as positive role models for participating students.

Since 2001, the Techtronics after-school program, sponsored by the Burroughs Wellcome Fund's Student Science Enrichment Program, has placed undergraduate and graduate Engineering Teaching Fellows in the after-school program working with K-12 students at Rogers-Herr Middle School in Durham, North Carolina. Initiated in the fall of 2001, Techtronics seeks to stimulate intellectual curiosity in engineering through exposure to four engineering disciplines: civil, mechanical, electrical/computer, and biomedical engineering. The mature program now includes fully developed lesson plans for two sections of twenty students, Techtronics I for 6th grade and Techtronics II for 7th grade, each led by a graduate student coordinator and five undergraduate teaching Fellows. Emphasis is placed on learning through hands-on experience and creating an environment that encourages inquiry. Students first study applicable scientific theory and are introduced to instrumentation and software tools that will be needed later. Each unit then culminates in the construction of a related project such as balsa wood bridges, Lego robots, AM radios, or heart monitors.

Through these programs, nearly 128 Engineering Teaching Fellows from the Pratt School of Engineering have worked with students in the North Carolina public school system. This paper examines the impacts on Fellows of participating in the programs and how the K-12 Engineering Teaching Fellows programs augment the standard undergraduate and graduate engineering curricula. Specifically, Engineering Teaching Fellows gain important skills, develop an improved grasp of engineering material in multiple disciplines, and develop an appreciation for the importance and challenges of K-12 education.

Recruiting and Selecting Fellows

Engineering Teaching Fellows were recruited using a number of different methods. The majority of Engineering Teaching Fellows in the Duke K-Ph.D. program are upperclass undergraduates with graduate Engineering Teaching Fellows assuming supervisory roles. Fellows were recruited for the Duke-NCSU Engineering Teaching Fellows and MUSCLE programs through advertising in upper level design courses. Interviews ensured that the students selected as Fellows were a good match for the program. Recruiting for the Techtronics program was conducted by word of mouth over the first two years of the program. During the third year of the program, a more formal application and interview process was instituted. There was significant interest in the program as 11 applicants had to be turned away. The process of using an application and interview improved the quality of Fellows admitted into the program but was more time consuming.

The primary purpose of interviewing for all of the Fellows programs is ensuring that the program is a good match for the interested undergraduate. A good candidate for the program is outgoing and enjoys working with elementary or middle school children. It is important that an undergraduate is genuinely interested in working in the school system. To ensure this, during initial years of the Techtronics program, Fellows were not told that the position was a paid position until after they had expressed interest in the program. This proved useful as Fellows who were willing to volunteer for the job were then hired. A problem with this strategy is that students plan to allocate less of their time when planning for a volunteer position than for a paid position. The amount of time students have to offer the program is also crucial to their success as Engineering Teaching Fellows. Interviewing students helps ensure that they have adequate time for productive program participation.

Fellow Trainings

Training in both classroom management and in inquiry-based teaching techniques is important to the success of Engineering Teaching Fellows in the classroom. Training in these two areas has been provided by a number of sources for Fellows in the Duke K-Ph.D. Program. From 1999-2002, it was provided by teachers at partner schools. During the 2003-2004 school year, it was provided by the Duke Center for Inquiry-Based Learning. During the 2004-2005 school year, training has primarily been provided by the coordinators of the Duke K-Ph.D. Program.

The data which follows was based on fellow surveys through the 2003-2004 academic year. On end-of-year fellow-completed surveys surveys, 63 Fellows from all three programs were asked to respond to the statement, "*I learned some effective styles of classroom management*" on a scale of 1 (strongly disagree) to 5 (strongly agree). The average was a 4.0 correlating with a general agreement that they had learned effective styles of classroom management. In general, the Undergraduate Fellows consider the training to be tedious. Fellows responded to the statement, "*The training classes at Duke were helpful*," on a scale of 1 (strongly disagree) to 5 (strongly agree). The average was 3.0, indicating an overall neutral response to the trainings. Fellows often thought that the training was irrelevant or that they already knew what they were being taught. In order for the Fellows to learn something from the trainings, the trainings should be directly relevant to the work they are doing in the classroom. Many of the trainings were for a

combined group of Fellows including those that work in classrooms with teachers in the MUSCLE and Duke-NCSU Fellows programs and those that work in the Techtronics after-school program. In school and after-school lesson planning and classroom management are entirely different and should be treated as such. Additionally, Fellows working with elementary school students were sometimes trained by middle school teachers and vice versa. These disparate groups of Fellows were combined because it was easier and less expensive to combine trainings. Unfortunately, this caused the trainings to be too general for the Fellows, many of whom did not feel they could directly apply much of what they had learned in the trainings to their classes. These problems have been corrected in the latest trainings designed for the new NSF GK-12 Track 2 MUSIC (Math Understanding through Science Integrated with Curriculum) program. Weekly or Bi-weekly meetings are also important to provide ongoing training and guidance to Fellows.

Summative Impacts on Engineering Teaching Fellows

Summative impacts on Engineering Teaching Fellows were assessed through end-of-year fellow-completed surveys. Quantitative data were available from 63 Engineering Teaching Fellows who participated in the Techtronics program from 2001 through 2004, the MUSCLE program during the 2001-2002 and the 2003-2004 school years, and the Duke-NCSU Fellows Program from 2000-2002. Qualitative, open-ended responses to questions on personal development were available for 29 Fellows in the Techtronics and MUSCLE Programs. The surveys were completed by Fellows at the end of each year, included questions about the program, students in the program, and self-reported impacts. The self reported impacts included improved skills in leadership, communication, and time management, improved understanding of engineering principles, and increased appreciation for the importance of education and the need for improved science education in the K-12 classroom. These positive impacts augment the engineering curriculum and provide marketable skills for graduating engineering students.

Skills

Fellows developed a number of important skills through their participation in these outreach programs. In response to the statement, "*My classroom communication skills improved over the course of the year*," students were asked to respond on a scale of 1 (strongly disagree) to 5 (strongly agree). The average response for the 63 students surveyed was 4.3 out of 5 as the majority of students agreed that their communication skills had improved. Only 2 students out of 63 disagreed with that statement.

29 responses from the MUSCLE and Techtronics programs were available to the qualitative, open-ended questions on personal development from the fellow surveys. Table 1 shows categorized responses to the question, "*Regarding your personal development, what skills that you developed will carry over into your post-school life?*" Many Fellows found they developed multiple skills during the program would carry over into their post college lives so the total number of responses is greater than the number of surveys collected in Table 1. Communication, time management and organization, patience, leadership, lesson planning and creativity were the main categories of responses to this open-ended question. Only one respondent stated that he/she learned no skills during the program that would be useful after college.

Table 1) Categorized responses to the open-ended question, "Regarding your personal development, what skills that you developed will carry over into your post-school life?" Respondents included as many skills as they felt appropriate to this open-ended question, so the total number of responses is higher than the number of Fellows who responded to the survey (n=29).

Response Categories	Number of Responses
Communication	17
Time Management and Organization	6
Patience	6
Leadership	5
Lesson Planning and Creativity	4
Nothing	1

A majority of the 29 respondents to the question in Table 1 responded that the Engineering Teaching Fellows program had allowed them to develop their communications skills. Those responses are further divided into more specific categories of communication in Table 2 below. As shown, Engineering Teaching Fellows learn a great deal from the many opportunities they have to practice talking in front of a class and explaining complex concepts in simple terms.

Table 2) Sub-categories of Responses in the Communication Category (based on the question, "Regarding your personal development, what skills that you developed will carry over into your post-school life?" from Table 1.

Communication Response Breakdown	Number of Responses
General Communication Skills	4
Ability to talk in front of a group	4
Ability to explain complex concepts in simple terms	4
Teamwork	4
Facilitation	1

These skills represent important positive programmatic impacts and would be an asset to any career path, particularly engineering, since engineers must be able to communicate their ideas simply to laypeople either inside or outside the companies for which they work. The following Fellow response to the question from Table 1 and Table 2 describes how the programs impact fellows' ability to explain complex material in simple terms and the importance of this skill in industry.

> My skills gathering information from books, classes, and the internet, into something that is understandable and exciting for a less informed audience will undoubtedly help me if I choose to work for an engineering company or if I were to be the liaison presenting information on a product to a potential buyer. In both situations I would need to compile my information so that it is both understandable and attractive.

Skills attained through such Engineering Teaching Fellows programs are especially important in the engineering work environment. In discussing skills learned, another Fellow wrote that the program affected her career outlook because it "served as a solid leadership position which demonstrated hard work, creativity, and self initiative to potential employers." She now has a job with Exxon Mobil.

Improved Understanding of Engineering

Teaching engineering topics requires Fellows to study content more thoroughly than if they were just learning for a class.[12] Through these programs, Engineering Teaching Fellows gain an improved understanding of engineering material both inside and outside of their majors because they are required to rethink material and present it at a level comprehensible to inquisitive young minds. Often, Fellows teach lessons associated with topics covered within their particular engineering discipline. For instance, in Techtronics, Civil Engineering students are generally in charge of the unit on bridge building. To create lesson plans, Fellows must develop an in-depth understanding of these topics.

Fellows also gain an improved understanding of areas outside of their discipline. Fellows interested in areas outside of their discipline are encouraged to learn about those engineering topics and develop project-based curricula covering them. They also work in teams in programs like Techtronics in which, under the guidance of a more experienced Civil Engineering student, a Biomedical Engineering student facilitates a unit on bridge building. The Biomedical Engineering student must learn the topic well enough to be comfortable teaching it in the classroom. Most engineering projects are interdisciplinary and working in teams of Teaching Fellows to develop project-based curricula provides opportunities for undergraduates to work on interdisciplinary projects. For instance, students in Techtronics build solar cars. The project covers electrical engineering in the circuits used, mechanical engineering in transferring energy from the motor to the wheels, and materials science in the semiconductor used to collect electricity from the sun's rays. On the end-of-year self-evaluations for all three programs (63 respondents), Fellows reported that they generally agreed with the statement, *"My understanding of science outside my field of expertise improved over the course of the year*," with an average response of 4.0 on a scale of 1 (strongly disagree) to 5 (strongly agree).

Increased Awareness of the Importance of K-12 Education

Engineering Teaching Fellows also develop an increased awareness of the importance of education and it is hoped that they remain active in the school systems no matter what their chosen career path. Table 3 includes categorized responses by 29 Fellows from the MUSCLE and Techtronics programs for which responses were available to the question, *"How did your experience as a teaching fellow impact your career outlook*?" Some surveys also included the additional question, "*What are your career plans*?" Responses to these two questions were grouped together where available so there are only 29 responses in Table 3, one from each Fellow.

Table 3) Categorized responses to the questions, "How did your experience as a teaching fellow impact your career outlook?"

Response Categories	Number of Fellows (n=29)
Already thinking about being a teacher when they started and still want to be a teacher	3
Considering being a teacher because of the program	5
Planning on a career that does not involve education but this program has caused them to want to stay involved in education in some other capacity	10
Indicated that the program taught them something about themselves that has led them to a career other than teaching through learning about their leadership abilities, engineering, desire to be a pediatrician, or knowledge that they do not want to be teachers.	7
Indicated that the program has not impacted their career outlook	4

As expected a few Fellows were already interested in becoming teachers prior to beginning their work as Engineering Teaching Fellows, but it is noteworthy that 5 of the 29 respondents are considering becoming a teacher because of their work in the program. One Fellow responded, "Simple Answer: I'm now looking at potentially getting involved with Teach for America after undergrad." Additionally, a third of respondents (10 out of 29) plan to stay involved in education in some capacity (tutoring, volunteering, etc.) as a result of their experiences in the Engineering Teaching Fellows program. It was encouraging that 7 of the respondents indicated that the program had taught them something about themselves, helping them make career decisions beyond teaching. This included Fellows who learned that they did not want to be teachers, Fellows whose exposure to engineering through the program encouraged them to be engineers, and Fellows whose leadership experience in the program has led them to pursue careers in management. One Fellow reported, "As for career outlook, I think it made me more excited about engineering and entering the engineering industry." Only four Fellows responded that the program has not affected their career outlook at all. A clear positive impact of the Engineering Teaching Fellows program is that it has influenced the career plans of so many Fellows.

Fellows were also asked if the experience will encourage them *"to be a school volunteer in the future regardless of career*," and if it will motivate them *"to be an advocate for schools*" in their communities. Of the 29 respondents, 23 said they are encouraged to volunteer in the future, 5 said maybe or somewhat encouraged, and only 1 said no. 24 said they are motivated to be advocates for the schools in their communities, 4 said maybe, and only 1 said no. A few open ended responses to these two questions from Fellows are provided below:

Question: *Did this experience encourage you of the need to be a school volunteer in the future regardless of career path*?

- After being a fellow, I have seen the importance of becoming involved in the local community. So many of these kids have a great deal of potential, but it simply doesn't seem like anybody has the time to really sit down and work with them. It doesn't seem like anybody has ever tried to show them that learning is fun, and that the things they are taught in school are interesting and important. Techtronics does this by showing simple principles applied to everyday life. I feel that this is important, and I will continue to work in my local community, perhaps even in schools, to ensure that kids are made aware of how important

learning is.

- To be a school volunteer takes a lot of time but it's definitely very rewarding so in my future career path, I do hope to be able to attend elementary/middle school events to be able to share what I'm doing with students.
  -From a fellow who said that Techtronics has "enhanced her desire to enter corporate America"
- Yes, it most certainly did. A lot of these students lack interest in science and engineering only because they have not really been exposed to the 'cool' and 'neat' things that science has to offer. By introducing the students to these things, we help increase their desire to learn. So I see the need for a Techtronics-like program, and I would like to volunteer for such a program in the future.

Question: Will this experience motivate you to be an advocate for schools in your community? How?

- Yes, schools are lacking in a lot of areas (science, facilities, technology, pay for teachers, etc.) I will continue to advocate policies to improve our schools.
- Yes, so many students don't see the importance of school and learning, but by seeing people that value education, they might change their outlook.
  -From a student who said the program developed no skills and who is going into engineering industry
- I definitely noticed a lot of deficiencies in the school and district. It made me think a lot.
- Yes, I saw how amazing my own education was and would like to make a difference in other schools.

Conclusion

Participation in the Duke Engineering Teaching Fellows programs has provided a number of positive impacts for Fellows. Results from end-of-year Fellows surveys from the Duke-NCSU GK-12 Fellows Program, the MUSCLE Program, and the Techtronics Program have been presented. The programs have improved Engineering Teaching Fellows' skills in leadership, organization and time management, and communication. Of particular importance for engineers, it has provided them the opportunity to practice explaining complex concepts in simple terms. The programs have also provided engineering undergraduates the opportunity to explore material both inside and outside of their disciplines in more depth and to work on multidisciplinary projects. Developing curricula has provided perspectives on material that students might not ordinarily have considered in their engineering classes. Finally, the programs have encouraged fellows to stay involved in the school system after graduation regardless of career path. Some fellows have even been encouraged to become teachers either now or later in life and others are motivated to continue to contribute to education from positions in industry. These positive impacts suggest that Engineering Teaching Fellows programs are useful augmentations to the undergraduate engineering curriculum.

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