The Impact of Reformed Courses on the Science Teaching Self-Efficacy Beliefs of Preservice and Inservice Elementary Teachers

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Abstract

The purpose of this study is to examine the impact of reformed undergraduate science courses developed through NASA Opportunities for Visionary Academics (NOVA) on elementary teachers' science teaching self-efficacy beliefs. In addition, this study examines subsequent relationships among participating inservice elementary teachers' science teaching self-efficacy beliefs, beliefs about their own and ideal science teaching practices, and observed science teaching practices. Eighty-five elementary teachers, 38 university faculty, and 190 undergraduate students from across the United States participated in this study. Data were collected during intensive on-site visits using the Reformed Teacher Observation Protocol (RTOP), semi-structured interviews, and the Science Teaching Efficacy Beliefs Instrument (STEBI-A). From the data set, eight case studies of inservice elementary teachers were examined in closer detail.

Results indicate that participants' levels of science teaching self-efficacy beliefs were both positively and negatively impacted by the reformed courses. Participants reported that they gained more confidence in their ability to teach science effectively from courses that (a) explicitly connected the science content to the teaching of that content, (b) gave students opportunities to teach the content to others, and (c) sparked students' interest in the content. Reformed courses may have influenced some individuals to have lower levels of self-efficacy by making them realize how much they do not know about science teaching. A clear relationship was not evident between science teaching self-efficacy and reformed science teaching; teachers with high STEBI scores were just as likely to be observed teaching in a reformed manner as teachers with low levels of self-efficacy. However, interviews and observations revealed additional possible relationships between self-efficacy and teaching and how levels of efficacy beliefs manifested themselves in different ways with different teachers. This study demonstrates the importance of using qualitative data to support quantitative data when studying self-efficacy beliefs of teachers and mechanisms for increasing efficacy.

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Introduction

Beliefs play a critical role in influencing the instructional practices of teachers (Pajares, 1992; Philipp, 2007). Therefore, if we are to improve the way that science is taught at the elementary level in the United States, we must understand which beliefs, and how these beliefs, impact the ways in which elementary teachers implement instructional strategies in their science lessons.

One set of beliefs that has been consistently linked to teacher behavior in a variety of educational fields is that of teacher self-efficacy (Tschannen-Moran, Hoy, & Hoy, 1998; Wheatley, 2005). In fact, a positive correlation is so generally accepted between the level of science teaching efficacy beliefs and effective science teaching practices, that the increase of preservice teachers' science teaching self-efficacy has been promoted as a primary goal of science teacher education (Brand & Wilkins, 2007). However, other evidence suggests that this positive correlation does not always hold true. A clearer understanding of not only the development of science teaching self-efficacy, but also how the relationships among elementary teachers' science teaching self-efficacy beliefs, their beliefs about science instruction, and their actual science teaching practices is needed in order to effectively and positively influence the ways in which science is taught at the elementary level.

Science Teaching Self-Efficacy Beliefs: An Overview

This study examines self-efficacy beliefs through a lens based initially in social cognitive learning theory (Bandura, 1982, 2001), further developed for the examination

of teacher behavior by Gibson and Dembo (1984) and of teachers of science by Riggs and Enochs (1990).

In general, teacher efficacy beliefs refer to beliefs about the level of confidence individuals have in their ability to influence student learning through their teaching behaviors. This construct is composed of two specific kinds of beliefs, corresponding to the two components of Bandura's (1982) model of efficacy: Personal Teaching Efficacy and Teaching Efficacy (Gibson & Dembo, 1984). According to Dembo and Gibson (1985), *personal teaching efficacy* is an individual's "belief that he or she [personally] has the skills and abilities to bring about student learning" (p. 175). *Teaching efficacy* beliefs, in contrast, are the beliefs of an individual related to teachers' abilities, as a general group, to influence student learning, or the extent to which students will learn if a teacher teaches effectively.

The construct of science teaching efficacy beliefs, introduced by Riggs and Enochs (1990), is different from general teaching efficacy beliefs in that it refers specifically to beliefs about the level of confidence individuals have in their ability to influence student learning related to science. Similar to general teaching efficacy beliefs, this construct is composed of two specific types of beliefs: Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). *PSTE* refers to a teacher's belief in his or her own ability to effectively teach science, while *STOE* reflects the extent of a teacher's belief that, if teachers provide appropriate science instruction, then their students will learn.

Self-Efficacy and Science Education Research

Since its introduction by Riggs and Enochs (1990), the construct of science teaching efficacy beliefs has developed into a popular area of research in science education, particularly in exploring the beliefs of preservice elementary teachers. In examining the related research literature, there seems to be sound reason for this popularity; a long history of evidence exists suggesting a positive link between efficacy beliefs and teacher behavior, both for general and science teaching efficacy beliefs. For example, research has demonstrated that teachers with low general teaching efficacy beliefs expect students to fail and place the responsibility for learning entirely on the student rather than the teacher (Ashton, 1984; Ashton & Webb, 1986). In addition, teachers with high general teaching efficacy beliefs have been shown to (a) spend less time engaged in discussion unrelated to the objectives of a lesson (Gibson & Dembo, 1984); (b) be more open to new ideas and more willing to try new instructional techniques (Allinder, 1994; Guskey, 1988; Scribner, 1999; Tschannen-Moran & McMaster, 2009); (c) employ a larger amount of planning and organization for their lessons (Allinder, 1994); (d) have greater enthusiasm for teaching (Allinder, 1994); and (e) are more committed to teaching as a profession (Caprara, Barbaranelli, Steca, & Malone, 2006; Coldarci, 1992; Klassen & Chiu, 2010).

Since 1990, researchers have seen similar evidence connecting science teacher efficacy beliefs to science teaching behaviors. For example, Czerniak and Shriver (1994) found significant differences between preservice elementary teachers with high and low self-efficacy in their choices of instructional strategies for science lessons and the ways that they measured success of a science lesson. Specifically, high-efficacy teachers tended to choose activities in which they expected students to use higher-level thinking

and problem-solving skills, and were more likely than low-efficacy teachers to use teaching strategies that were based on research or theory. In addition, Czerniak and Shriver found that the teachers with high science teaching self-efficacy were oriented toward the goals of developing students' critical thinking and decision-making skills, and tended to measure success of their science lessons by whether or not they believed these goals were achieved. In contrast, the teachers with low science teaching self-efficacy tended to measure success of a science lesson by their ability to control students and to keep the class orderly and quiet. Preservice elementary teachers with high science teaching self-efficacy have also been shown to be more likely to claim that activity-based instruction, in which students learn through cooperation and experience, is the most appropriate method of teaching science at the elementary level (Enochs, Sharmann, & Riggs, 1995).

Research regarding inservice elementary teachers has also suggested a positive correlation between science teaching efficacy beliefs and reformed teaching practices. Haney, Lumpe, Czerniak, and Egan (2002), for example, found that elementary teachers with higher Personal Science Teaching Efficacy (PSTE) scores

> were more likely to design lessons that: incorporated inquiry, depicted careful planning, attended to student prior knowledge and experiences, attended to issues of equity, utilized appropriate and available resources, encouraged a collaborative approach, and assessed students in a way that was consistent with the intended purpose. (p. 179).

The authors also found that, as compared to their colleagues with lower PSTE, these high-efficacy teachers were "more likely to convey science content appropriately by presenting content that was: significant and worthwhile, developmentally appropriate, accurate, dynamic and interdisciplinary in nature, and tied to the real world" (p. 179).

Other evidence suggests that inservice teachers with higher levels of science teaching self-efficacy (a) claim to ask more open-ended questions; (b) do a better job of connecting science content to students' lives (Riggs, Enochs, & Posnanski, 1998); (c) teach more science per week (Desouza, Boone, & Yilmaz, 2004); (d) report using more hands-on activities (Marshall, Horton, Igo, & Switzer, 2009; Ramey-Gassert, Shroyer, & Staver, 1996); and (e) exhibit more positive attitudes toward science education reform (Czerniak & Lumpe, 1996).

Evidence from research such as that cited above demonstrates science teaching self-efficacy to be a potentially powerful construct influencing the ways in which elementary teachers teach science. Therefore, if we are to improve elementary science education, it is relevant and worthwhile to examine in greater detail how science teaching efficacy beliefs develop in teachers, and how we as science teacher educators can positively influence those beliefs (Brand & Wilkins, 2007).

The NOVA and NSEUS Programs

The NOVA (NASA Opportunities for Visionary Academics) program was established in 1996 and supported by the National Aeronautics and Space Administration to reform science courses for preservice elementary teachers (Sunal et al., 2001). The reasoning behind this project was that in order to reform elementary science education we must reform the undergraduate science education of elementary teachers. Among the many goals of the NOVA project was that undergraduate science courses taught in a reformed manner would help to increase preservice elementary teachers' science teaching self-efficacy, thus making their science instruction more effective when they entered the classroom.

Teams consisting of STEM (science, technology, engineering, and mathematics) and teacher education faculty, along with administrators from universities nationwide participated in the NOVA project to help reform undergraduate science content courses experienced by preservice elementary teachers. Following professional development, team members worked with a NOVA mentor to develop an action research funding proposal designed to establish a new course or extensively reform an existing course. As a result of the NOVA project, 167 reformed undergraduate science courses have been established at 101 universities across the United States.

In 2006, the National Study of Education in Undergraduate Science (NSEUS) project was funded by the National Science Foundation (NSF) in order to examine the short- and long-term impacts of the established reformed courses on undergraduate students and inservice elementary teachers (Sunal et al., 2009). Over the span of the last five years, the NSEUS project has collected a significant amount of data nationwide regarding various ways the reformed courses have potentially impacted elementary teachers and their teaching of science. Due to the apparent important influence of science teaching self-efficacy on science teaching practices, NSEUS has collected qualitative and quantitative data regarding this construct, including surveys, artifacts, interviews, and observations. The study presented in this paper examines some of these data in an attempt to explain many of the important ways reformed courses, such as those developed through the NOVA program, influence the development of preservice and inservice elementary teachers' science teaching efficacy beliefs.

Beyond the Impact of Reformed Undergraduate Science Courses on Self-Efficacy

While research results suggest that it is important and worthwhile to examine the potential impacts of undergraduate science courses such as those developed through NOVA on the science teaching self-efficacy of elementary teachers, further evidence indicates that this one factor alone does not tell the entire story.   Although there is a great deal of evidence suggesting the important influence of science teaching self-efficacy beliefs on science teaching practices, several under-addressed issues in the related research indicate that the intricacies of the relationships between these beliefs and practices are not clear.

Several inconsistencies exist in recent research suggesting that higher self-efficacy does not always lead to more effective teaching (Wheatley, 2005). For instance, although Haney et al. (2002) found that, for five out of the six teachers in their study, greater self-efficacy scores correlated with more reformed science teaching practices. The one participant who did not follow this pattern demonstrated high self-efficacy beliefs but observations and interviews revealed that her science teaching strategies were primarily teacher-centered and lecture-based with little to no use of inquiry. Similarly, Settlage, Southerland, Smith, and Ceglie (2009) and Bhattacharyya, Volk, and Lumpe (2009) noted that, although the preservice elementary teachers whom they studied had relatively high levels of science teaching self-efficacy, the teaching behaviors of several subjects demonstrated a relatively low level of reform. Kind (2009) also observed that preservice secondary science teachers did a *better* job of choosing appropriate instructional strategies for scientific topics that they felt *less* confident teaching.

Unfortunately, much of the current research regarding science teaching self-efficacy beliefs has depended on quantitative and self-reported data. Due to the limited

number of studies examining the relationship between inservice elementary teachers'

self-efficacy beliefs and their observed, as opposed to self-reported, teaching practices

(Haney et al., 2002; Riggs et al.,1998), many aspects of the relationship between science

teaching self-efficacy and science teaching behaviors of practicing teachers remain

unclear. In order to be meaningful, future research about science teacher efficacy beliefs

should include interview and observational data to support data derived from quantitative

survey instruments (Pajares, 1992; Perkins, 2007; Wheatley, 2005).

It is clear that additional research is needed not only on the potential factors

impacting science teaching self-efficacy beliefs, but also on the intricate relationships that

potentially exist between these beliefs and science teaching practices, both perceived by

teachers and observed by researchers. Thus, in the study presented here we take the

research a step beyond simply examining the influences of the reformed courses on

science teaching self-efficacy by exploring how inservice elementary teachers' self-

efficacy beliefs translate into their observed classroom practices and their self-described

beliefs about those practices.

Purpose of the Study

The purpose of this study is to examine the impact of reformed undergraduate

science courses developed through the NOVA program on elementary teachers' science

teaching self-efficacy beliefs. Specifically,

- to what extent did the reformed courses impact elementary teachers' science

  teaching self-efficacy beliefs?

In addition, this study examines subsequent relationships among participating elementary teachers' science teaching self-efficacy beliefs, beliefs about science teaching practices, and observed science teaching practices. Specifically,

- to what extent do the science teaching self-efficacy beliefs of participating inservice teachers relate to these teachers' beliefs about ideal and personal science teaching, and observed science teaching practices?

Methods and Analysis

Participants

As part of a multiyear NSF-funded project, the National Study of Education in Undergraduate Science (NSEUS), a sample of 19 universities was selected by random stratification based on institutional type from the national population of 103 NOVA-participating institutions. The selected sample of universities includes a variety of Carnegie classifications and represents a wide geographic region, encompassing Alabama, Alaska, California, Texas, Massachusetts, Michigan, Connecticut, Oklahoma, Kansas, North Carolina, Wisconsin, Virginia, Idaho, West Virginia, and Indiana.

At each of the 19 selected universities, a course developed through the NOVA program (*reformed course*) and a course of comparable subject and academic level that was not developed through NOVA (*comparison course*) were identified. Data were collected from the instructors and students in each of these courses. In addition, at every site four to seven inservice elementary teachers (approximately 50% who took the reformed course and 50% who did not) were recruited to take part in the study through coordination with a faculty member at the university acting as a NSEUS research associate ($n = 85$).

Data Collection

During the course of the NSEUS project, an intensive weeklong site visit was conducted at each of the 19 universities, including: (a) observations and interviews of the two identified undergraduate science course instructors; (b) focus group interviews with students enrolled in each of the two identified undergraduate courses; and (c) observations and interviews of each of the four to seven identified inservice elementary teachers. In addition, a variety of surveys were given to participating undergraduate students and elementary teachers.

The overall data set collected by the NSEUS project is large and designed to answer a variety of research questions, many of which are not the focus of the research presented here. For this reason, only the data relevant to answering the immediate research questions are discussed.

Observations

Using the Reformed Teacher Observation Protocol (RTOP; Sawada and Pilburn, 2000), at least two trained project researchers observed minimally one full class session for each undergraduate course, and the science lessons taught by the elementary teachers. In cases of university courses where lecture and lab were separate, both were observed. Observed undergraduate class sessions ranged in duration from one to three hours, while observed elementary school lessons lasted 25-85 minutes. The content and strategies for all observed lessons were decided by the instructors and teachers.

Immediately following each observation, project researchers individually rated the observed lesson on each item of the RTOP and then discussed all ratings. Overall, the interrater reliability was approximately 90%. In the cases where there was a discrepancy

between researchers' ratings, a consensus was achieved through discussion. In cases of undergraduate courses where lecture and lab were observed separately, researchers agreed on a combined score, treating the two together as one complete class session.

Interviews

Semi-structured focus group interviews were conducted with four to six undergraduate students in each class following the observed undergraduate course sessions. During these interviews students were asked questions regarding how they felt their undergraduate science courses, the observed course in particular, had influenced their beliefs and attitudes toward science as well as their scientific knowledge. Students were also asked questions regarding their confidence in their ability to become an effective science teacher and the factors influencing that level of confidence.

Following each elementary classroom observation, a one-on-one semi-structured interview was conducted with the elementary teacher lasting approximately 30-40 minutes. During these interviews, participants were asked a variety of questions regarding their beliefs about science teaching in general, how they believe they teach science in their classroom, and what factors they felt had influenced their beliefs. Teachers were also asked questions regarding their backgrounds such as, how many years they had been teaching and at what grade levels, whether or not they had been involved in specialized teaching, what courses they had taken as undergraduate students, and the extent to which they had participated in professional development. In addition, elementary teachers were asked a series of questions regarding the observed lesson (e.g. goals of the lesson, rationale for the strategies used, mechanisms for assessment, etc.).

STEBI-A

Following the onsite visits, each elementary teacher completed the Science Teacher Efficacy Beliefs Instrument form A (STEBI-A; Riggs and Enochs, 1990). This survey was used to determine the level of Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) for each participant.

Data Analyses

Impact of NOVA Courses on Participants' Science Teaching Self-Efficacy

From the 85 inservice elementary teachers from which data were collected, 66 completed the STEBI (35 who were students in the reformed courses and 31 who were not). A preliminary test for the equality of variances indicated that the variances of the two groups were not significantly different for the overall STEBI (F = 0.881, p = 0.35), nor for the separate constructs of PSTE (F = 1.107, p = 0.39) and STOE (F = 0.680, p = 0.14). Therefore, a two-sample t-test was performed that assumes equal variances.

To determine the extent to which the reform level of the reformed courses potentially influenced the self-efficacy of the elementary teachers who took those courses, Pearson's correlation coefficient was calculated between the STEBI scores of the elementary teachers and the RTOP scores for the reformed courses in which they were students. Because it was unknown which university courses the comparison elementary teachers took, a correlation was not calculated for this group.

In addition, in order to examine some of the specific factors that participants perceived as influencing their science teaching self-efficacy, elementary teacher and undergraduate student interviews were analyzed qualitatively to uncover themes in

participants' responses regarding their confidence in teaching science. Data were examined by multiple coders in order to establish inter-rater reliability (90%).

Relationships Among Participants' Self-Efficacy, Beliefs about Science Teaching, and Practice

In order to determine whether a quantitative relationship existed between participating elementary teachers' science teaching self-efficacy and the level of reform in their observed teaching, STEBI (PSTE and STOE) and RTOP scores were plotted and a Pearson's correlation coefficient was calculated between the two. In addition, the correlation between STEBI and RTOP scores was examined in relationship to several different demographic factors of the teachers in order to determine whether any of these factors seemed to influence the relationship between science teaching self-efficacy and observed science teaching practices for this group of teachers. These factors included gender, years of teaching at their current grade level, years of teaching experience overall, amount of professional development, and number of science content courses.

Out of the 85 inservice elementary teachers from which data were collected for the NSEUS project, four at each of the extremes of high and low STEBI scores were examined more closely. Of these eight case profiles, 50% had high RTOP scores and 50% had low scores. Case profiles of all eight teachers were examined and coded according to themes to provide a more detailed picture of relationships among science teaching self-efficacy beliefs, beliefs about science teaching, and practices of the inservice elementary teachers in this study. Again, data were examined by multiple coders in order to establish inter-rater reliability (90%).

Results

The results are presented in two parts, addressing each of the two research questions for this study.

To what extent did reformed courses impact elementary teachers' science teaching efficacy beliefs?

Overall STEBI, PSTE subscale, and STOE subscale scores were slightly lower for teachers who took a reformed undergraduate course than for those who did not take the course (Table 1). However, these differences were not statistically significant.

Table 1. Comparison of STEBI, PSTE, and STOE scores for participating teachers

	n	STEBI	PSTE	STOE
Reformed Course Teachers	35	$M = 72.34$ $SD = 20.13$	$M = 36.20$ $SD = 14.42$	$M = 36.14$ $SD = 7.39$
Comparison Teachers	31	$M = 79.52$ $SD = 21.16$	$M = 42.97$ $SD = 13.62$	$M = 36.55$ $SD = 8.82$

Based on observations, the 38 participating undergraduate courses varied widely in their application of reform-based teaching practices; RTOP scores for the observed reformed class sessions ranged from 40-90 out of a possible 100 points. Therefore, in order to determine whether the elementary teachers who experienced a greater level of reform in their reformed courses had higher levels of science teaching self-efficacy than those who experienced less reform, a Pearson correlation was conducted between STEBI (PSTE and STOE) scores of the elementary teachers who were enrolled in the reformed courses and the RTOP scores of the reformed courses that they took. This comparison revealed no significant relationship between the RTOP scores of undergraduate reformed

courses and the STEBI, PSTE, or STOE scores of the elementary teachers who took those courses.

While there was no statistically significant difference between the two groups, qualitative data from interviews with undergraduate students currently enrolled in the courses and with inservice elementary teachers who completed these courses revealed several factors believed by participants to influence their science teaching self-efficacy. Factors cited by undergraduate students as influencing their confidence in science teaching focused primarily on aspects of the undergraduate science courses they had experienced so far, while the factors discussed by inservice teachers covered a variety of areas and experiences.

Factors Influencing Preservice Teachers' Self-Efficacy

Results from focus group interviews with undergraduate students enrolled in reformed and comparison courses indicate that students in 47.4% of the focus groups ($n = 38$) gained more confidence in their ability to teach science in courses that explicitly connected the content to how to teach it and/or gave students an opportunity to teach the content to children or to one another. Examples of students' quotes expressing this idea are:

> *We get to do it and experience it instead of just her telling us. She's modeled it for us so we have the confidence to model it for our kids.*

> *Getting some experience in teaching science in this class, to the other students in the class and to elementary kids, has made me more confident that I can teach science.*

For students enrolled in undergraduate courses that did not offer experiences such as these, several students stated that they had more confidence since they had experiences

teaching science to others outside of class, such as in a summer camp or tutoring situation.

Undergraduate students in 71.0% of the focus group interviews also stated that they were more confident teaching content that they enjoyed learning about in their courses and/or content that they were "passionate" about. For example, students stated

> [I can't become an effective science teacher] until I gain interest in it. I can't teach it if I don't like it.

> I was worried that if I ever had to teach science I wouldn't be interested in it. But now I'm not afraid of it. This class helps me think about the concepts in the minds of my students. Now if I had to teach science I think I could be enthusiastic about it.

Undergraduate student focus groups (55.3%) also stated that overall they were more confident teaching science content areas that they had taken more courses in and/or had more content knowledge about. In several cases, because the reformed course was the only science course that they had taken, some individuals reported that they felt most confident to teach the content area(s) covered in that course alone.

In the case of 23.7% of the focus groups, students expressed that some of their undergraduate courses in which they had very positive experiences and learned a great deal about science education actually make them feel less confident to teach science. In these cases, students explained that the courses had made them realize how much they did not know about learning and teaching science, and while a majority of students who expressed this opinion thought that they could become effective science teachers in the future, they did not yet feel confident in their current abilities.

Factors Influencing Inservice Teachers' Self-Efficacy

During one-on-one interviews, inservice elementary teachers were asked what science content areas they felt most or least confident teaching and why. Of the 77 teachers who described their reasons for confidence or lack thereof, there were a variety of reasons cited (Table 2). The contributing factors to participants' confidence were not mutually exclusive, and in many cases teachers' cited a combination of factors interacting together to influence their perceived ability to teach particular areas of science. For example, one teacher stated:

> *In college, I learned that science lessons need to be big and involved with big experiments. That really intimidated me. Now, thanks to [a colleague] I realize they don't always have to be. She's taught me a lot about how to teach science and now I like it. It makes me feel a lot more confident that I can do it. I can teach science.*

The factor of "personal interest in the topic" seemed to be particularly connected to other factors. For example, teacher participants explained that if they are interested in a certain scientific topic, they are more likely to seek out additional knowledge on that topic from university courses, professional development, colleagues, and/or other sources.

In addition, approximately half of the teachers (46.8%) described their undergraduate courses as being related to one or more of the factors contributing to their confidence. For example, teachers described undergraduate science courses as providing or not providing content knowledge and/or pedagogical content knowledge, promoting or dissuading interest in the content matter, and/or making certain topics in science seem "basic" or "complicated."

Table 2. Reported reasons for levels of confidence to teach particular science content

(*n* = 77)

Reason (in descending frequency)	% Teachers	Example(s)
Amount of knowledge regarding the content	54.5	I have a degree in biology with a minor in physics so I feel pretty secure in my ability to teach all content areas of science. I like to be very knowledgeable about my topic, and if I don't feel confident in it then I won't do it unless I was able to go back to school and learn more and be confident.
Personal interest in the content	41.6	I feel most confident teaching biology because it's my passion. I feel least confident teaching physical science because I just never liked it.
Amount of experience teaching the content	40.3	I feel comfortable with what I am teaching now since I have taught it for four years. I guess [science] is a little intimidating. I'm not really familiar with the subject, not like with reading or something else that I've taught more.
Judgment of whether the content was "basic" or "complicated"	24.7	I feel prepared to teach pretty much everything at this level because it's all pretty basic. I don't feel comfortable teaching physics because it's just so complicated.
Grade level teaching	20.8	At least at the third grade level, I think I'm pretty comfortable teaching out of the science book. I think I understand everything that a third grader would know. For what I'm teaching I'm prepared, but if I was going to teach another grade level, I would definitely take those classes so that I could learn what to do.
Amount of pedagogical content knowledge regarding the content	14.3	I know kind of where they are and what the problems are going to be as they get through the topic. I just don't know how to bring it down to a 1st grade level.
Perceived role of standards and/or mandated curriculum	14.3	I'm pretty confident about what the pacing guide tells me, to direct me to teach. I'm going to have left that to the experts to decide that.
Support from others (colleagues, university faculty, and/or others)	11.7	A fellow teacher has been a good mentor. He empowers me to be confident in teaching science. I feel most confident teaching chemistry because my wife is a bio chemist, so she serves as an extra resource for me.
Student reception of the content	10.4	I feel really confident teaching about space because the kids just love it.

To what extent do the science teaching self-efficacy beliefs of participating inservice teachers relate to these teachers' beliefs about general and personal science teaching and the reasons for these beliefs, and observed science teaching practices?

Quantitative Data

Elementary teachers' STEBI scores ranged from 38 to 111 (out of a possible 125 points). Within the total STEBI, PSTE scores ranged from 13 to 63 (out of a maximum 65 points) and STOE scores ranged from 18 to 51 (out of a maximum 60 points). RTOP scores for all elementary teachers ranged from 23 to 92 (out of a maximum 100 points). Analysis of quantitative data revealed that there was no correlation between STEBI (PSTE or STOE) scores and RTOP scores. Inservice elementary teachers with high science teaching efficacy levels as measured by the STEBI were just as likely to be observed teaching in a reformed manner as teachers with low self-efficacy.

This lack of correlation between STEBI and RTOP scores remained even when taking a variety of other factors into account, including gender, grade level, total years of experience, years of experience at current grade level, number of science content courses, and extent of professional development. The only groups of teachers for which a statistically significant correlation could be found were (a) those teaching 6th grade and above (correlation between STOE and RTOP scores: $r(7) = 0.80$) and (b) those who had taken three or more undergraduate science courses (correlation between PSTE and RTOP scores: $r(4) = 0.86$). However, the number of teachers in each of these groups (nine and six respectively) is small.

Table 3. Characteristics of case profile teachers

Teachers	One	Two	Three	Four	Five	Six	Seven	Eight
Score Designation	High STEBI / High RTOP		Low STEBI / High RTOP		High STEBI / Low RTOP		Low STEBI / Low RTOP	
Total STEBI-A*	105	103	45	42	100	95	44	57
- **PSTE**	- 58	- 63	- 21	- 15	- 52	- 54	- 17	- 24
- **STOE**	- 47	- 40	- 24	- 27	- 48	- 41	- 27	- 33
RTOP**	81	82	84	92	54	48	37	29
Reformed vs. Comparison	Reformed	Comparison	Comparison	Reformed	Comparison	Comparison	Reformed	Comparison
Gender	Female	Female	Female	Male	Female	Female	Female	Male
Type of School	Private	Public	Public	Public	Public	Private	Public	Public
Grade Level	2nd Grade	3rd Grade	2nd Grade	6th Grade	4th/5th Combo	3rd Grade	6th Grade	4th Grade
Total Years Taught	3	1	21	4	11	3	1	4
Years Taught at Current Grade	3	1	16	2	1	3	1	1
Science Background	Several undergraduate science courses for preservice teachers	Extensive	Few undergraduate science courses (did not remember)	Extensive	None	Few undergraduate science courses	Four undergraduate science courses for preservice teachers	Four required science courses as an undergraduate
Science Education Background	One science teaching methods course	Extensive (Currently earning her M.S. degree in science education)	None	Extensive (Has an M.S. in education with a focus on science)	None	One science methods course	Two elementary science education courses	One science methods course
Professional Development	Some	Extensive	Some	Extensive	None	Some	Some	None

* Maximum possible score is 125 for the total STEBI-A, 65 for PSTE, and 60 for STOE.

** Maximum possible score for the RTOP is 100.

Elementary Teacher Case Profiles

In order to examine potential reasons for this apparent lack of a quantitative relationship between science teaching efficacy and reformed science teaching, eight teacher case profiles were examined, which included detailed notes and transcriptions from the teachers' observations and interviews. The overall specifics of these case profiles can be found in Table 3.

In examination of the eight teacher case profiles, several key themes related to teacher beliefs interacting with self-efficacy and science teaching behaviors emerged: (a) their meaning of "hands-on"; (b) level of classroom control; (c) ongoing university faculty support; (d) beliefs about provided curriculum; and (e) availability of resources. These themes, discussed in the following sections, help to explain the differences in the manifestation of high or low reform-levels in observed teaching with such disparate levels of self-efficacy.

The Meaning of "Hands-on"

All eight teachers expressed "hands-on" to be the best way to teach science at the elementary level. However, the teachers varied greatly in their description of what the term "hands-on" means to them and, in turn, the ways that "hands-on teaching" was manifested in their observed lessons. In addition, teachers' beliefs about the meaning of "hands-on" impacted not only the ways that they were observed teaching science, but also the beliefs about their own efficacy as teachers of science.

The two teachers who had low RTOP scores and high STEBI scores (Teachers Five and Six) both felt that they were teaching science the way that it should be taught, in

a "hands-on" manner. However, observations and interviews revealed that both of these teachers had images of effective activity-based science teaching that were very different from those of science education researchers. Teacher Six, for example, described working with computers and having her students answer simple questions on the SMART Board as "hands-on" and "interactive." Since she felt confident in her ability to integrate technology into her science lessons due to professional development workshops, she felt that she was teaching science effectively. Unfortunately, her observed lesson showed that her activities involved little to no complex student thought or interaction, and actually perpetuated misconceptions about the science content. Similarly, Teacher Five described her lesson in which her 4th and 5th graders blew bubbles as "hands-on," the kind of activity that she "should really be doing all the time for science." Although her students did use their hands to conduct an activity in her observed lesson, little student thought or reflection in connecting the activity to the science content was apparent.

On the other end of the spectrum, all four teachers with high RTOP scores described "hands-on" science in a more inquiry-based context, one much more closely aligned with current national science education guidelines (Huffman et al., 2008; NRC, 1996, 2000). In their observed lessons and in their own descriptions of the ways science should be taught at the elementary level, these four teachers stated that students should be given the opportunity to discuss scientific topics among themselves, make and test predictions, and investigate the answers to their own questions. The differing levels in self-efficacy among these teachers seemed to be primarily due to personal reflection of the effectiveness of their ability to use inquiry in their classrooms; although all four teachers with high RTOP scores had views of effective science teaching that coincided

with those of the science education researchers, the two teachers with low STEBI scores seemed to be much more concerned as to whether or not they were implementing inquiry in their classrooms effectively. Teachers Three and Four (high RTOP scores and low STEBI scores) stated that their biggest barrier in planning and teaching science was finding the best ways to effectively implement inquiry-based instruction in their classrooms while appropriately assessing student learning and understanding.

The two teachers with low RTOP scores and low STEBI scores were mixed in their description of hands-on science teaching. Teacher Seven had a view that was similar to Teachers Five and Six, describing her observed teaching strategy as "hands-on note-taking" in which students silently copied notes into "foldables" that she directed them to make out of construction paper. She believed that this strategy was demonstrative of good teaching practices since the students were "using their hands to learn about science." On the other hand, Teacher Eight's description of ideal science teaching was much more related to the ideas of teachers with high RTOP scores. However, due to his lack of classroom control and his desire to keep his students quiet and orderly, Teacher Eight expressed a helplessness to enact his beliefs about effective science teaching in his own classroom, resulting in low confidence in his ability to effectively teach science and low levels of reform in his observed science teaching.

Classroom Control

The two case profile teachers with low RTOP scores and low STEBI scores seemed to be very concerned with keeping tight control of their classrooms. Teacher Seven, for example, spent a great deal of time during her observed lesson correcting

student behavior and keeping students quiet. Even more extremely, Teacher Eight was very uncomfortable with his inability to "control students' excitement in science." He spent a majority of his lesson unsuccessfully trying to keep his students quiet and orderly. Due to his lack of control during science activities in his classroom, Teacher Eight seemed to feel little confidence in his or his students' ability to engage in inquiry-oriented activities in the classroom. Consequently he much preferred that his students be engaged in activities such as silent reading, where the students could more easily be kept quiet. ("It's so nice and quiet. Reading time is so much better than science time.", *RTOP Notes for Teacher Eight*)

All four teachers with high RTOP scores, on the other hand, regardless of STEBI scores, were more concerned about the learning needs of their students and not as concerned about "messiness" or behavioral issues.

As in several of the other themes, the two case profile teachers with low RTOP scores and high STEBI scores were mixed in their focus on classroom management. Teacher Five seemed comfortable with student-student interaction, although this interaction was ultimately orchestrated by the teacher and focused primarily on social skills rather than science content. In contrast, Teacher Six kept things quiet and orderly during her observed lesson, discouraging student talking unless she called upon them.

Ongoing University Faculty Support

During their interviews, all four teachers with high RTOP scores described the ongoing support they received from local university faculty through coursework, professional development, and/or personal contact. In three of these cases (Teachers

One, Two, and Three) this interaction was with faculty members who had participated in the NOVA program. One difference that existed between the two teachers out of the group with high STEBI scores and the one with low STEBI scores is the extent to which university faculty members served as mentors to them. That is, both teachers with high RTOP scores coupled with high STEBI scores (Teachers One and Two) had ongoing personal relationships with local NOVA faculty members who provided them with encouragement and support. This seemed to not only boost these teachers' beliefs in their own ability to teach science, but also provided them with continuing resources and guidance to help them teach science more effectively. For the two teachers who had high RTOP scores but low STEBI scores (Teachers Three and Four), university faculty had provided the resources and support to teach science but not at a high level of personal encouragement.

Beliefs about Provided Curriculum

Several of the case profile teachers with varying RTOP and STEBI scores differed in their attitudes toward and beliefs about science curricular materials provided (or not provided) by their school districts. These attitudes impacted teachers' confidence in their ability to teach science and, to some extent, the strategies they used to teach science in their classrooms. For example, in some instances teachers felt that district-mandated kits positively influenced their ability to teach science, although this was not evident in observations of their science lessons.

In one specific example, Teacher Seven, who had low RTOP and STEBI scores, felt limited by the fact that she did not have the district-provided activity kits for science

that the lower grades at her school did. Because of this, she felt that she lacked materials and guidance that would be helpful for her to teach science effectively. Teacher Five, who had low RTOP and high STEBI scores, seemed to feel empowered by the curricular materials she was given despite the fact that she had virtually no science background. She felt that these materials gave her direction by telling her what she should be teaching, thereby boosting her confidence even though her observed lesson revealed low levels of reform. ("I read what I have to do and then I do it……'m pretty confident about what the pacing guide tells me, to direct me to teach……I'm going to have left that to the experts to decide that……" *Interview Transcript for Teacher Five*)

In contrast, teachers with high RTOP scores who used district mandated kits or other curricular materials treated these materials in a different way. Teacher Two, for example, who had high RTOP and STEBI scores, used district-mandated kits, but it was not the driving force of her science instruction. Instead, she seemed comfortable adapting the curriculum and taking the pieces that best served her instructional goals, incorporating aspects of scientific inquiry whenever possible.

Availability of Resources

Teachers differed in their reaction to the availability of science instructional materials in their classroom. Both Teachers One and Six, for example, worked at private schools with a large amount of resources, especially in the area of technology. Both of these teachers also described the presence of materials for science class, particularly the availability of a SMART Board in the classroom, as being a contributor to their ability to successfully teach science. However, while both teachers had high confidence in their

ability to teach science, they differed greatly in the reform level of their observed teaching. Based on observations, the difference in the reform level between the two seems to be partially due to differences in their background knowledge regarding science and science education. As an undergraduate major in elementary science and mathematics, Teacher One had a good understanding of scientific concepts. This understanding was apparent in the way in which she effectively utilized resources available in her classroom. She used her SMART Board as an effective tool to support the lesson's inquiry-based activity. Teacher Six, on the other hand, centered the majority of her lesson on PowerPoint slides and pre-made SMART Board activities during which she called on individual students to answer low-level questions. Throughout the lesson, Teacher Six did not stray from the provided SMART Board materials. She did not expand upon them, could not answer students' questions about the concepts (indeed, she discouraged questions), and unfortunately perpetuated student misconceptions.

Discussion

The Impact of Reformed Undergraduate Science Courses on Elementary Teachers' Science Teaching Self-efficacy

The quantitative measurements of the STEBI and the RTOP revealed no significant difference between the science teaching self-efficacy of inservice elementary teachers who took the reformed courses and those who did not. Nor did they reveal any relationship between teachers' self-efficacy and the level of reform of the reformed courses they took as undergraduates. However, this does not necessarily indicate that **no** relationship exists between reformed undergraduate courses and science teaching self-efficacy of the students in those courses. For example, the observed course sessions on which RTOP scores were based may not have been representative of the courses that the

Impact of Courses on the Science Teaching Self-Efficacy Beliefs

teachers experienced as undergraduates, some of which the participants took several
years ago. Indeed, several of the science courses developed through NOVA had changed
instructors over time and, as a result, the content and approach of the courses may have
strayed from the original concept of the designed courses. In addition, data were not
available regarding the reform level of the undergraduate courses taken by those inservice
elementary teachers who did not take the NOVA courses, or the variety of other
undergraduate courses that participants completed.

Fortunately the qualitative data available through observation notes of elementary
lessons and interviews with participating preservice and inservice elementary teachers
have given us greater insight into some more specific characteristics of reformed
undergraduate science courses that may have influenced their self-efficacy beliefs
regarding science teaching. The top three factors cited by undergraduate students as
influencing their science teaching self-efficacy were essentially the same as those
described by inservice teachers, although in a slightly different order: (a) perceived
knowledge of the content, (b) teaching experience regarding the content, and (c) interest
in the content. The first two factors have both been extensively linked to the science
teaching self-efficacy of preservice and inservice teachers (Bhattacharyya et al., 2009;
Brand & Wilkins, 2007; Cantrell, Young, & Moore, 2003; Carrier, 2009; Cone, 2009;
Enochs et al., 1995; Gunning & Mensah, 2011; Hechter, 2011; Kind, 2009; Perkins,
2007; Ramey-Gassert et al., 1996; Swars & Dooley, 2010). Although interest or positive
attitude has seldom been cited as an important factor influencing science teaching self-
efficacy (Ramey-Gassert et al., 1996), this factor emerged as an important self-perceived
influence on the self-efficacy of participants in the study presented here. The level of

personal interest was not only perceived by participants to directly increase their confidence in their abilities to teach science, but also led many of them to pursue further education and experiences related to the content, thereby leading to an increase in both science content knowledge and science teaching experiences. In addition, these cited factors were reflected in comments made by others in the larger study, supporting their importance.

While the key factors noted by participants as being the most influential on their self-efficacy levels were the same for preservice and inservice teachers, the sources of these factors were slightly different for the two groups. All undergraduate focus groups cited their undergraduate courses as having at least some influence on their confidence to teach science. In the case of inservice teacher participants, however, less than 50% cited their undergraduate course experiences as influencing their confidence in their ability to teach science. More than half of the inservice teachers described factors they experienced after graduation as influencing their self-efficacy. This indicates that undergraduate course experiences, and therefore any characteristics of reformed undergraduate science courses, seemed to have had the most influence on participating elementary teachers prior to their entering the elementary classroom. Once they became inservice teachers, these course experiences still had an influence on the self-efficacy of some of them, but for others this influence had faded over time or disappeared altogether as more recent endeavors took precedence over undergraduate experiences.

Relationships among self-efficacy beliefs, beliefs about science teaching, and observed teaching practices

Perhaps even more importantly than how elementary teachers' undergraduate courses impact their self-efficacy is how self-efficacy beliefs translate into behavior in the classroom. That is, if undergraduate science courses are successful in increasing teachers' science teaching self-efficacy beliefs, will this lead to more reformed science teaching? According to our nationwide data set, the answer is not necessarily no; we did not see a significant correlation between self-efficacy as measured by tsihe STEBI-A and reform level in science teaching as measured by the RTOP but other factors have surfaced and warrant additional study.

There are several credible reasons for these results. First, it is possible that single observations of each teacher were not representative of the teachers' normal science teaching practices. However, researchers for the NSEUS project attempted to account for this by asking each teacher whether or not the observed lesson was typical for the ways in which they teach science. A second possible explanation is that STEBI-A scores are not representative of teachers' overall level of self-efficacy for teaching science. It has been argued that self-efficacy is a context-dependent construct (Bandura, 1997). The science teaching efficacy beliefs of one teacher may change depending upon the particular group of students he or she is teaching (Angle & Moseley, 2009; Ramey-Gassert et al., 1996; Raudenbush, Rowan, & Cheong, 1992) and the science content being taught (Kind, 2009; Perkins, 2007). In addition, Perkins (2007) demonstrated that preservice elementary teachers' responses to the STEBI survey changed when it was administered multiple times. The teachers who participated in this study may be more or less confident teaching science overall than is represented by the single STEBI-A survey they filled out.

As revealed by the interviews and observations of eight case profile teachers, the relationship between science teaching self-efficacy and practice is much more complex than a simple quantitative correlation and is impacted by a variety of factors, such as other beliefs teachers hold. For example, case profile teachers differed in their beliefs about what it means for a science lesson to be "hands-on" and about the role of district-provided curriculum. Elementary teachers' beliefs regarding what effective science instruction means can have a large impact on self-efficacy beliefs, and thus have an unintended impact on science teaching behaviors, especially if these beliefs do not coincide with those of science education researchers (Bhattacharyya et al., 2009; Haney et al., 2002) or if a mismatch exists between how teachers *believe* they are teaching and how they are *actually* teaching (Wheatley, 2005; Roehrig, Turner, Grove, Schneider, & Liu, 2009). For example, the case profile teachers in this study who had high levels of confidence in their abilities to teach science but low levels of reform in their observed teaching, believed that effective science teaching involved activities in which students simply "used their hands" in some way and a classroom in which the teacher had tight control of his or her students. Since these teachers' self-efficacy beliefs were based upon a different image of effective science teaching than that of proponents of reformed science teaching, the fact that the teachers had high confidence in their own abilities to teach science well was not transformed into teaching in a reformed inquiry-oriented manner.

In addition, as observed in other studies (Czerniak & Schriver, 1994; Kind, 2009; Settlage et al., 2009), because case profile teachers with high STEBI scores and low RTOP scores believed they were using teaching practices that were consistent with

effective science instruction, they seemed to feel little need to critically reflect upon their teaching practices. Wheatley (2002) claimed that this is one of the dangers of focusing too narrowly on the elevation of teacher efficacy beliefs; if teachers have no doubts regarding their teaching efficacy, then they will not experience a perturbation, leading them to feel no need to reform their teaching practices even if reformation would improve student learning. This contrasts greatly with case profile teachers who had high reform level in their observed lessons but low self-efficacy levels. These two teachers seemed to actually be hyper-reflective, critical concerning almost all aspects of their lessons and particularly focused upon whether or not they were effectively implementing inquiry-based teaching strategies to promote student learning.

Teachers with varying levels of self-efficacy and reform in their science teaching also differed in their judgment of the skills required to be an effective science teacher. This impacted their own perceived efficacy as a science teacher. Bandura (1997) claimed that, "Evaluation of one's self-diagnostic skills requires not only self-knowledge of capabilities but also understanding of the types of skills needed for different activities" (p. 115). Thus, teachers may over- or under-estimate their own efficacy based on the self-perceived importance of their skill set. For example, Teacher Five did not have any formal background in science or science education; she did not take any science content or methods courses and had not participated in any professional development for improving her science teaching. In her eyes, however, these were not important criteria for her to be an effective science teacher. Instead, Teacher Five felt high confidence in her ability to teach science due to her assurance of the effectiveness of the district-provided science curriculum and in her self-perceived ability to meet the specific needs

of her students. In contrast, Teacher Three also had very little formal science content or science education background, but saw this as a detriment to her ability to teach science well. Consequently, Teacher Three lacked confidence in her ability to effectively teach science to her students, although her observed science lesson demonstrated a high level of reformed inquiry-oriented teaching.

Concluding Remarks

It is important and worthwhile to examine the factors of reformed undergraduate courses, such as those courses developed through NOVA, and how they impact the development of elementary teachers' science teaching self-efficacy. Perhaps even more importantly, however, is how these beliefs translate into practice. Our premise is that one of the most critical outcomes of this study is that a straightforward correlation between science teaching self-efficacy and *observed* reformed inquiry-oriented teaching was *not* seen for a large nationwide group of teachers with widely varying backgrounds. Therefore, a blanket assumption cannot be made that increasing the efficacy beliefs of preservice and inservice elementary teachers will automatically improve their ability to effectively teach science to their students. The relationship between science teaching efficacy beliefs and science teaching behaviors is much more complex than we might assume.

In addition, this study highlights the importance of the use of interviews and observations in self-efficacy research and the caution to not rely solely on quantitative instruments and/or self-reported data. Further research, including longitudinal studies with multiple interviews and observations that focuses on the relationships that exist between self-efficacy and teaching practices, is needed.

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