Learning through Teaching: A Longitudinal Study on the Effects of GK-12 Programs on Teaching Fellows

Brian E. Gravel, Christine M. Cunningham, Meredith T. Knight, Russell Faux
Tufts University Center for Engineering Educational Outreach/
Museum of Science, Boston/
Davis Square Research Associates

Abstract

In 1999, the National Science Foundation Division of Graduate Education began a new project called the GK-12 program. These grants are awarded to universities to have graduate students and faculty in STEM fields work with teachers, schools, and students to improve STEM education. These grants are also awarded with the mission of educating the future industry and professorial workforce on the culture and importance of K-12 STEM education. Tufts University received its first three-year GK-12 grant in 2000, called "GK-12 Engineering Fellows: A K-12 Resource for Integrating Engineering, Math and Science." The project was awarded a three-year continuation in 2003 under the name "Tufts Engineering the Next Steps (TENS) GK-12." These projects developed a cohort of over 20 graduate students from various engineering disciplines (including computer science), who have worked to infuse engineering into existing math and science curricula in K-12 schools.

The model of GK-12 at Tufts University is one of small team work; one Fellow works with 1-3 teachers--the Fellow serves as a technical resource for the teacher and classroom and the teacher serves as an expert about pedagogy and classroom teaching. The Fellow helps to design engineering activities that align with science and math curriculum frameworks for all grades. The Fellow spends a majority of his/her time co-teaching each class and is therefore exposed first hand to the challenges and intricacies of public education.

Evaluation data collected throughout both Tufts GK-12 projects have suggested an apparent trend in how the Fellows' understanding of teaching and schools changes over the course of their Fellowship. Furthermore, many of the Fellows report improvement in their communication and teaching skills. This paper will investigate further the following hypothesis: Participating in a time-intensive outreach program, where Fellows are teaching science, math, and engineering concepts, helps engineering graduate students to understand public school environments, develop better communication skills, and hone their career plans.

Introduction

The state of STEM education in U.S. public schools could benefit greatly from the deep and sustained involvement of industry, government, communities, and perhaps most importantly from universities and colleges. One way to achieve this is to break down the line dividing K-12 education and collegiate academia and to bring some of the many resources that abound in universities, especially those related to current science and engineering content knowledge, to K-12 teachers, students, and classrooms. At the present time, outreach activities in universities are increasing, which is helping to create and strengthen this continuum. Questions remain, however, as to what constitutes the most effective methods of outreach? If the purpose is not only to benefit schools but also college students, what outreach program models have lasting effects on both?

At the Center for Engineering Educational Outreach (CEEO) at Tufts University, "to do (STEM) outreach" means engaging engineering and computer science in K-12 schools and communities using innovative techniques and pedagogies derived from collegiate curriculum, research, resources, and teaching. We believe outreach to K-12 schools should be the primary civic focus of university community service as education is a primary focus of both institutions. Encouraging university students to do outreach can provide the bridge to K-12 education that is needed, but also benefits college students.

The National Science Foundation released a program solicitation in 1999 entitled, "NSF Graduate Teaching Fellows in K-12 Education," or simply GK-12.[1] Introduced by then director Dr. Rita Colwell, GK-12 is intended to promote outreach and service amongst graduate students in US universities and colleges. The program synopsis reads:

> From the NSF GK-12 Program Solicitation (2004)[1]
>
> *This program supports Fellowships and associated training that enable graduate students and advanced undergraduates in science, technology, engineering, and mathematics to serve in K-12 schools as resources knowledgeable about both the content and applications of these disciplines. Academic institutions apply for awards to support Fellowship activities. Institutions are responsible for: 1) selecting Fellows; 2) partnering with school districts for placement of Fellows in schools; 3) providing appropriate training for Fellows, and 4) designing and implementing an effective mechanism for documenting the outcomes of the project. The Fellows serve as resources for teachers in science and mathematics instruction. Expected outcomes include improved communication and teaching skills transferable to a variety of occupations, and enhanced ability to function within and capitalize on working partnerships and teams for the Fellows, enriched learning by K-12 students, professional development opportunities for GK-12 Teachers, and strong partnerships between institutions of higher education and local school districts.*

The Tufts University School of Engineering received an initial 3-year GK-12 grant in its inaugural year and a 3-year track 2 extension grant in 2003. The second round project is called Tufts Engineering the Next Steps (TENS) GK-12 and works with Malden, MA public schools;

an urban rim school district. The overall philosophy of outreach in GK-12 at Tufts is one of mutual benefit to schools and Tufts students. Fellows serve as a content resource for teachers in the classrooms, working with one or more teachers for an entire school year. Fellows integrate engineering and computer science into K-12 classrooms by developing activities and lessons that focus on the *existing* curriculum; doing so allows for an easier and more sustainable introduction of engineering and computer science concepts in the classroom. Graduate Fellows spend 10 hours per week working in the classroom and an additional 5 hours per week developing curriculum and attending education seminars. These graduate students are not formally trained in pedagogy or educational theory, thus a co-principal investigator from the education department runs a seminar on these topics for the Fellows once a week. A staff of undergraduate Fellows exists to support the efforts of the graduate Fellows, but also spends a smaller number of hours (5) in local classrooms as well.

TENS Fellowships are not limited to one-year appointments, but rather Fellows are encouraged to participate in the program throughout their graduate career. In this model, the Fellow has more time to adjust to the school/classroom environment and thus becomes a better resource for the teacher. Additionally, the skills learned by the fellow (teaching, communication, presentation, etc…) are better developed with greater time spent in the classroom. This model does result in fewer graduate students going through the program, but the benefit to schools and teachers is worth the trade-off in Fellowship volume. Furthermore, the support structure design of TENS allows for a more successful sustainability of engineering and computer science concepts in K-12 classrooms.

Currently in Year 2 of the project, there are nine TENS graduate Fellows working in the Malden Public Schools. Fellows are placed in grades ranging from 1st through 12th and on average, each Fellow works with 3-6 teachers. TENS began with a cohort of 8 teachers who participated in an NSF Research Experiences for Teachers project in the summer of 2003. This initial group served as the partner teachers in Year 1 and Fellows branched out to other teachers throughout the course of the school year. In Year 2, Fellows work with "newer" teachers in the GK-12 program (those who spent limited time working with a Fellow in Year 1), and offer peripheral support to primary teachers from Year 1. This allows for Year 1 teachers to begin using what they've learned in terms of integrating engineering and computer science into their classrooms on their own, with the support of a content resource near by. By placing the responsibility and motivation on the teacher, with support available when needed, there is a better chance these activities and methods will continue after the program's completion in 2006.

There are approximately 120 GK-12 programs across the country, receiving a combined total of nearly $60 million in NSF funding each year. Throughout the four years of GK-12, approximately 1,000 graduate students have held Fellowships. Each site conducts extensive program evaluation about Fellow impacts and benefits, but long-term effects of such an intense service program have been largely ignored, in part because the program is young. In fact, there is a significant amount of K-12 outreach in both academia and industry, yet in general, formal research on the benefits to outreach providers is lacking. National interest and subsequent research on the benefits to college students participating in service-learning projects helps to support the anticipated benefits of the GK-12 program. Although service-learning research

focuses on credit bearing coursework, review of this research literature can provide insight into future research directions on the benefits of the GK-12 model of service work.

Definitions of service learning vary. Bringle and Hatcher (1996) define service learning as, "credit-bearing educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility."[2] According to the American Association of Higher Education (2000), experiential education can range from formal internship/cooperative experiences to undergraduate research experiences, project-based coursework, laboratory experiences, and field trips.[3] Over the last 20 years, a shift in engineering education to include "softer skills" has taken place. These skills include communication, teamwork, leadership, understanding of the diversity of people in engineering, appreciation of the societal impacts of engineering, and an ability to apply these skills in engineering careers. Thus service learning became the vehicle through which many of these softer skills are taught. In fact, the Accreditation Board for Engineering and Technology's (ABET) criteria for engineering programs emphasizes the importance of developing these soft skills. ABET requires, "Engineering programs must demonstrate that their graduates have: (1) an ability to apply knowledge of mathematics, science, and engineering; (2) an ability to function in multi-disciplinary teams; (3) an understanding of the professional and ethical responsibility; (4) an ability to communicate effectively; (5) the broad education necessary to understand the impact of engineering solutions in a global and societal context; and (6) a recognition of the need for, and an ability to, engage in life-long learning.[4] The need for development of non-technical skills in engineering is apparent and supported by the efforts of ABET, AAHE, and even the ASEE Engineering Deans Council.[5] Service learning, as defined above, has proven to be beneficial to students in developing critical thinking skills, problem solving skills, an ability to devise multiple solutions to problems, and students who participate in service learning tend to rate their coursework experience higher than those that do not.[6,7] The benefits of a GK-12 model outreach program should align with the benefits of service learning as they are closely related. The question that still remains is: does the GK-12 style of community service learning results in long-term or lasting effects on softer skills and possibly career direction in students? Thus outreach as a research topic and not simply a subject of program evaluation emerges as a legitimate research direction, arguably separate from the service learning research already conducted.

Evaluation data collected throughout both Tufts GK-12 projects have suggested a trend in how the Fellows' understanding of teaching and schools changes over the course of their Fellowship. This trend correlates to the understanding of societal needs and impacts discussed in service-learning research. Furthermore, many of the Fellows report improvement in their communication and teaching skills. This paper will investigate further the following hypothesis: Participating in a time-intensive outreach program, where Fellows are teaching science, math, and engineering concepts, helps engineering graduate students to understand public school environments, develop better communication skills, and hone their career plans.

Sample & Methods

The data grounding this paper are derived from two studies. First, we conducted a survey of prior GK-12 Fellows, examining long-term effects of intensive outreach work. (The program's longevity of five years provides the outer limit for our time frame.) This instrument was designed based heavily on results from our second study—the annual program evaluations from the GK12 project. Items that Fellows had raised as important or influential in this instrument were probed again in the long-term survey.

Long-term effects of participation in the GK-12 program at Tufts were measured using an online retrospective survey. The survey focused on three essential questions:

- What lasting effects on former Fellows, particularly those related to "soft skills" can be attributed to participation in the program?
- How did participation in the project affect career and research choices of the Fellows?
- Did participation in the GK-12 project result in any ongoing motivations of the Fellows to participate in outreach activities?

The survey was administered via the Web to all former GK-12 Fellows who could be located (N=13). (The majority of these were no longer students at Tufts). The Fellow response rate was 85% (n=11) consisting of 7 female subjects and 4 male subjects. Three of Fellows had pursued PhD degrees, four Masters Degrees and four Bachelors Degrees. The Fellows were drawn from Chemical Engineering (n=4), Mechanical Engineering (n=2), Computer Science (n=3), Environmental Health (n=1), and Environmental Engineering (n=1). During their Fellowships, all Fellows worked in classrooms ranging from grades 3-8. 36% of Fellows (36%) held Fellowships for one year and 64% held positions for two or more years.

Data from the former Fellows surveys were analyzed using simple statistical analysis. Qualitative data were reviewed and open-coded for common thematic responses. The resulting codes have an interrater reliability of 80%, and are presented in Table 2. Numerical results from this study allowed for specific items to be ranked and compared with results of the program evaluation study to outline common trends in impacts and benefits on GK-12 Fellows. This comparison also provided insight into what impacts and benefits made a lasting impression on former GK-12 Fellows.

External program evaluation for the 2003-2004 grant year was conducted by Davis Square Research Associates; Somerville, MA. TENS Fellows were surveyed using a retrospective pre/post survey method with a Fellow response rate of 100% (n=12). The essential question driving the inquiry regarding Fellows was: What is the effect of the GK-12 program on Fellows? Participants were asked to recall their familiarity with key features of teaching and their teaching skills at the start of the year, then again at the end of the year. These data were analyzed using a paired-samples *t*-test.

Results

Former Fellows Study – Impacts of GK-12 on Outreach, Career, and Research

All Fellows (n=11) reported positive impacts regarding their Fellowship positions. Since completing the Fellowship, 27% (n=3) of former Fellows have been involved in outreach activities. However, of those who have not participated in outreach, 100% (n=7) reported that the Fellowship did not diminish interest in outreach and more than half (57%, n=4) have plans to do outreach in the future. Six of the responding Fellows have recently graduated and are less than one year removed from the Fellowship, thus the lack in continued outreach at this point is not surprising.

Regarding career directions as a result of participating in the GK-12 program, four Fellows reported that participation in the GK-12 program had an impact on their career plans. Their responses included:

- "I will more likely consider going into teaching later in my career as a result of my GK-12 experience."
- "Yes. Although I do not currently work in a position where I do outreach and work with children, I focused a significant amount of time searching for opportunities that would have allowed me to continue working with children. I plan on trying to find more opportunities that will allow me to continue my work as a GK-12 fellow in the future."
- "While my immediate career goals have not changed, I am now considering becoming a professor later on in life."
- "Yes. I would like to teach engineering at a university level. My experiences with GK12 exposed me to teaching and education. I enjoy teaching and want to continue doing it."

One Fellow reported no change in career interest as he/she intended to pursue a professorial position prior to participating in the GK-12 project.

One concern often voiced by college academic advisors about the GK-12 is that participation in the program will increase students' time to degree. The majority of our respondents reported the Fellowship had no effect on their academic research (82%, n=9), while two Fellows (18%) reported that the Fellowship increased the length of time it took to complete their degree.

Former Fellows Study – Impacts of GK-12 on Personal Skills

Fellows were asked to rate the degree to which they felt various skills were strengthened by their experience as a fellow. As Table 1 indicates, mean scores for the majority of skill topics were relatively high, with the specific skills impacted the most by GK-12 being working with children, working with teachers, understanding school culture, oral communication, and understanding school culture.

Table 1: Impact on Fellows' Skills (1 = not at all; 10 = a lot)

Mean	
8.4	Working With Children
8.0	Working With Teachers
7.8	Understanding School Culture
7.6	Confidence in Presenting Information
7.4	Explaining STEM Concepts to the General Public
7.2	Oral Communication
7.0	Explaining STEM Concepts
6.9	Working With School Administrators
5.4	Time Management
5.3	Written Communication

These results are further supported by the responses to an open-ended question asking former Fellows to report the three most valuable things learned during the Fellowship. The most common responses with percentages of respondents mentioning them are as follows:

Table 2: Qualitative Responses from Former Fellows

Understanding K-12 Education	%
➢ Teaching Skills	60
➢ Teaching as a Profession	30
➢ Complexity in Education	30
➢ Teaching is rewarding	30
➢ Politics	20
Soft Skills	
➢ Teamwork	40
➢ Realization of Personal Strengths	30
➢ Communicating technical concepts to people of differing backgrounds	20
➢ Presentation skills and methods of teaching	20

Common themes seen in the scored response to which skills were developed (Table 1) and most valuable things learned as a result of participating in the GK-12 program are evident: teaching skills, understanding of school culture and complexity of teaching as a profession, and teamwork with teachers and students. When compared with program evaluation data, these same themes remain.

Program Evaluation Study – TENS GK-12 Program Evaluation

The Davis Square Research Associates report on the TENS GK-12 evaluation yielded results pertaining to impacts on Fellows as a result of participating in the GK-12 program that are similar to results from the Former Fellows study. Fellows' were asked to rank their familiarity with key concepts in the public education system (i.e. school culture, classroom structure, frameworks, etc.), the results are as follows:

Table 3: Changes in Fellows' Familiarity (1=not at all familiar; 5=very familiar)

Mean *before* GK12	Mean *after* GK12	
1.92	4.67*	Massachusetts State Science and Technology/Engineering Standards
2.25	3.92*	Developing university outreach programs
2.73	3.73*	Leading outreach programs such as hands-on activities, presentations, or field trips
2.09	3.91*	Assessing student learning
2.00	3.92*	Developing curricula
2.25	4.00*	Inquiry-based learning
2.92	4.17*	K-12 education system
3.08	4.67*	K-12 classroom environment
3.00	4.08*	Diverse learning styles
2.58	4.33*	Constraints on classroom teachers
1.83	4.58*	Integrating engineering/computer science into (science/math/elementary) classrooms

*Significant at $p<.05$

All areas listed show consistent significant gains in Fellows' familiarity with the topics listed above. In regards to the open-ended responses, DSRA analysis found that Fellows tended to attribute importance to particular personal aspects of the experience.[8] In particular, Fellows consistently cited their newly acquired insights into students and the work of teachers as being of greatest value.

Fellows grew in their appreciation for the complexities of working as a teacher. Consistently, Fellows expressed a heightened understanding of and sensitivity toward teaching students. The Fellows observed their partner teachers conducting lessons in environments that were often limited by a lack of student interest or preparation. The Fellows appeared to have worked hard to overcome these limitations, bringing new and innovative activities to the classroom. This is

consistent with former Fellows who cited understanding the complexity of teaching and students as a lasting impact of the GK-12 Fellowship.

Regarding personal skills, or "soft skills", Fellows' skill development reported in pre/post format are as follows. Fellows were asked to rate how their ability to conduct certain tasks had been influenced as a result of participating in the TENS GK-12 program.

Table 4: Changes in Fellows' Skills (1= not at all able; 5=very able)

Mean *before* GK12	Mean *after* GK12	
2.25	4.33*	Designing a lesson that is appropriate for elementary or middle school students
2.25	4.33*	Teaching engineering/computer science to K-12 students
2.25	4.25*	Leading students in engineering/computer science projects
2.92	4.33*	Communicating with K-12 students
2.67	4.25*	Communicating with K-12 teachers
2.33	3.83*	Classroom management
1.67	2.58*	Engaging faculty or other graduate students in outreach efforts
2.17	4.25*	Linking engineering/computer science to K-12 students' lives
Data unclear	Data unclear	Talking about your own research with people who know little about it

*Significant at $p<.05$

Discussion

The results of both investigations reported herein suggest that GK-12 fellowship positions are a positive experience for the Fellows that have held them at Tufts University. A variety of skills, understanding, and appreciation for K-12 education and teaching have resulted from participation as a GK-12 Fellow and thus the goals for the GK-12 program outlined by NSF and the goals of the TENS program have, at this point, been met. Lasting impacts on Fellows from previous years expose interesting trends as well.

While few former Fellows have engaged in outreach since concluding their fellowship, of those reporting, 37% said they planned to do outreach in the future. Combined with those that have done outreach, 64% of former Fellows plan to do outreach in the future. While NSF and the

TENS PIs would like that number to be higher, many former Fellows have only recently graduated and thus as these individuals establish themselves in their careers we feel this number could increase. Of the 11 Fellows reporting, four said the fellowship altered their career plans, many citing teaching on the K-12 or collegiate level as possible future occupations. While not specifically a goal of NSF or TENS, increased interest in education is a testament to the impact the fellowship has on graduate and undergraduate students.

Regarding skills and lasting impacts, the results from both investigations suggest similar specific skills and knowledge areas are improved as a result of the GK-12 program. Former fellows and those surveyed while currently in a fellowship position report similar personal skills as having benefited as a result of participation in GK-12 activities. Fellows surveyed while involved in the program reported a statistically significant improvement in ability and familiarity with a number of areas as a result of their GK-12 work. The specific skills impacted the most include working with teachers and students, presenting material to diverse groups, and oral communication. Looking specifically at lasting impacts, understanding school culture and appreciation for teaching as a profession appear to stand out in the former Fellows minds. While these scored high in Table 1, the coded qualitative data also shows these topics as lasting impressions as a result of GK-12 participation. And while the skills listed in both surveys were not participant generated, they appear in the open-response questions as well, suggesting validity in the results. Thus the skill development that occurs during a Fellow's work appears, to a degree, to have a lasting impact.

Expected outcomes of GK-12 projects according to NSF include, "improved communication and teaching skills transferable to a variety of occupations, and enhanced ability to function within and capitalize on working partnerships and teams for the Fellows." Looking at the data presented here, GK-12 programs definitely improve teaching and communication skills, while also leaving Fellows with an understanding of school culture and the complexities of teaching as a profession. However, the results presented here are a pilot study with only Tufts University GK-12 Fellows and thus a larger implementation of this study with the nearly 120 GK-12 programs across the country could offer interesting data regarding lasting impacts of time intensive outreach programs.

Conclusion

The TENS GK-12 project is a time-intensive outreach program that impacts the Fellows involved in a variety of ways. The National Science Foundation has clear goals each program should meet pertaining to skill development by the Fellow as well as exposure to certain aspects of the public education system. The results presented here suggest that the TENS project has previously and is currently meeting the goals of developing teaching and communication skills while also exposing graduate and undergraduate students to the reality of public education in this country. Expansion of this research to gauge impacts and benefits of outreach to all college students would provide more information and possibly support the notion that outreach and teaching is of benefit to all students.

This material is based upon work supported by the National Science Foundation under Grant No. 0230840. Any opinions, findings, or conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Bibliography

1. National Science Foundation (2004) *NSF Graduate Teaching Fellows in K-12 Education (GK-12).* Available at the NSF GK-12 website <http://www.ehr.nsf.gov/dge/programs/gk12/>.

2. Bringle, R.G. & Hatcher, J.A. (1996) Implementing Service Learning in Higher Education. *The Journal of Higher Education*, **67**:2, 221-239.

3. Tsang, E. (ed.) (2000) Projects that Matter: Concepts and Models for Service-Learning in Engineering. *American Association of Higher Education Series of Service-Learning in the Disciplines*. Available at the AAHE website at <http://www.aahe.org>.

4. Accreditation Board for Engineering and Technology (2004) Engineering Criteria. Available at ABET website at <http://www.abet.org>.

5. American Society of Engineering Education (1994) *Engineering Education for a Changing World*. A joint project report of the Engineering Deans Council and the Corporate Roundtable of the ASEE. Available at the ASEE website at <http://www.asee.org>.

6. Eyler, J., Root, S. & Giles, D.E. (1998) "Service-learning and the development of expert citizens: Service-learning and cognitive science." In *With Service in Mind : Concepts and Models for Service Learning in Psychology: Contents.* Edited by Robert G. Bringle and Donna K. Duffy. American Psychological Association. Pp 85-100.

7. Markus, G., Howard, J. & King, D., (1993) Integrating Community Service and Classroom Instruction Enhances Learning: Results From An Experiment. *Education Evaluation and Policy Analysis*. **15**:4, 410-419.

8. Faux, R. (2004) *Final Evaluation Report for Tufts Engineering the Next Steps (TENS) GK-12 Project*. Somerville, MA: Davis Square Research Associates.

Biographical Information

BRIAN GRAVEL works as the GK-12 Program Manager at the Tufts University Center for Engineering Educational Outreach (CEEO). He is a former GK-12 Fellow from his years as a Masters candidate, working in 9th and 5th grade classrooms. Brian holds a BS and MS in Mechanical Engineering from Tufts University and is actively pursuing educational outreach into the use of movie making in science, technology, and engineering education.

DR. CHRISTINE CUNNINGHAM works as the Vice President of Research at the Museum of Science, Boston. In this position she oversees research and evaluation efforts related to learning and teaching in the Museum and in K-12 classrooms; a curriculum development project, *Engineering is Elementary: Engineering and Technology Lessons for Children*; and a number of teacher professional development programs about engineering and technology for

teachers of kindergarten through community college. Christine received a joint BA and MA in Biology from Yale University and a PhD in Science Education from Cornell University.

MEREDITH KNIGHT is a research associate at the Center for Engineering Educational Outreach (CEEO) at Tufts University. She is the Program Manager for the Pre-College Engineering for Teachers (PCET) Program and the 4 Schools for Women in Engineering Program.

DR. RUSSELL FAUX is a partner at Davis Square Research Associates in Somerville, MA. He holds an Ed.D. from Boston University.