AC 2007-2277: COMPARISON OF OUTCOMES FOR ENGINEERING AND SCIENCE GK-12 FELLOWS

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Comparison of Outcomes for Engineering and Science
GK-12 Fellows
Abstract

In the National ScienceFoundation's Graduate Teaching Fellows in K-12 (GK-12) programs, graduate students from science, technology, engineering, and math (STEM) disciplines act as school-based resources for K-12 classroom teachers. This study compares how participation in one GK-12 program influenced graduate level students from two different disciplines, Science and engineering. The graduate students, called GK-12 Fellows, were members of a mixed STEM cohort that worked collaboratively in partnerships with middle Science and/or math teachers in their classrooms for one to two days each week over an entire school year.

A number of data collection instruments were employed to capture changes in GK-12 Fellows’ ideas, understandings and perceptions. These included pre and post interviews and surveys, as well as weekly journals and periodic field-based observations. While the surveys focused mainly on ideas and issues related to Science and math education, the other data collection instruments were open-ended, thereby allowing themes to emerge from the data collection and analysis rather than preceding them.

Analysis of the data indicated that participation in this type of outreach significantly improved the GK-12 Fellows’ understanding of contemporary notions of teaching and learning, especially as they relate to Science and math instruction. At the end of the outreach experience the GK-12 Fellows expressed greater confidence in their ability to create and implement problem-solving activities that incorporate math and Science concepts. The GK-12 Fellows also held more complete understanding of inquiry-based teaching practices, as well as improved abilities to help students design and implement their own research projects as a result of this outreach. The outreach also enhanced GK-12 Fellows’ understanding of issues and obstacles related to K-12 Science and math instruction, as well as their stated commitment to outreach in their future professional lives.

The discussion presented here also focuses on how the experience of teaching middle schools students about research influenced the GK-12 Fellows’ own research agendas and their understandings of their own disciplines. This portion of the paper includes an implications component resulting from these findings.

Literature

In 1999 the National Science Foundation (NSF) initiated the Graduate Teaching Fellows in K-12 Education (GK-12) program. This program employs science, technology, engineering, and mathematics (STEM) graduate students, called Graduate Teaching Fellows (GK-12 Fellows), as resources for K-12 Science and math teachers. Since its inception, the NSF has provided over 250 million dollars to sponsor approximately 200 university-based GK-12 projects [1]. This huge investment in public funding represents one of the first major attempts to form collaborative partnerships between university STEM experts and K-12 Science and math teachers working together in the school setting. The NSF's investment is aligned with reform documents that call for STEM
experts and the Science and math education communities to work together to develop the knowledge, reasoning, and thinking skills of Science and math educators [2, 3, 4, 5, 6, 7].

GK-12 projects across the country have foci that vary from Marine Science in Rhode Island to community-based projects in Idaho [1]. The exact nature and scope of GK-12 projects are determined by individual principle investigators; however most follow one of two implementation models [8]. Some projects use an “Exposition Model” in which GK-12 Fellows do presentations in many schools or districts. Other projects follow a “Classroom Immersion Model” where the GK-12 Fellow works directly with one or two classroom teachers and their students over an extended period of time. The NSF’s goals for the GK-12 program include; improved communication, teaching and team building skills for the Fellows; professional development opportunities for K-12 teachers; enriched learning for K-12 students; and strengthened partnerships between institutions of higher education and local school districts [1].

Even though there has been a significant investment in GK-12 programs, research on these types of partnerships is limited. Buck et al. [9] studied how GK-12 programs lead to STEM experiences that are more compatible for women. Thompson, et al, examined the influence that participation in a GK-12 program had on the GK-12 Fellows [10] and participating teachers [11], as well as how participation in a GK-12 project influenced students’ perceptions of the GK-12 Fellow’s discipline [12, 13]. Although informative for those with interest in GK-12 programs, these research efforts generally focused on mixed cohorts of GK-12 Fellows from a variety of STEM disciplines or only GK-12 Fellows from a single discipline. This focus was based on the assumption that participation in GK-12 programs had similar effects, regardless of the discipline of the GK-12 Fellow. Anecdotal evidence led this team of researchers to suspect that there might be differences in how GK-12 Fellows from differing disciplines were influenced by these experiences. This research examined just this set of assumptions by studying a group of Engineering GK-12 Fellows and comparing the effect of program participation to the effects on Science GK-12 Fellows from the same program.

Context

This study focuses on one GK-12 intervention that followed the Classroom Immersion model called the Partners in Inquiry Project (Project Pi). Over the course of one academic year Project Pi partnered five Engineering and seven Science GK-12 Fellows with twelve upper elementary and middle school Science and math teachers. The GK-12 Fellows worked 10-20 hours a week, with the majority of their time being spent in classrooms. The GK-12 Fellows focused on helping the teachers show the application of science, technology, engineering, and mathematics concepts in their instruction. The GK-12 Fellows took one education course each semester designed to help them understand issues related to teaching and learning science and math in middle school. The courses also focused on helping GK-12 Fellows involve students in aspects of research and design as part of this work whenever possible. The GK-12 Fellows’ roles in these partnerships varied, depending on the needs of their teacher partners, however the majority of their activities fell into the categories described below:
Lessons – The most common work of the GK-12 Fellows involved finding, revising, and in some cases creating hands-on lessons and labs for student use. The GK-12 Fellows taught some of these lessons independently but it was more typical that these lessons were co-developed and co-taught by the GK-12 Fellow and the teacher.

Research Presentations – In some cases GK-12 Fellows gave presentation of their own research projects, in others GK-12 Fellows embedded their research topics in lessons. For example, one GK-12 Fellow presented her research agenda that focused on the effects of pollution on Mussel populations during a study of ecosystems.

Resource Gathering – GK-12 Fellows gathered and created materials for use in the classroom. Types of resources ranged from PowerPoint presentations, to sets of trebuchets for student labs, to materials needed to construct homemade speakers from butter dishes.

Extra Curricular Activities – GK-12 Fellows took part in Science and engineering related activities and clubs outside of class. These included such things as science fair and robotics competitions among others.

Data Collection

A number of data collection instruments were employed to capture changes in the GK-12 Fellows’ ideas, understandings and perceptions. These included a pre/post, forced choice, likert-type survey (see Appendix A) as well as pre/post written, open response questions (see Appendix B). Fellows also completed semi-structured, pre and post interviews that were used to verify participants’ survey and open-ended responses as well probe their understanding of related topics (see Appendix C). All GK-12 Fellows also completed weekly journals, and periodic field-based observations/visits were conducted on a random basis. While the surveys focused mainly on ideas and issues related to Science and math education, the other data collection instruments were open-ended, thereby allowing themes to emerge from the data collection and analysis rather than preceding them.

Data Analysis

Appropriate statistical analysis was conducted on all relevant quantitative data. Additionally, initial participant responses on survey items were used to inform the development of future data collection instruments and efforts. Qualitative data were analyzed using the constant comparative methods of Glaser and Strauss [14]. In the qualitative analysis, the various data were first analyzed individually and then collectively to test the validity of developing assertions. The ultimate goal of the data analysis was to determine generalizable patterns that could be attributed to participation in project activities. The variety of data sources (surveys, open-response questions,
interviews, notes, artifacts) permitted the triangulation of data and supported the validity of these findings. Finally, the pre and post profiles were compared to determine the degree of change that could be attributed to project participation.

**Findings**

**Teaching/Schooling**

Across both groups of GK-12 Fellows the consensus was that these experiences left participants better positioned to teach within their respective content areas. Survey data showed positive pre to post change in teaching self-efficacy across several domains. Areas of change included the ability of GK-12 Fellows to engage students in problem solving activities related to math and science, the ability of GK-12 Fellows to develop and conduct inquiry-based activities, and the ability of GK-12 Fellows to challenge students to accept responsibility for their own learning.

Pre-data indicated that both groups of GK-12 Fellows expected to learn how to be better teachers. The notion that this actually took place was supported by post-data analysis which showed that both groups of GK-12 Fellows learned important instructional techniques and strategies that they could employ in their own teaching. This is captured as this Mechanical Engineer talked about what he gained from this program,

> Engineers are introverts by nature. So, they don’t like to stand and talk in front of people, they would rather stick to their books and numbers and leave me alone. But, it (GK-12) makes you an extravert. I think everybody should be having this type of experience. It has definitely helped my ability to teach a lot (Fellow 10, post-interview).

At the same time both groups of GK-12 Fellows also indicated that they learned much more about the context of schooling, which enabled them to better understand public school policies, issues, and controversies. This notion is captured during this post-interview with an Engineering GK-12 Fellow. In response to the question, “What do you feel you’ve gained by doing GK-12?” she stated, “When you see the laws that are passed, that are pressed on teachers, you understand that most people have no idea what is going on in the public school system” (Fellow 9, post-interview).

In addition to gaining a more complete understanding of schools and schooling, several of the GK-12 Fellows spoke about how events that took place in the school impacted them. In some cases this was negative, for example GK-12 Fellows reported that the trauma and emotion of an intense school day or event sometimes left them lacking the energy to conduct their other work related requirements. As stated by a GK-12 Fellow, “It makes for a long intense day to deal with the stuff associated with teaching and then going to do other work. I don’t think most professors realize the kind of work, and intensity of the work, that happens in public schools” (Fellow 6, post-interview).

In some cases the enhanced understandings were positive, as in this example,

> I learned about more than just teaching and learning. I learned more of the stuff you hear in Sociology class. You know, some kids don’t get any knowledge or respect in the class and they feel forced to act out to get it.
That wasn’t something I expected to see or learn (Fellows 8, post-interview).

**Communication Skills**

Both groups of GK-12 Fellows also reported that participation in the program enhanced their abilities to talk about their disciplines with others. The GK-12 Fellows perceived that one of the biggest reasons for this change stemmed from having to regularly explain concepts and ideas to novices.

The biggest thing is taking technical information and being able to bring it down to a sixth-grader’s level. When you’re dealing with a lot of people in the world, you’re going to be dealing with a lot very ‘untechnical’ people. Essentially you’ll have to do the same thing when you talk about your field to others. So, it’s taught me to be able to take what I want to get across and gear it towards my audience a whole lot better than I was able to do at the beginning of the year (Fellow 5, post-interview).

In addition to perceiving that the GK-12 experience helped them to better communicate with those outside of their respective disciplines, GK-12 Fellows also reported that program participation enhanced their abilities to communicate with those within their disciplines. A GK-12 Fellow talked about this during his post-interview,

I learned a lot about presenting information in a logical, coherent sequence so that others can understand it better. This really helped in terms of my research presentation skills. I find myself applying things I learned from teaching in GK-12 to my research presentations (Fellow 11, post-interview).

**Dual Foci**

Both groups of GK-12 Fellows experienced professional tension as they attempted to both learn how to teach and how to conduct independent research. Consistent with prior research [10] these GK-12 Fellows, even those who were successful in both the program and their research, felt tension from two distinct worlds with distinct ideas about what this commitment to teaching would mean. A Science GK-12 Fellow talked about this when asked to share any problems the program had created for him.

I think the only problem that I’ve had is managing, not even managing my time, but balancing. Dealing with my research and the GK-12, as far as preparation, it took a lot of time. Trying to find the time to do the prep work became harder for me because there were so many other things to juggle and to get done in a quality manner (Fellow 8, post-interview).

These two distinct worlds, that of the research lab and that of the secondary science or math classroom, often created conflicts and the GK-12 Fellows had to decide how best to handle these tensions. This notion is captured in this quote from a GK-12 Fellow majoring in Chemistry, “How difficult it is for someone who’s learning, when they are at
their place learning how to do research just to tackle learning how to teach at the same
time” (Fellow 2, post interview).

**Dual Foci in Engineering**

Engineering GK-12 Fellows struggled with the tension created by this dual foci, however
everal of these Fellows felt that the experience of teaching in the GK-12 program
actually improved their ability to conduct research. As stated by one Engineering GK-12
Fellow, “In a sense, when you are doing research, you kind of have to teach yourself
certain things, and then you have to teach other people what you learned. So I guess, in a
sense, it has improved my thinking about research” (Fellow 9).

Another Engineering GK-12 Fellow indicated that he had a high degree of interaction
focused on his research agenda within the school setting, which may have influenced his
research abilities. This is captured here as this GK-12 Fellow talks about interacting with
his partner teacher,

- She will ask me about my research and she was very interested in general.
- So, she would always ask me what was I doing, where was I going, what
  exactly I am trying to do, why I am doing this, what’s the purpose, etc?
- She would ask about my research privately and also encouraged me to
  share with the students as well. Constantly talking about research with
  them has helped me to clarify my own thinking (Fellow 11).

The power of thinking about research and communicating that thinking to a novice group
was also captured here, “It’s just been good for me, to actually get a chance to use that
research that I had and to show it to the kids. It actually helps me to go forward in my
research, myself” (Fellow 12, post-interview).

**Dual Foci in Science**

Most Science GK-12 Fellows saw these types of learning as being distinct with little
overlap that would allow for any crossover or reduction in the cognitive demands this
tension created. This idea is highlighted during this post-interview,

- It’s interesting because it’s two totally different learning types…. You are
  not only trying to investigate new ways of thinking and new ways of
  inquiry for yourself, this is going to be your life. You also have to
  introduce that same thing to others. I mean it is helpful in the sense that
  you going through it and you are trying to show others how to go through
  it. But it’s hindrance and you are frustrated because you’re going through
  it at the same time as well (Fellow 3).

Another Science GK-12 Fellow talked about the time demands and their influence on her
work in the research lab,

- I felt like I was always two steps behind. Prior to GK-12 I always knew
  what was going on in our lab and who was doing what. Just not being
there everyday made me feel like an outsider in my lab when I came back. I also missed out on things in the department (Fellow 4, post-interview).

Engineering Perceptions

One of the major drawbacks for Engineering GK-12 Fellows stemmed from the perceptions others held of engineering, including the partnering teachers. In most cases the perceptions of engineering held by the classroom teachers were as uninformed as those held by the students. An Engineering GK-12 Fellow talked about this when asked to discuss problems she encountered.

Just the past week, he still told the class that I was a scientist. I was like ‘no’. He and I even had this conversation where he said something like ‘you are a scientist’. I said, “I am an engineer”. The he said, ‘It’s the same thing’. That made me wonder, how could I have been in your classroom for a year and you still think it’s the same thing? (Fellow 10, post-interview)

The Engineering GK-12 Fellows saw this as a genuine obstacle to helping students understand engineering and offered some possible remedies. One such suggestion was, “Putting scientists together with an engineer to allow kids to see the differences. I think it would be a good idea, especially in the math class. That would let kids see I use math this way and scientists use it that way. It would let them see a different perspective” (Engineering Fellow 9, post-interview).

Content Match/Understanding

Consistent with prior research [10], both groups of GK-12 Fellows felt that program participation enhanced their understandings of their own disciplines. The GK-12 Fellows, by virtue of their standing in graduate level research labs, have developed expertise in very narrow fields of study. The experience of participating in the GK-12 program forced them to relearn topics they hadn’t studied for some time or learn about them for the first time in order to teach them. At the same time both groups of GK-12 Fellows expressed frustration at the number of topics they were expected to know about and teach that weren’t associated with their areas of research.

Within this project, GK-12 Fellows were placed in both science and math classrooms. All Science GK-12 Fellows were placed in science classrooms, while some Engineering GK12 Fellows were placed in math classes and others in science classes. The type of classroom placement for the GK-12 Fellows appeared to have some influence on the degree to which additional learning was required of the GK-12 Fellows. The Engineering GK-12 Fellows appeared to be better suited to teach in the math classes and placement in these classes resulted in less relearning or new learning. The type of classroom placement also impacted the degree to which the GK-12 Fellows were able to teach about important aspects of their disciplines. As stated by this Engineering GK-12 Fellow, I think I was more effective in the Algebra class. The plant and life science things were interesting, but I had to go out and study up on those
things. Which is not bad but I couldn’t really give them this great story about how this ties into what I do.

Implications

The GK-12 Fellows in this program experienced changes in their understanding that seemed to vary by discipline. Further research will need to be done to examine the sustainability of these changes as well as factors that mediate the changes. These findings also hint that collaborative teaching experiences that emphasize the planning and implementation of inquiry-based instruction and are maintained over a sustained period of time may alter these differing points of view. A new question then arises as to which of these factors or combination of factors -- collaboration, planning, teaching, inquiry-based strategies, or length of collaboration -- most influenced the GK-12s' views. Identifying the pivotal features might streamline the processes of GK-12 involvement in K-12 science and math education by including only those factors that provide the greatest pay-off with the least investment.

These types of studies could also help reduce the pressures experienced by young scientists and engineers attempting to become involved in science and math education while maintaining their current research agendas. In the meantime, conscious attention needs to be given to each of these factors as programs similar to GK-12 are implemented. For example, acknowledging that teachers and young scientists and engineers come to the classroom with different points of view may ameliorate some of the tension.

These findings also highlight the need for the total buy-in by all the parties involved, including those who appear to have the least to gain in the short term, experienced research scientists and engineers. Young scientists should not be placed at risk professionally when they respond to the call for more involvement in schools.

The insights into middle grades science teaching gained through this collaboration appeared to have a positive influence on young Science and engineering researchers. While not yet documented, the potential benefits to students are easy to imagine. Among these potential benefits are increased opportunities to interact with "real" scientists and engineers, with a consequent understanding of who scientists and engineers are and what they do. With so much to gain from these types of collaborations in classrooms, losing them should not be an option for those charged with raising the level of scientific literacy of all Americans.
References
## Appendix A

*Pre/Post Survey*

<table>
<thead>
<tr>
<th>1. Appropriately engage children in problem solving activities that incorporate math and Science concepts</th>
<th>Not yet competent</th>
<th>Competent</th>
<th>Very competent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Conceptualize activities that use math and Science concepts to solve problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. Manage a class using hands-on/laboratory activities</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. Can develop appropriate forms of assessment</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. Construct developmentally-appropriate plans</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>6. Aware of individual differences and needs among students</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. Conduct my own inquiry into authentic questions that emerge from student experiences</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. Conduct interviews with students to investigate naïve conceptions</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>9. Reflect on my own teaching</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>10. Adjust instructional plans to meet student needs</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>11. Use appropriate questioning techniques to facilitate student learning</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. Use computer technology and other instructional media as teaching tools</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. Challenge students to accept and share responsibility for their own learning</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. Identify various investigative forms appropriate for children</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. Design and implement appropriate investigations for children</td>
<td>1</td>
<td>2</td>
<td>3</td>
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Appendix B
Written, Open-Ended Questions

1. One of the highest priorities of current science education efforts is to create students who are able to engage in independent inquiries. What scientific process skills do you think middle school students need to know in order to engage in independent inquiries?

2. Another priority of current science education efforts is the creation of a scientifically literate populace. What does being scientifically literate mean to you?

3. Starting in Kindergarten, the Science Education Standards state that process skills should be embedded throughout content instruction. What does this imply about the way science should be taught?

4. Is it important that students learn the scientific method? Why do you think this?

5. Research and literature on teaching and learning suggests that what a person believes about how people learn influences the way(s) he/she teaches. Briefly describe how you believe people learn content in a meaningful way.
Appendix C

Pre/Post Interview Questions

What is your major?

What are the most important ideas about your discipline that you would like to pass along to your students?

What do you hope to gain from this experience?

What are your biggest concerns about being involved in this program?

Describe your relationship with advisor.

Describe your professional goals.

Do you feel your training as an engineer/scientist/mathematician has prepared you for this experience as a teacher? How?

Ask how they responded to survey question about scientific method.

Do you use the scientific method in your own work?

Is it important that students learn the scientific method?

What is your view of scientific inquiry (what is it)?

How does scientific inquiry relate to the scientific method?

Other questions will stem from program goals and participant responses on surveys.