GK-12 Enhances Teaching Skills of Engineering Graduate Students

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Abstract
The National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) program at the University of South Carolina provides fellowships for graduate students in engineering to serve as content resources in K-12 public schools. During its first year, the USC GK-12 program improved the teaching and communication skills of 11 engineering graduate students, enhanced the ability of 51 elementary school teachers to use engineering applications to teach science, and inspired hundreds of elementary children. This cohort of Fellows included 4 PhD, 5 MS and 2 BS/MS students from the departments of mechanical, chemical, civil, and environmental engineering. The Fall 2001 cohort of 11 teacher partners were from schools that are part of USC's Professional Development School network. The spring 2002 cohort of teachers were from schools that have not traditionally benefited from a relationship with the university. In addition, 29 elementary teachers from across the state participated in the GK-12 Summer Institute for Teachers. During the institute, the Fellows presented to the teachers the best activities that they had implemented during the school year. For most Fellows, this was their first opportunity to teach adults in a formal setting. In a post-institute survey, all of the participants strongly agreed or agreed that the Fellows were good teachers. The comprehensive assessment data indicates that the program is meeting its objectives. This paper focuses on the experiences of the graduate students participating in the program. This includes descriptions of an education course developed specifically for the GK-12 fellows, their in-school activities with two different populations of students and their development and implementation of the GK-12 Summer Institute for Teachers.

I. Introduction

The University of South Carolina (USC) received an award from the National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program[1] to support fellowships and associated training that will enable graduate students in engineering to serve as resources in K-12 schools. USC is one of over 50 institutions funded by NSF through this program. A major objective of USC's projects is to help prepare today's engineering graduate students to be the engineering faculty of tomorrow. To succeed, these future faculty must be prepared to teach to a generation of students that has grown up in a global, high-tech society. To teach these students, they will need better communication and teaching skills, and greater knowledge of cognitive processes that enhance student learning than today's faculty possesses. Two major program goals that address this objective:

1. To develop the science related communication and teaching skills of project Fellows.
2. To develop Fellow's understanding of and the ability to apply principles of cognitive processes that enhance student learning.

This paper includes descriptions of an education course developed specifically for the GK-12 Fellows, their in-school activities with two different populations of students and their development and implementation of the GK-12 Summer Institute for Teachers. Data from a comprehensive assessment process has been used for both formative and summative assessment of the program.

II. Program Description

The first cohort of GK-12 Fellows at the University of South Carolina included four PhD, five MS and two BS/MS students from the disciplines of mechanical, chemical, civil and environmental engineering. Student selection criteria included U.S. citizenship, admission to a graduate program in the College of Engineering and Information Technology, disciplinary knowledge as evidenced by the student's resume and GPA, and a personal statement describing teaching and career interests. Of prime importance was the maturity and personality to contribute effectively to a partnership with a K-12 teacher. As part of the GK-12 program, the graduate student's teaching skills and knowledge were further developed through a four-part educational plan as described below.

Formal Coursework

During their first semester of project involvement, the Fellows participated in a field-based university-credit course developed by co-author Christine Ebert. The course, EDTE 701 Special Topics in Teaching Science, consisted of two facets: formal instruction and practicum. Throughout the semester, the fellows met each week for two hours of formal in-class instruction followed by a two hour practicum. The in-class portion was taught by faculty in the College of Education, while the weekly practicum was supervised by teachers in the Professional Development Schools (PDS). These teachers have years of practice supervising and mentoring people who have no experience working with children in school settings. These master teachers helped to design appropriate field-based experiences for the practicum portion of the course, supervised the Fellows in the elementary schools, and provided feedback to the Fellows as they adjusted to the K-12 setting.

The course focused on pedagogy, communication, teaching principles, cognitive processes and learning styles, matching learning tasks to diverse learners and communication skills. The primary objective of the course was to provide the Fellows with an overview of current, applicable educational theory that could be immediately implemented in the K-12 classrooms. The course goals were met through the combination of the formal training and the practicum. Of substantial importance to the Fellows, the methodologies for educating the K-12 population were consistently expanded to include the similarities and differences for teaching at the university level.

Fall Teacher Partnering
As part of the EDTE 710 practicum and the conditions of their fellowship, the GK-12 Fellows spent 10 hours per week working directly with elementary school teachers and students. During the Fall 2001 semester, the participating schools belonged to the University of South Carolina's PDS network and the Teacher Partners had previous experience working with student teachers and interns. In the elementary schools, the GK-12 Fellows learned from their Teacher Partner role model while they implemented hands-on activities and design challenges that are aligned with state science standards.

Spring Teacher Partnering
For the spring 2002 semester, each trained and experienced Fellow moved to a different elementary school. These schools were not part of the PDS network had not historically benefited from a close relationship with the university. In most cases the teachers had only a few years of experience and/or had not mentored pre-service teachers before. The move to the new schools enabled Fellows to share their expertise with teachers more likely to need help with science and mathematics content knowledge. It also gave the Fellows an opportunity to better understand and appreciate the issues facing K-12 education in South Carolina. But most importantly, by changing teachers, the Fellows were given another role model to help with the development of their own teaching and communication skills.

Summer Teacher Institute
After a full year of in-school service learning with elementary schools students, the Fellows designed and implemented the GK-12 Summer Institute for Teachers. This was a 3-day workshop for elementary school teachers on the USC campus. Each Fellow selected 2 or 3 of the activities that they had developed and implemented during the school year, and taught the twenty-nine participating elementary school teachers how to implement the activity during the workshop. The Institute was the Fellows project from planning through implementation. The PI and coPI approved or disapproved funding for supplies and helped with some of the logistics only when requested. The Fellows designed the workshop syllabus and schedule, prepared the instructional materials, designed the activities, acquired the supplies and instrumentation needed, and taught the teachers. The intended benefits to the Fellows included developing the ability to organize and execute professional meetings, developing the ability to proactively organize teams, and enhancing their professional skills such as leadership, communication, and professional responsibility.

III. Assessment Procedures

Fellow Surveys
Prior to starting the GK-12 program in the Fall 2001 semester, and again at the end of the Spring 2002 semester, a Likert-scale survey was administered to the Fellows. Each survey contained the same 15 items; these were designed to measure the Fellow's perceptions of their ability to teach and of their level of knowledge for teaching and learning strategies. Fellows rated statements regarding their abilities with the subscale: 1 = Not competent, 2 = Some competence, 3 = Competent, 4 = More competent, and 5 = Very competent. For questions regarding knowledge of teaching strategies the subscale was, 1 = Not knowledgeable, 2 = Some knowledge, 3 = Knowledgeable, 4 = More knowledgeable, and 5 = Very knowledgeable.

Fellow Focus Groups
Two focus groups were conducted with the 11 graduate Fellows. The first focus group took place during the Fall 2001 semester, about three months after the Fellows began the program. The second focus group was conducted in the summer of 2002 after the Fellows had completed the GK-12 program year. Each focus group required about one and one-half hour to complete. Prior to the start of a focus group, the purpose was explained and each participant agreed to be audiotaped. This focus group was facilitated by a trained moderator. The moderator asked slightly different questions to the focus group participants in the fall and in the summer. However, in both cases there were 11 open-ended questions concerning the Fellows', teachers' and students' experiences. Each focus group audiotape was transcribed verbatim, then software coded to identify and define issues and themes. All information collected in each focus group was kept confidential and summarized in such a way that individual responses could not be identified.

Research Advisor Interviews
Telephone interviews were conducted with the research advisors of six of the 11 Fellows. This subset of advisors was selected because two of the Fellows were undergraduates and did not have research advisors, two of the Fellows were advised by the project leader Dr. Lyons, and one of the advisors was on sabbatical at the time of data collection. The six advisors that were interviewed could be objective about the GK-12 program and should have good knowledge of its impact on their students. The advisors were asked five questions: (1) Tell me, what do you know about the GK-12 program? (2) Tell me how the GK-12 Fellowship of your advisee is affecting the progress towards his/her degree? (3) Tell me how participating in the GK-12 program is affecting the communication and teaching skills of your Fellow? (4) Would you, as an adviser, encourage other students to apply to the GK-12 program? Why? or why not? And (5) What other thoughts do you have about the GK-12 program? The advisors answers that related directly to the Fellow's teaching and communication skills and to how the participating in the GK-12 program is integrated into the student's program of study are included here.

Teacher Partner Focus Groups
Focus groups were conducted with the participating teachers. The first set of focus group was conducted with the Fall semester cohort of teacher partners and occurred in October, approximately two months after the program began. The second set of focus groups was conducted with the Spring semester cohort of teacher partners and occurred in March, approximately three months after these teachers were assigned Fellows. The size of each focus group ranged from 3 to 6 teachers. The primary purpose of the focus groups was to determine how the GK-12 program was affecting the teachers' knowledge, attitudes, beliefs and behaviors with respect to teaching science and applying engineering problem solving strategies. However, information was obtained that relates to the effect of the program on the graduate student Fellows, also. Such information is included in the results of this paper. Data collection and analysis procedures were identical to that used for the Fellow focus groups.

Workshop Teacher Survey
At the end of the GK-12 Institute for Teachers, the participants were administered a survey consisting of four sections. The first section asked participating teachers to provide demographic information on themselves. In the second section teachers were asked to indicate their level of

agreement for each of nine statements concerning their experiences in the institute. The third section asked teachers to indicate which of 21 available activities they participated in and whether or not an activity they participated in was appropriate for use in their classroom. The last section of the instrument asked teachers to provide suggestions for improving the workshop or any other comments they may have concerning the workshop. Several of the questions from the second section were indicators of the Fellow's teaching effectiveness. The results of only those questions are presented here.

IV. Assessment Results

Goal 1. To Develop the Science Related Communication and Teaching Skills of Project Fellows.

Fellow Survey Results

Seven items on the pre/post fellow survey instrument directly addressed Goal 1. The results for these items are shown in Figure 1, where the bars represent mean values and the lines represent one standard deviation in responses. In all cases, the mean response increased over time. This increase was statistically significant for all items except item 7, as measured by the application of Student's t-test with a 99% confidence level. The results suggest that the fellows' abilities to teach using laboratories, activities, investigations and computer technology was improved though the GK-12 program.

Fall Fellow Focus Group Results

At the three-month focus group, Fellows were asked how EDTE 710 and how being in the elementary classroom helped them develop their teaching and communication skills. All of the Fellows agreed that transferring information learned in EDTE 710 to their assigned school was helpful. For some of the Fellows it was their first opportunity to teach. Those participants said the GK-12 program gave them an idea of whether they would want to be teachers or not. For those Fellows who have had teaching experience, the GK-12 program enhanced their teaching abilities. "It's taught me to ask questions to see if they understand it and what kind of phrasing I should use to explain concepts." For a couple of the Fellows, learning methods in EDTE 710 and then using them in their assigned school helped them teach undergraduates at the college level. "I had to teach an engineering lab, and I could tell. I had to teach it last year, I could tell a total difference. I was more comfortable and I just knew what to do, even though it was on a higher level. You're still teaching to people who don't know what you're teaching them. I was surprised." Another Fellow reported, "I've basically turned the table on them and instead of doing typical college spoon feed them about theory and the procedure, I've taken what we've done in here and said, 'OK let's open this up and let's prepare a divergent exercise and gave them just the theory and what I expected. I gave them a questionnaire later and found that an overwhelming majority agreed with the statement, 'I learned more.' Getting the students involved is a win-win."

Summer Fellow Focus Group Results

At the year-end focus group, each Fellow was asked to discuss how the summer workshop helped them develop science-related teaching and communication skills. In general the Fellows

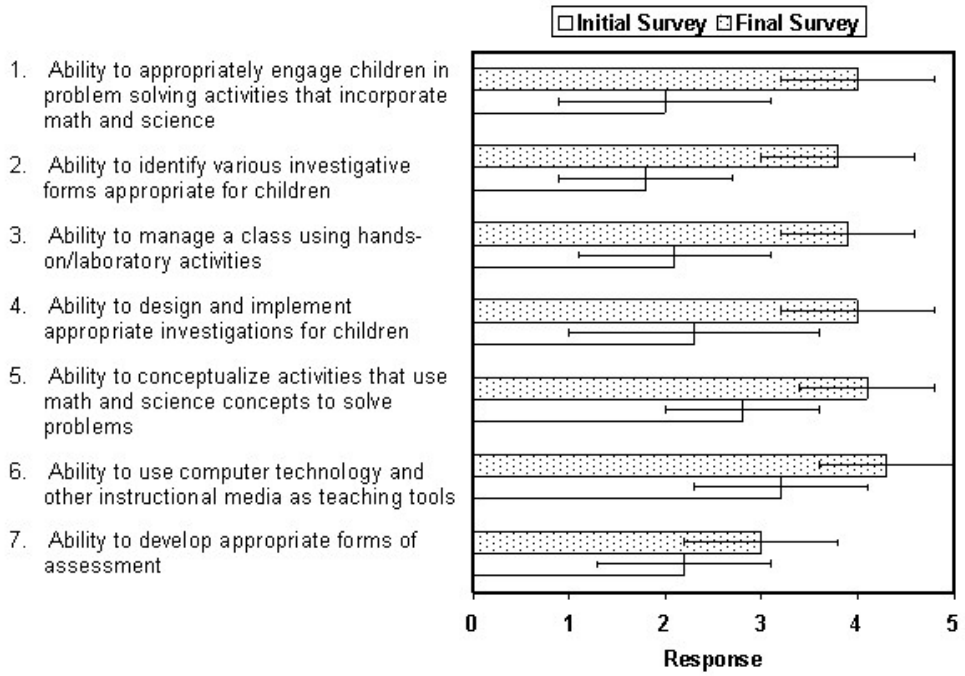

Figure 1. GK-12 Fellow responses to pre/post survey questions related to teaching and communication skills.

thought it was good because it was one of the first opportunities to actually teach adults. They thought it was an opportunity to speak to different audiences and different age groups. One Fellow said, "It sounds kind of silly, but at least you got a chance to show them and see how your experiments work correctly because with the kids it gets a little bit confusing and you don't know if you're getting anything across so at least, I felt fulfilled at the end that at least somebody had learned something by the end." Another Fellow said, "It was nice because you can teach 30 kids, but if you teach a teacher they may teach it for 15 more years so you're getting more impact through that." A Fellow did point out that it was more difficult than teaching the students because the Fellows "didn't have any power over them, for example, being able to take away their recess."

Research Advisor Interviews

In their interviews, the research advisors were asked "Tell me how participating in the GK-12 program is affecting the communication and teaching skills of your fellow." Four of the six advisors believed that the GK-12 program improved their student's communication and teaching skills. They provided comments like "It is improving skills – especially in taking the education communication course" and "He teaches and subs for me in class. He's able to communicate better with the students because of this program." One advisor stated "I think she's getting a lot of strength in both areas. It is also helping her focus on her career choices." The two advisors who did not notice an improvement in their Fellows' communication and teaching skills stated that they were "great to begin with anyway" and "already excellent in her case."

Teacher Focus Group Results

During the teacher focus groups, all teachers described hands-on activities brought to their classrooms by the Fellows that initiated excitement and learning in their students. The teachers all reported that the Fellows consistently mentioned problem solving and higher order thinking such as hypothesizing during the experiments. Some teachers said they could tell that their students could verbalize what was going on in an experiment better than they could before having the Fellow in the classroom. "They may not be able to pass it on a test, but they have a better understanding of what's going on in the experiments now." The Fellows usually went above and beyond what was in the textbook in all subject areas including language arts by relating the lesson back to science and problem solving when appropriate. These are all indicators of fellows' competency in science-related communication and teaching.

Workshop Teacher Survey Results

Several questions on the survey given to participants after the GK-12 Institute for Teachers addressed Goal 1. These survey results are shown in Figure 2, which shows the number of teacher responses in each category for seven of the survey questions. The only scale categories used by participating teachers for any of the survey items were "Agree" and "Strongly Agree" and this is reflected in Figure 2. About 86% strongly agreed the engineering Graduate Fellows were helpful resource experts, and a majority (66%) strongly agreed the engineering Graduate Fellows were good teachers. Most strongly agreed the workshop improved his/her ability to teach science and be able to implement new science-related activities in my classroom. That these evaluation results were from professional educators is an indication that after completing the GK-12 program, the graduate fellows had good communication and teaching skills.

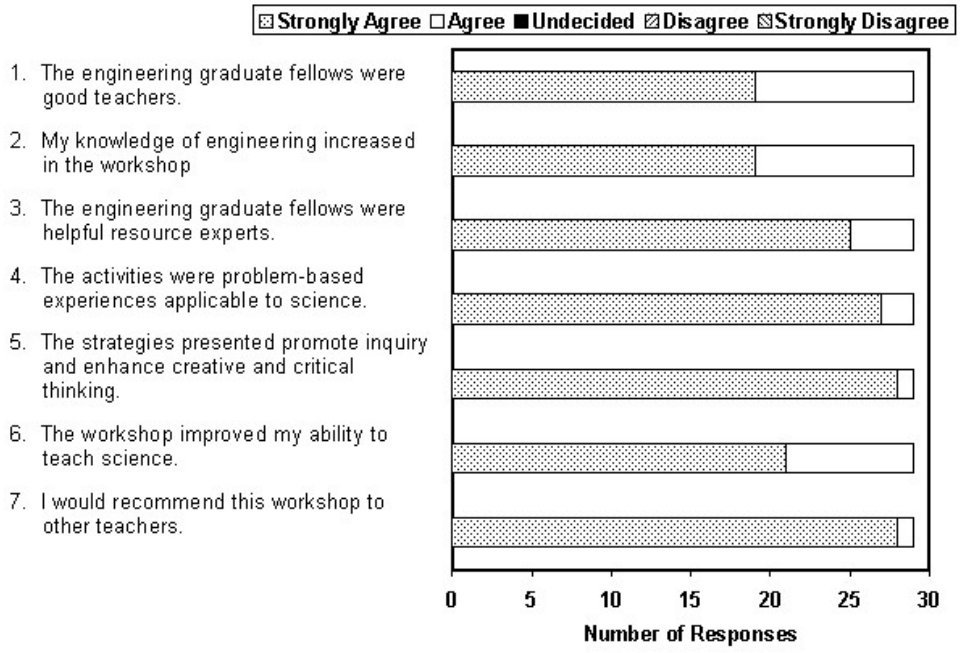

Figure 2. Teacher workshop participant responses to survey questions related to the teaching and communication skills of GK-12 Fellows.

GOAL 2: To develop Fellow's understanding of and the ability to apply principles of cognitive processes that enhance student learning.

Fellow Survey Results

Seven items on the pre/post fellow survey instrument addressed Goal 2. The results for these items are shown in Figure 3, where the bars represent mean values and the lines represent one standard deviation in responses. In all cases, the mean response increased over time. This increase was statistically significant, as measured by the application of Student's t-test with a 99% confidence level, for all items except item 14. The increased ability to use different developmentally-appropriate instructional strategies and an increased awareness of differences and needs among students is an indication that the fellows' understanding of cognitive processes that enhance student learning was increased through the GK-12 program.

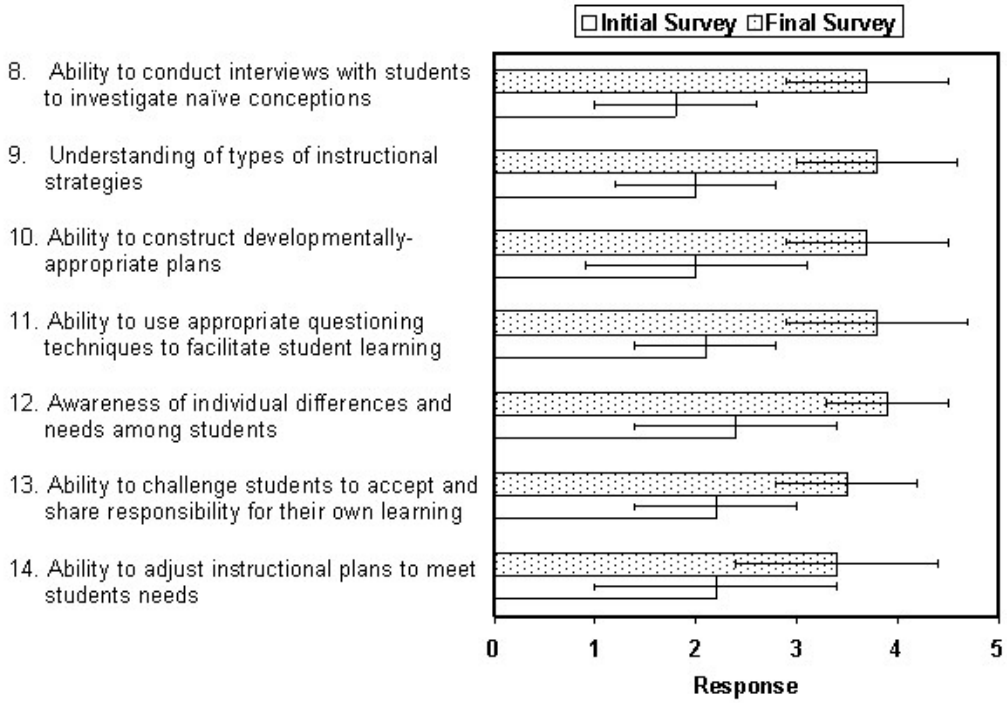

Figure 3. GK-12 Fellow responses to pre/post survey questions related to their understanding of cognitive processes that enhance student learning.

Fall Fellow Focus Group.

At the 3-month focus group, the Fellows were asked questions to determine the extent that they understood and were learning to apply cognitive principles to enhance student learning. The Fellows talked about collaborating with their respective teachers to encourage alternative problem solving through diverse activities with a diverse group of learners. One participant reported being able to "prove to" the assigned teacher that "you don't have to be an engineer or scientist to teach these concepts or the methods we use." Several Fellows reported having an impact on the comfort level of the teacher in teaching something she had a limited knowledge about. Another Fellow reported that because the students' interest in science had increased, the teacher was incorporating science into the other subjects she teaches such as using science as

part of English class – "she does writing assignments based on a science activity that we may have done." Other Fellows reported that their assigned teachers already were comfortable with teaching science, but having the Fellow there made it possible to do more activities and to do more advanced problem solving. Fellows were prompted as to how they knew whether they were teaching at the appropriate level. They cited physical cues that were indicators as to when students were "getting it," and when students were "switching off."

Conclusions

The various forms of assessment data collected and analyzed indicate the GK-12 program has had a positive impact on the graduate student participants. Most notably, there is agreement among Fellows, participating teachers, and research advisors that the program has improved the Fellows ability to effectively educate students. The Fellows all demonstrated an improvement at using laboratories, kinesthetic activities, investigations and computer technology to teach science, math, and problem solving skills. These initial results from the GK-12 program indicate a program that is successfully adding to the development of future university faculty members.

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Biographical Information

JED LYONS is an Associate Professor of Mechanical Engineering at USC and PI on the GK-12 grant. He conducts research on reinforced plastics and composites, develops mechanical engineering laboratories, and improves the teaching and communication skills of graduate students.

JOHN BRADER is a PhD candidate in Mechanical Engineering, researching advanced actuators and mechatronic design. He is the president of the University of South Carolina ASEE Student Chapter and was a GK-12 Fellow.

CHRISTINE EBERT a Professor of Education and the Associate Dean of the Graduate School and Co-PI on the GK-12 grant Dr. Ebert is instrumental in teaching engineering students how to teach.