AC 2010-1364: MEASURING CHANGE IN ENGINEERING AND SCIENCE GRADUATE STUDENTS' TEACHING EFFICACY AS A RESULT OF PARTICIPATION IN A GK-12 PROJECT

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Measuring Change in Engineering and Science Graduate Students' Teaching Efficacy as a Result of Participation in a GK-12 Project

Abstract

In the 1990s the National Science Foundation (NSF) introduced the Graduate Teaching Fellows in K-12 Education (GK-12) initiative. The GK-12 program supports the participation of graduate students from STEM disciplines, called GK-12 Fellows, in K-12 Science and Mathematics education. One of the primary goals of the GK-12 initiative is to improve GK-12 Fellows' communication and teaching skills in the hope that these improvements will lead to more effective teaching when GK-12 Fellows matriculate into the professorate. This study examined how participation in one GK-12 program influenced the teaching beliefs and self-confidence (known as *teaching efficacy*) of the participating GK-12 Fellows. Teaching efficacy has been shown to correlate with student achievement, instructional innovation, instructor enthusiasm and persistence, and student interest in school. The GK-12 Fellows involved in this study were members of two different cohorts that worked collaboratively in partnerships with middle school Science teachers. The GK-12 Fellows, from engineering and science disciplines, spent one to two days each week over an entire school year in the middle school classrooms. Their primary objectives in the classrooms were co-developing and co-teaching student lessons focused on science and engineering concepts.

The Science Teaching Efficacy Belief Instrument (STEBI-B) and supporting focus group data were used to measure the GK-12 Fellows' teaching efficacy. The STEBI-B was originally developed by Enochs and Riggs to measure elementary Science teaching efficacy. The STEBI-B has been validated and found to be a reliable instrument for measuring Science teaching efficacy. Since its development, modified versions have been widely used to measure the Science teaching efficacy of various teacher groups. A modified version of the STEBI-B was used in this study. STEBI-B pre and post-study results (25-item survey) were obtained for 23 GK-12 Fellows (13 in 2007-8 and 10 in 2008-9). Pre and post focus group data were also analyzed using qualitative data analysis techniques. The STEBI-B contains two subscales. Personal Science Teaching Efficacy (PSTE) which captures the construct of self-efficacy and Science Teaching Outcome Expectancy (STOE) which measures outcome expectancy regarding Science teaching and learning. A dependent t-test, using an alpha of .05, was computed for the two subscales to determine if there was a significant difference between the mean scores for the pre and post-study surveys.

Key findings include pre to post change on the PSTE subscale, indicating significant change in GK-12 Fellows' science teaching efficacy. At the same time pre to post change on the STOE subscale was found to be insignificant. Discussion in the paper focuses on how the overall improvement in the Fellows' self-efficacy indicates that the teaching experience in the middle schools positively impacted this change. The authors also discuss the lack of significant change found in the Fellows' STOE scores which suggests the Fellows' teaching experience may have negatively impacted, to a small extent, their attitude regarding teaching outcomes.

Introduction

In the 1990s the National Science Foundation (NSF) introduced the Graduate Teaching Fellows in K-12 Education (GK-12) initiative [1]. The GK-12 program supports the participation of graduate students from science, technology, engineering and mathematics (STEM) disciplines, called GK-12 Fellows (Fellows), in K-12 science and mathematics education. One of the primary goals of the GK-12 initiative is to improve Fellows' communication and teaching skills [1] in the hope that these improvements will lead to more effective teaching when the Fellows matriculate into the professorate. This study examined how participation in one GK-12 program influenced the teaching beliefs and self-confidence (known as *teaching efficacy*) [2] of the participating Fellows. Teaching efficacy has been shown to correlate with student achievement [3], instructional innovation [4, 5], instructor enthusiasm and persistence [6], and student interest in school [7].

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-based science, technology, engineering, and mathematics (STEM) experts and K-12 science and mathematics 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 mathematics education communities to work together to develop the knowledge, reasoning, and thinking skills of science and mathematics educators [8, 9, 10, 11, 12, 13].

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 [14]. Some projects use an "Exposition Model" in which Fellows do presentations in many schools or districts. Other projects follow a "Classroom Immersion Model" where the 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].

Literature

Even though there has been a significant investment in GK-12 programs, research on these types of partnerships is limited. Buck et al, [15] 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 participating teachers [16], as well as how participation in a GK-12 project influenced students' perceptions of the Fellow's discipline [17, 18, 19]. Thompson, et al, also conducted several studies focused on how participation in GK-12 experiences impact the participating Fellows [20]. These studies highlighted the mixed impact GK-12 experiences have on the Fellows' time to degree completion as well as the positive impact these experiences have on Fellows' Communication and Teaching skills. This study sought to look more closely at one aspect of the previous research conducting on Fellows, the teaching dimension. Specifically, this paper asked, "How did participation in one GK-12 program influenced the teaching beliefs and self-confidence (known as teaching efficacy) [23] of the participating Fellows?"

One of the primary goals of the GK-12 initiative is to improve Fellows' communication and teaching skills [1] in the hope that these improvements will lead to more effective teaching when GK-12 Fellows matriculate into the professorate. To measure change in teaching skills this study focused on teaching efficacy, a variable often linked with effective teaching and learning [7]. Teaching efficacy is closely associated with a situation-specific construct known as self-efficacy [23]. Self-efficacy beliefs are believed to shape how people think, feel, are motivated and act in any given context which in the case of this study was the science classroom. The degree of self-efficacy a person holds varies depending on contextual factors as well as personal beliefs and self-confidence. Thus, the degree of personal efficacy a person holds will vary depending on how prepared and/or qualified that person is to deal with a given contextual situation. The decision to focus on teaching efficacy was influenced by the fact that it has been shown to correlate with student achievement [3], instructional innovation [4, 5], instructor enthusiasm and persistence [6], and student interest in school [7]. Thus, teaching efficacy was seen as a good indicator of how the GK-12 experiences impacted the teaching skills of the participating Fellows.

To capture Fellows' science teaching efficacy the Science Teaching Efficacy Belief Instrument Form B (STEBI-B) instrument was employed [2]. The instrument has been validated and found to be reliable for measuring science teaching efficacy [23]. Since its development, modified versions have been widely used to measure the science teaching efficacy of various teacher groups. The STEBI-B is composed of the Personal Science Teaching Efficacy Belief Scale (PSTE) and the Science Teaching Outcome Expectancy Scale (STOE). The PSTE Scale reflects a science teacher's confidence in his/her ability to teach science. The STOE Scale reflects a science teacher's belief that student learning can be influenced by effective teaching. A modified version of the STEBI-B was used in this study.

Context

This study focuses on one GK-12 project that followed the Classroom Immersion model called the Partners in Inquiry Project (Project Pi). Over the course of two academic years Project Pi partnered thirteen engineering and ten science Fellows with twenty-three middle school science teachers. The partnerships were located in six different low performing middle schools in both urban and rural locations. The Fellows worked 10-20 hours a week, with the majority of their time being spent in classrooms. The Fellows focused on helping the teachers show the application of science, technology, engineering, and mathematics concepts in their instruction. The Fellows took one education course each semester designed to help them understand issues related to teaching and learning science and mathematics in middle school. The courses also focused on helping Fellows involve students in aspects of research and design as part of this work whenever possible. The 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 Fellows involved finding, revising, and in some cases creating hands-on lessons and labs for student use. The Fellows taught some of

these lessons independently, but it was more typical that these lessons were co-developed and co-taught by the Fellow and the teacher.

Research Presentations – In some cases Fellows gave presentation of their own research projects, in others Fellows embedded their research topics in lessons. For example, one Fellow presented her research agenda that focused on studying the aftermath of natural disasters to improve the design and building of structures.

Resource Gathering – 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 – 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 and Analysis

The same pre-post modified STEBI-B instrument was utilized for both Fellow cohorts. The instrument consisted of 25 attitudinal statements, 13 positively-written and 12 negatively-written. Respondents assign a rating to each statement along a scale ranging from 1 to 5 that is anchored by the following descriptors: *strongly agree* (5), *agree* (4), *undecided* (3), *disagree* (2), and *strongly disagree* (1). After the reversal of the negatively worded items, total scores for each subscale were calculated for each participant group. Dependent t-tests were computed to provide an indication of the difference in the overall Likert scores on the pre- and post-study surveys.

The STEBI-B survey was administered to the Fellows at the beginning and the end of the 2007-08 and 2008-2009 school years. Pre and post-study results were obtained for 23 Fellows (13 in 2007-8 and 10 in 2008-9). Pre and post focus group data were also collected at the beginning and end of each school year.

The STEBI-B contains two subscales PSTE and STOE. Appropriate quantitative analysis was conducted for the two subscales to determine if there was a significant difference between the mean scores for the pre and post-study surveys. The PSTE and STOE subscales of this instrument measure the constructs of self-efficacy and outcome expectancy regarding science teaching and learning. Pre and post focus group data were also analyzed using qualitative data analysis techniques.

Findings

PSTE

The PSTE Scale reflects a science teacher's confidence in his/her ability to teach science. A significant result was obtained when the change in total PSTE scale scores for the Fellows were compared pre to post, $\underline{t}$ (n=23) = 3.54, $p < .002$. The analysis of mean scores (pre = 53.87, post = 57.13) for the PSTE suggest that Fellows had a more positive outlook regarding their teaching skills at the end of project participation than at the beginning. The results also suggest that they developed improved self-confidence in their own teaching abilities after their experience in the middle school classrooms.

Examination of specific items on the STEBI-B shows two dimensions in which the change in the Fellows' teaching efficacy was greatest (See Appendix B for all items scores and frequency distributions). Fellows experienced large gains in their confidence to find better ways to teach science concepts (item mean scores - pre = 4.174, post = 4.652). In pre-survey responses to survey item 2, "I am continually finding better ways to teach science", five (5) Fellows responded that they were undecided while only ten (10) strongly agreed. On the same item on the post-survey no (0) Fellows were undecided while fifteen (15) strongly agreed.

In pre-survey responses to item 5, "I know the steps necessary to teach science concepts effectively", eleven (11) Fellows agreed or strongly agreed with this item. Nine (9) indicated they were undecided. In response to the same questions on the post-survey, twenty (20) Fellows responded that they agreed or strongly agreed with the statement. Only three (3) Fellows indicated they were undecided on the post-survey. These results suggest that Fellows improved their understanding of the steps necessary to teach the science concepts effectively as a result of participating in the program.

This notion of self-efficacy was not lost on the Fellows themselves. Many indicated that participation in the GK-12 Fellows Program resulted in increased teaching efficacy. The combination of outcomes; enhanced communication and teaching abilities, in conjunction with clearer understanding of their research, impacted how they viewed themselves professionally. This idea is captured by this Fellow quote, "It (GK-12 Fellows Program) has provided the means to think critically about how I learn and present new information to others" (Focus group comment).

The growth in Fellows' teaching self-efficacy is important to note. The overall improvement in the Fellows' self-efficacy may indicate that the experience in the middle schools positively impacted this change. It also suggests that the types of experiences described in this article can serve to enhance graduate level students' teaching abilities. As these students move into the professorate the quality of instruction they provide will also be enhanced as a direct result of participation in the Engineering Fellows Program.

STOE

The STOE Scale reflects a science teacher's belief that student learning can be influenced by effective teaching. A non-significant result was found when the change in total STOE scale scores were compared pre to post, $\underline{t}$ (23) = -.82, p, <.45. Analysis of pre and post means scores shows a positive change, (pre = 41.22, post = 42.39), however this change did not reach a significant level. In fact, initial examination of the results appeared to indicate a negative change in Fellows' beliefs related to teaching outcomes. Specifically, there appeared to be a change in beliefs that desirable learning outcomes are the result of specific teaching behaviors. Examination of individual items within this scale seemed to support this notion that the experiences had negatively impacted the participants' belief that good teaching can positively impact learning.

For example, in response to survey item 10, "The low science achievement of some students cannot generally be blamed on their teachers", fourteen (14) Fellows either strongly agreed (3) or agreed (11) on the pre-survey. On the post-survey only nine (9) Fellows still agreed with the statement and none (0) of them strongly agreed. On item 13, "Increased effort in science teaching produces little change in some students' achievement", the results were similar. On the pre-survey eleven participants agreed (10) or strongly agreed (1) while on the post-survey only four (4) participants strongly agreed.

However, when these results were compared with other survey items a slightly different set of beliefs emerged which seemed to be influenced by the context in which the Fellows completed their work. On item 20, "Effectiveness in science teaching has little influence on the achievement of students with low motivation" only four (4) Fellows agreed on the pre-survey. On the post survey six (6) GK-12 Fellows agreed and one (1) strongly agreed with this statement.

As noted earlier the Fellows worked primarily in low-performing schools. In these settings classroom discipline issues were common and many students displayed apathetic attitudes towards school in general. It is the belief of these researchers that the context in which the participants worked influenced their responses to these items. This interpretation was supported by post-experience focus group comments. Several Fellows discussed learning about the inter-workings of the public school system, how to respond to questions, keeping the students on track, and patience. They also discussed what teachers "go through" everyday and empathized with teachers working in high poverty, low-performing schools.

General Findings

Some Fellows indicated that the GK-12 experience helped them fully comprehend some of the basic science concepts. Fellows indicated that they learned or enhanced a variety of skills as a result of their participation in the program. Most Fellows agreed that they learned how to speak about science topics in a more simplified way so that they could explain concepts within the student's level of understanding. As one GK-12 Fellow elaborated about teaching and sharing knowledge with the students, "What good is it if you can't convey it?" The Fellows indicated that they learned how to better organize their thoughts for the presentations. As teachers, they learned the necessity of covering a lot of material in a short time frame and how to make lessons inquiry-based.

Discussion

These findings provide important data related to the professional training graduate students receive related to instruction. It is well known that professors generally receive little training in teaching methods. The lack of teaching pedagogy creates an additional stress on an aspect of doctoral preparation that can not be disregarded if workforce shortages in engineering and sciences are to be resolved. Fellows involved in this work expressed increased confidence and abilities in terms of teaching. The potential of this type of collaboration as a positive factor in this arena should not be ignored. Further, the gains reported are in addition to positive outcomes related to their communication and research abilities previously reported.

This evidence highlights the need to conduct additional studies on these types of collaborations. Many will argue that this type of engagement is not the work that colleges of engineering and sciences should be doing. It certainly is not what is currently valued in university settings. At the same time, the positive outcomes reported here are difficult to ignore. They seem to reveal that what may not be valued in universities may be the very thing that is most beneficial to them, while also most needed in K-12 education.

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Appendix A
Pre/Post Survey

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters.
SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1. When a student does better than usual in Science, it is often because the teacher exerted a little extra effort. SA A UN D SD

2. I am continually finding better ways to teach Science. SA A UN D SD

3. Even when I try very hard, I don't teach Science as well as I do most subjects. SA A UN D SD

4. When the Science grades of students improve, it is most often due to their teacher having found a more effective teaching approach. SA A UN D SD

5. I know the steps necessary to teach Science concepts effectively. SA A UN D SD

6. I am not very effective in monitoring Science experiments. SA A UN D SD

7. If students are underachieving in Science, it is most likely due to ineffective Science teaching. SA A UN D SD

8. I generally teach Science ineffectively. SA A UN D SD

9. The inadequacy of a student's Science background can be overcome by good teaching. SA A UN D SD

10. The low Science achievement of some students cannot generally be blamed on their teachers. SA A UN D SD

11. When a low achieving child progresses in Science, it is usually due to extra attention given by the teacher. SA A UN D SD

12. I understand Science concepts well enough to be effective in teaching Science. SA A UN D SD

13. Increased effort in Science teaching produces little change in some students' Science achievement. SA A UN D SD

14. The teacher is generally responsible for the achievement of students in Science. SA A UN D SD

15. Students' achievement in Science is directly related to their teacher's effectiveness in Science teaching. SA A UN D SD

16. If parents comment that their child is showing more interest in Science at school, it is probably due to the performance of the child's teacher. SA A UN D SD

17. I find it difficult to explain to students why Science experiments work. SA A UN D SD

18. I am typically able to answer students' Science questions. SA A UN D SD

19. I wonder if I have the necessary skills to teach Science. SA A UN D SD

20. Effectiveness in Science teaching has little influence on the achievement of students with low motivation. SA A UN D SD

21. Given a choice, I would not invite the principal to evaluate my Science teaching. SA A UN D SD

22. When a student has difficulty understanding a Science concept, I am usually at a loss as to how to help the student understand it better. SA A UN D SD

23. When teaching Science, I usually welcome student questions. SA A UN D SD

24. I don't know what to do to turn students on to Science. SA A UN D SD

25. Even teachers with good Science teaching abilities cannot help some kids learn Science. SA A UN D SD

Adapted from Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teacher’s Science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

Appendix B

GK-12 Fellows Pre and Post Survey Results

Frequencies and Percentages of Responses

	Strongly Agree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
	N (%)	N (%)	N (%)	N (%)	N (%)
1. When a student does better than usual in Science, it is often because the teacher exerted a little extra effort.					
Pre-study	5 (22%)	9 (39%)	5 (22%)	4 (17%)	0
Post-study	4 (17%)	13 (57%)	4 (17%)	2 (9%)	0
2. I am continually finding better ways to teach Science.					
Pre-study	10 (43%)	7 (30%)	6 (26%)	0	0
Post-study	15 (65%)	8 (35%)	0	0	0
3. Even when I try very hard, I don't teach Science as well as I do most subjects.					
Pre-study	0	0	0	9 (39%)	14 (61%)
Post-study	0	0	2 (9%)	11 (48%)	10 (43%)
4. When the Science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.					
Pre-study	5 (22%)	15 (65%)	1	1	1 (4%)
Post-study	4 (17%)	17 (74%)	2	0	0
5. I know the steps necessary to teach Science concepts effectively.					
Pre-study	1	10 (43%)	9 (39%)	3 (13%)	0
Post-study	5 (22%)	15 (65%)	3 (13%)	0	0
6. I am not very effective in monitoring Science experiments.					
Pre-study	0	0	2 (9%)	13 (70%)	8 (35%)
Post-study	0	0	2 (9%)	13 (70%)	8 (35%)

GK-12 Fellows Pre and Post Survey Results (continued)

7. If students are underachieving in Science, it is most likely due to ineffective Science teaching.					
Pre-study	5 (22%)	4 (17%)	7 (30%)	6 (26%)	1 (4%)
Post-study	0	7 (30%)	8 (35%)	8 (35%)	0
8. I generally teach Science ineffectively.					
Pre-study	0	0	3 (13%)	11 (48%)	9 (39%)
Post-study	0	0	0	12 (52%)	11 (48%)
9. The inadequacy of a student's Science background can be overcome by good teaching.					
Pre-study	8 (35%)	11 (48%)	3 (13%)	1 (4%)	0
Post-study	7 (30%)	12 (52%)	3 (13%)	0	1 (4%)
10. The low Science achievement of some student cannot generally be blamed on their teachers.					
Pre-study	3 (13%)	11 (48%)	5 (22%)	4 (17%)	0
Post-study	0	9 (39%)	6 (26%)	6 (26%)	2 (9%)
11. When a low achieving child progresses in Science, it is usually due to extra attention given by the teacher.					
Pre-study	2 (9%)	16 (70%)	2 (9%)	3 (13%)	0
Post-study	3 (13%)	14 (61%)	5 (22%)	1 (4%)	0
12. I understand Science concepts well enough to be effective in teaching Science.					
Pre-study	13 (57%)	8 (35%)	2 (9%)	0	0
Post-study	16 (70%)	6 (26%)	1 (4%)	0	0
13. Increased effort in Science teaching produces little change in some students' Science achievement.					
Pre-study	1 (4%)	10 (43%)	4 (17%)	7 (30%)	1 (4%)
Post-study	4 (17%)	0	2 (9%)	15 (65%)	2 (4%)

GK-12 Fellows Pre and Post Survey Results (continued)

14. The teacher is generally responsible for the achievement of students in Science.					
Pre-study	2 (9%)	13 (57%)	5 (22%)	3 (13%)	0
Post-study	0	14 (61%)	6 (26%)	3 (13%)	0
15. Students achievement in Science is directly related to their teacher's effectiveness in Science teaching.					
Pre-study	4 (17%)	10 (43%)	5 (22%)	3 (13%)	1 (4%)
Post-study	2 (9%)	12 (52%)	4 (17%)	5 (22%)	0
16. If parents comment that their child is showing more interest in Science at school, it is probably due to the performance of the child's teachers.					
Pre-study	1 (4%)	15 (65%)	6 (26%)	1 (4%)	0
Post-study	10 (43%)	6 (26%)	6 (26%)	1 (4%)	0
17. I find it difficult to explain to students why Science experiments work.					
Pre-study	0	0	3 (13%)	11 (48%)	9 (39%)
Post-study	0	0	0	12 (52%)	11 (48%)
18. I am typically able to answer students' Science questions.					
Pre-study	10 (43%)	11 (48%)	2 (9%)	0	0
Post-study	12 (52%)	11 (48%)	0	0	0
19. I wonder if I have the necessary skills to teach Science.					
Pre-study	0	2 (9%)	7 (30%)	8 (35%)	6 (26%)
Post-study	1 (4%)	0	1 (4%)	12 (52%)	9 (39%)
20. Effectiveness in Science teaching has little influence on the achievement of students with low motivation.					
Pre-study	0	4 (17%)	7 (30%)	9 (39%)	3 (13%)
Post-study	1 (4%)	6 (26%)	3 (13%)	7 (30%)	6 (26%)
21. Given a choice, I would not invite the principal to evaluate my Science teaching.					
Pre-study	0	1 (4%)	5 (22%)	14 (61%)	3 (13%)
Post-study	0	0	0	12	11

				(52%)	(48%)

GK-12 Fellows Pre and Post Survey Results (continued)

22. When a student has difficulty understanding a Science concept, I am usually at a loss as to how to help the student understand it better.					
Pre-study	0	0	1 (4%)	13 (70%)	9 (39%)
Post-study	0	0	0	14 (61%)	9 (39%)
23. When teaching Science, I usually welcome student questions.					
Pre-study	14 (61%)	9 (39%)	0	0	0
Post-study	18 (78%)	5 (22%)	0	0	0
24. I don't know what to do to turn students on to Science.					
Pre-study	0	0	8 (35%)	12 (52%)	3 (13%)
Post-study	0	0	2 (9%)	16 (70%)	5 (22%)
25. Even teachers with good Science teaching abilities cannot help some kids learn Science.					
Pre-study	1 (4%)	6 (26%)	9 (39%)	3 (13%)	4 (17%)
Post-study	0	9 (39%)	7 (30%)	5 (22%)	2 (9%)