Exposing Engineering Graduate Students to a Constructivist Approach to Teaching Elementary and Middle School Science

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Abstract

Training and competency are essential attributes of teachers at any societal level; however, most college professors are trained in a technical area instead of the art and science of teaching. Knowing a student's learning style, developmental level, strengths, and weaknesses will help to educate that student in a meaningful way; at the college level, these factors are historically overlooked. Using the microcosm of the engineering departments at the University of South Carolina's Columbia campus, this paper will explore the effects of an education course (EDTE 701 Special Topics in Teaching Science) that is part of an NSF Graduate Teaching Fellows in K-12 Education program. This class is taken by engineering and computer science graduate students that are prospective faculty. It includes practicum teaching experiences in elementary and middle school grade classrooms. The course is compared to the college-wide teaching assistant training and any professional training received by the faculty. The recipients of the various training methods are self-assessed on the basis of competency questions regarding their understanding of their students and teaching itself as opposed to the discipline being taught. This paper will compare these results and will discuss the applicability of teacher training aimed at teaching the elementary grade levels to teaching courses at the higher university level.

1. Introduction

The National Science Foundation (NSF) provides fellowship support to select engineering graduate students at the University of South Carolina (USC) through an award designed to enable these students to serve as resources in South Carolina public K-12 schools. Among the intended goals of the GK-12 fellowship program, such as providing K-12 educators and students with methods for introducing technology and elements of engineering design into their science curriculum, is to provide classroom teaching experience, with an emphasis on learner-centered teaching methods, to future engineering educators.

Those engineering graduate students interested in an academic career have limited options when it comes to preparing to teach the next generation of engineers. These options can include teaching assistantships (TAs) which can be accompanied with a teaching workshop, teaching seminars, and under rare circumstances a graduate course on engineering education that can incorporates lesson-planning and learning theory. The GK-12 fellowship program provides USC’s engineering graduate students experience with developing and implementing lesson plans.
for elementary and middle school science classrooms, as previously mentioned, as well as a course on the constructivist approach to primary science education and a mentorship from a current engineering faculty member through the framework of the course.

The primary goal of this paper is to study and compare the different methods of teacher training available in the microcosm of the engineering departments at USC. This was done by a primary investigation of the types of training available to engineering faculty, teaching assistants, and the unique case of the GK-12 fellows. The means of training were collected via an anonymous survey distributed throughout the engineering departments to the groups specified herein. The secondary goal of this paper is to discuss the results of a self-assessed survey determining the effectiveness of said training in practical teaching situations.

2. Methodology

The various levels of teaching experience at the University of South Carolina, College of Engineering, were assessed by an anonymous survey asking faculty, teaching assistants, and GK-12 fellows to report the training they received to prepare them for active teaching in a classroom environment. The results of this survey are presented along with the self-assessment by the same participants concerning their abilities to actively engage in twelve important aspects of teaching. These aspects are briefly discussed with the results and categories of response from each question. There is also an analysis of the overall response and a discussion of the free response questions asked of each group among the findings presented in 3.1 and 3.2. We received 26 faculty responses, 11 GK-12 fellow responses, and 29 TA responses.

3. Results

3.1 Teacher Training Methods

The first group from the microcosm analyzed was the faculty of the engineering departments. It was a significant pattern that most of the respondents had not received any type of formal teacher training before becoming an active professor. The constant among the responses was the fact that the university did not apparently require or provide any mandatory formalized teacher training for faculty members. Several of the respondents cited outside sources of teacher training.

The nature of the survey did not allow for clarification of responses; therefore, the responses are noted with as much clarity as possible. Two of the professors out of the twenty-six that responded indicated that they had received a small amount of formalized training from conference sessions. Another professor indicated that he or she had previous experience working with a center devoted to teaching excellence in universities; the specific location and center was unspecified. Dr. Richard Felder’s (NC State University) articles were cited by one instructor as a source of teacher training; no specific article was mentioned. The United States Navy was cited as a source of teacher training by one participant as well as unspecified National Professor Training workshops. A unique reference was made to attendance at Provost Teaching Seminars held at USC. USC was also the source of one participant’s formal one-hour training sessions sponsored by AIChe. From this data, it can be concluded that there is no standard program of training required for faculty at USC to be placed in front of the classroom other than
demonstrated knowledge in their particular field of study. There are, however, many references to active supplemental attempts at gathering a greater understanding of teaching as an art and a varied array of organizations and resources from which to acquire that training if one is seeking it.

The teaching assistants at USC receive a two-day workshop on classroom teaching, including sessions on planning lessons, giving presentations, and guidelines on creating assessments. All of the TAs at USC are placed in the same training workshop regardless of area of study. The sessions are generally one hour each and the topics are discontinuous; students are given the option to decide between sessions at various points so that the training is more suited to their field of study; for example, a TA in the field of art education may opt out of the computer lab training session and choose a subject more appropriate to maintaining a classroom as an art studio. Attendance is taken at the sessions to ensure that the TAs attend a required number of sessions to complete the training. Groups of students are sectioned off and given their own faculty mentor for a series of core sessions in which the faculty mentor instructs the students in the techniques by which they handle such things as lesson planning and assessments. The students are given a series of manuals and materials for further study in terms of university policies and an informal guide to teaching.

The respondents to the survey under the teaching assistant category were asked to explain whether the teaching assistant training was beneficial to them in their classroom experience and how it improved their communication abilities. The responses on the question were quite varied; some of the students were highly impressed with the training and felt that it provided them with a great deal of confidence, while some felt that the training did not adequately prepare them for facing the challenges of the classroom. The split was generally even with a significant number of people who did not respond to the question. As far as the benefit of the teaching assistant training, the responses included the following:

“I felt that in my situation I learned about trying to teach people who are older than me”; “It really equipped me with what to expect and prepared me beforehand”

“It gave me elements to work around situations that I have no idea how to deal with. It also gave a new perspective on the principles of evaluating the students; I was completely off on that one”

“The TA training received here was somewhat informative, but not very helpful in preparing for actual classroom interaction”

“I feel that I learned what my short comings are in regards to being a TA. I also developed more confidence in myself as a TA”

“I have already taught, in both middle schools and at two year institutions, so the TA training provided little additional confidence.”

These responses were completely anonymous, and, again, due to the nature of the survey, no clarification on comments could be acquired.
In response to the question about the improvement in communication abilities received at the teaching assistant training, the responses were also varied, but in this case the responses were more heavily centered on the response that the TA training did not offer a substantial benefit in communication abilities. Of the twenty-nine teaching assistants who responded to this survey, only five claimed a benefit in communication ability from the TA training seminar. The general conclusion that can be made based on these responses is that the teaching assistant training is beneficial for helping the TAs to overcome their initial fears and in giving some expectation of what they will face in the classroom; however, the training was not apparently significant among the respondents in improving communication abilities and enlightening them on how to approach the students as individuals or how to utilize the different teaching styles such as questioning and guided exploration. The teaching assistants who responded also gave the following comments and suggestions regarding the TA training:

“I feel that professors could help more out in the training and during the semester. This helped in my ability to communicate to persons that have more experience in what I am doing.”

“My TA training involved several opportunities to conduct recitations independently and work closely with students during office hours. Those experiences have helped me feel very comfortable in front of a classroom. I've also learned from observing my own instructors--both the excellent ones and those that were not as good.”

“I think clarity and fairness are two very important goals that I assumed were easier to achieve but were not. Some things were apparently clear, but in reality were not.”

“Simply going to class and teaching as I have been taught, (in a professional and simplistic manner) an absorbing the experience is the surest learning tool.”

The NSF GK-12 fellowship offers a unique teacher training experience. This program provides graduate students in the various engineering departments the opportunity to experience teaching in a K-12 classroom while receiving the benefit of faculty mentoring and formal training from an elementary education specialist. For one semester, the fellows must enroll in the EDTE 701 Topics / Teaching Science. This course meets for three hours a week and serves the dual purpose of covering teaching methods and providing a forum for the fellows to address the issues that they find with teaching in the classroom. The fellows gain practical experience with ten hours per week in the classroom including a one-hour planning session with their teacher partners; for the 2002-2003 school year, the fellows entered middle school classrooms and for the 2003-2004 school year, the students are in elementary classrooms. One of the goals of this program is for the fellows to share science knowledge and bring new activities to the partnering teachers’ classrooms and for the partnering teachers to serve as an additional guide and mentor for the fellows. For this reason, the fellows change classrooms over the December/January holiday to gain the expertise of another teacher partner.

The EDTE 701 course provides instruction in many of the areas of concern for teaching. These topics are almost always reinforced with a hands-on classroom activity that demonstrates the theory. A notable example was an activity in which the fellows were asked to get into groups of
three to four and combine their ideas for what constitutes whether or not something is alive. The means of combining these ideas was to have a representative write down all of the ideas presented by each member of the group without comment or question. When each person’s ideas were written down, the ideas were discussed within the group to determine themes that occurred throughout the responses. The common ideas were then recorded separately and reported to the entire class. The class responses were then compiled and refined for a set of criteria determining life. This activity demonstrates a means by which the ideas of the entire class are shared without singling out any of the students; the importance of this is to actively involve the shy students within the class and prevent anyone’s response from being argued or chided based on the person presenting the idea. This is one of the techniques by which a greater response level can be achieved using simple techniques; this is representative of the types of activities and topics that are approached in the EDTE 701 course. These activities greatly enhance the resources at a teacher’s disposal for dealing with a classroom of students effectively.

The respondents in the GK-12 category from 2002-2003 and 2003-2004 were asked to provide comments on how the GK-12 program has aided them in the classroom. The most notable of the responses are as follows:

“The program allows me to see first hand the challenges faced by elementary school teachers. I have an opportunity to see how these teachers handle the problems and also to come up with my own solutions. It has also given me a great deal of practice dealing with individuals on different levels.”

“I am now able to read the students so that I may adjust my lesson accordingly. I have had practice breaking down complex concepts into elementary forms.”

“As a TA, I was given an experiment to run in the labs and make sure that the students taking the lab did the experiment correctly. This program has taught me how to expand my thought processes beyond, ‘Are they doing it right?’ I am more apt to use the learning cycle for any activity that I conduct than just a lecture.”

“The meetings with the fellows give me ideas and encouragement. The hands-on practice in the classroom is invaluable. This is a unique opportunity to be in that environment.”

These responses show the effectiveness of boosting the confidence and aiding the thought process associated with presenting a lesson to a class in terms of the teaching process.

The culmination of the GK-12 program is a three day seminar called the GK-12 Institute in which thirty K-12 school teachers are invited to USC to receive training in the most prominent and successful lessons found or developed by the fellows throughout that year. This is a mutually beneficial experience for both the teachers in attendance and the fellows running the institute. The teachers receive the benefit of new lesson plans to utilize in the classroom and the fellows are given the opportunity to test their abilities at providing instruction to a different age group.

3.2 Aspects of Teaching
The following section details the findings of the self-assessment survey according to the aspects of teaching that are considered to be universal among all of the possible student age groups and developmental levels. Each aspect is presented along with the mean results of the survey response for the following groups: faculty, teaching assistants, and GK-12 fellows from the 2002-2003 and 2003-2004 groups. The participants were asked to rate themselves in terms of confidence in each of the proceeding aspects. A rating of 1 would be the lowest confidence and 5 would be the highest level of confidence. The participants were also allowed to select non-applicable as a response, in which case that person’s answer was omitted from the calculation of the mean response.

![Developing Appropriate Forms of Assessment](chart1.png)

**Figure 1.** Mean confidence levels for developing appropriate forms of assessment.

The first aspect under consideration is developing assessments for students. This entails designing means by which the level of understanding of the students can be accurately assessed; tests are only one means of assessment, which is a fact often overlooked on the college level. The response to this question shows that the confidence level of the GK-12 fellows is higher than both of the other respondent groups.

![Recognizing and Correcting Student Misconceptions](chart2.png)

**Figure 2.** Mean confidence levels for recognizing and correcting student misconceptions.

The response to the aspect of recognizing and correcting student misconceptions has the potential to be affected by a lack of understanding in terminology. The faculty and teaching assistants scored higher than the faculty, which may indicate a need for better communication and understanding of the terminology used in assessing student misconceptions.
Conducting inquiries to resolve student questions is an important aspect of teaching in maintaining the students’ confidence in the instructor as an authority on the subject being taught. The results of this aspect are reasonable in that the GK-12 fellows have an understanding of conducting inquiries from the EDTE 701 class and the faculty has a greater means by which to conduct such inquiries than the teaching assistants. The confidence level on this question shows the highest confidence level for any of the faculty responses.

Questioning techniques are one of the subjects that are strongly emphasized in the EDTE 701 course. The “I wonder…” model is given as a starting point for the GK-12 fellows to get their
students involved in asking well-formed questions. There is also an emphasis on the use of different levels of questions to elicit varying responses to meet the needs of the lesson.

### Incorporating Hands-On Activities into Classes

<table>
<thead>
<tr>
<th>Response Groups</th>
<th>GK-12</th>
<th>TAs</th>
<th>Faculty</th>
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</thead>
<tbody>
<tr>
<td>Mean Confidence Level</td>
<td>4.5</td>
<td>3.8</td>
<td>3.2</td>
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</tbody>
</table>

Figure 5. Mean confidence levels for incorporating hands-on activities into classes.

Hands-on activities are often an excellent means by which students can get a better understanding of a concept being presented. Again, the GK-12 fellows are responsible for bringing hands-on activities to the classroom, so it is not surprising that their confidence level in this area would be high. Active participation by students not only keeps them involved in the lesson, it also promotes the most lasting impression of a subject.

### Adjusting Instructional Plans to Meet Student Needs

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<td>4.8</td>
<td>4.3</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Figure 6. Mean confidence levels for adjusting instructional plans to meet student needs.

Adjusting plans to meet student needs is an important aspect of effective teaching. This involves changing teaching styles and the direction of a lesson to allow the students to gain a better understanding of a subject. It may also mean that the lesson needs to be repeated in another way.
Learning is the means by which a student gains knowledge of a subject while teaching is a means of providing information in a meaningful way that a student can comprehend and accommodate it in their understanding of the universe. This is an important distinction that should be made by educators on any level. It can be seen that the GK-12 fellows again have the highest confidence in this aspect.

The GK-12 fellows show a greater confidence in their abilities to discern between student and instructor-centered approaches to teaching. A greater understanding of the differences between the two approaches increases the likelihood that lesson plans can be correctly adjusted; balancing the various learning styles with the course goals.
Using Various Teaching Styles to Reach a Wider Base of Students on a More Meaningful Level

![Bar Chart](image)

**Figure 9.** Mean confidence levels for using various teaching styles to reach a wider base of students on a more meaningful level.

The most commonly encountered teaching style on the college level is lecture, but this is not the only means of instruction. There are many different styles of teaching. One of the most emphasized teaching styles in the GK-12 program is inquiry, in which the students are provoked to explore a subject to gather their own understanding of the matter.

Recognizing When Learning Has Occurred

![Bar Chart](image)

**Figure 10.** Mean confidence levels for recognizing when learning has occurred.

When a concept is the base of future knowledge, it is crucial for a teacher to know when learning has occurred in students. If a basic concept is not well-understood, it can lead to problems with later material that could have been prevented by the recognition that the subject was not initially understood. One means of determining this is by an application in which the students are asked to apply the knowledge that they have acquired.
Reflection is an aspect of teaching that is stressed in the GK-12 program specifically through the completion of reflective journals in which the fellows are required to react to the experiences throughout the week. This applies to both the lessons learned in the EDTE 701 class and the practical classroom experience. This reflection is key to improving the teaching process.

Most of the teachers at the college level are familiar with problem solving. The distinction between problem solving and creative problem solving is that creative problem solving presents an open problem that has multiple solutions. This is important in not limiting the students to the concept of one right answer, something that occurs often in all levels of education.

4. Conclusions

The analysis of the responses presented concludes that the GK-12 program is an effective means of providing teacher training to graduate students. This effectiveness can be traced to its methods for increasing the awareness of, and confidence in, the different aspects of teaching, such as utilizing the various teaching styles. The respondents trained as faculty or teaching assistants demonstrate a lower confidence level in these areas; some of whom may harbor misconceptions regarding concepts discussed. There were several respondents in both the faculty and teaching assistant groups that rated themselves a 1 or 2 in all of the categories. This
was not found in a single entry of the GK-12 fellows. The nature of the GK-12 program gives the participants the benefit of faculty mentoring on the university level and teacher partners at the level of classroom teaching. Dealing with the elementary and middle school classes also prepares the fellows for teaching at different developmental levels. The GK-12 program provides a more extensive training to the participants than the standard USC teaching assistant training seminar partly due to the extended nature of the EDTE 701 class; in terms of the faculty, there is not even a required training seminar at USC in the engineering departments. Awareness and confidence in the twelve aspects analyzed herein demonstrates the overall competence of the GK-12 fellows over other participants in the survey in terms of these areas. While the GK-12 program is aimed at teaching on the elementary and middle school level, it is the understanding of teaching that is the most crucial benefit to the participants in the fellowship program. The art and science of teaching is one that can be extended to any developmental group once a general understanding of teaching is acquired; adjustments must be made in terms of the material presented and the language used for the target group of students. However, one who is skilled at communication can adapt as necessary and present a coherent lesson to any audience.

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6. Bibliography


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