Exploring the Relationship between Science Content Knowledge and Science Teaching Self-Efficacy among Elementary Teachers

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Abstract

Elementary school teachers are commonly known to have low self-efficacy in mathematics and science. Previously conducted research on science teaching self-efficacy and content knowledge has often focused on whether methods courses, professional development or other interventions improve both self-efficacy and content knowledge among elementary teachers. This study investigated whether teachers' knowledge of science content influenced their levels of self-efficacy, and compared teachers' who were in a STEM education graduate degree program to teachers and students in a regular elementary teaching program. The participants of this study were 82 in-service and 27 pre-service elementary teachers in affiliation with a large northeastern university. The participants completed a science self-efficacy survey (STEBI-B) and a science content knowledge survey called the Science Beliefs Tests. The results of this study found that pre-service teachers had a higher self-efficacy score in comparison to in-service teachers. Most participants were able to answer a little more than half of the Science Beliefs questions correctly. Additionally, there was a negative relationship between one's belief that they could teach science effectively and their Science Beliefs score, meaning that the more science self-efficacy they possessed, the lower their science knowledge. It is important that teachers become aware of their lack of content knowledge in order to remedy the insufficiency, and to avoid passing along misconceptions to their students. If teachers believe that they have high self-efficacy, they may not be aware that they must continually improve their science content knowledge. Accordingly, teachers can benefit from continued education in topic areas where they scored the lowest.

Keywords: Elementary teachers, science teaching, self-efficacy, science beliefs, misconceptions about science, pedagogical content knowledge

Introduction

Self-efficacy is a person's confidence in his or her ability to complete tasks to the highest potential to attain certain goals (Bandura, 1997). In the field of education, educators have certain beliefs about their abilities and skills as teachers, which can affect their successes in teaching. Many factors can influence a teacher's self-efficacy such as training, preparation, and studying at a higher education level before they begin teaching in a classroom., However knowledge of science among elementary schools is notoriously low and self-efficacy for teaching the subject may be low as well. This study sought to investigate the relationship between science teaching self-efficacy (STSE) and science content knowledge among both pre-service and in-service elementary school teachers. This study also examined whether a graduate program intended to train elementary teachers to be science specialists improved science teaching self-efficacy and content knowledge.

If teachers are educated properly in science content and science teaching methods, they will have high levels of scientific literacy and scientific knowledge which will allow for high levels of self-efficacy (Al Sultan, Henson, & Fadde 2018). The research on the STSE of elementary teachers is vast and wide. Some of research indicates that a teachers' self-efficacy is not related to their content knowledge, although it is an important factor in defining expectations of their students. Teachers with high levels of self-efficacy tend to make use of highly effective teaching strategies, are usually more dedicated to the profession of teaching, and are less likely to burn out (Woolfolk, Hoy & Davis, 2006; Zee & Kooman, 2016). In a synthesis of 40 years of self-efficacy research, Zee and Koomen (2016) reported that teacher self-efficacy in general is positively related to student achievement, teacher well-being and classroom quality (e.g., a supportive environment), among other variables. Many of the studies reviewed below have shown that interventions to increase science knowledge and self-efficacy have been shown to be effective. Accordingly, this study sought to investigate the relationship between science content knowledge and STSE among pre-service and in-service elementary teachers. The authors hypothesized that with more years of experience, in-service teachers would likely have more science content knowledge and higher STSE than pre-service teachers. Lastly, we sought to determine whether students who graduated from a master's degree program specifically designed to train elementary teachers to be STEM specialists, with an emphasis on engineering design, had higher STSE or science content knowledge than teachers and students in a regular elementary education program. The implications for this research can inform program development and professional development for teachers.

Science Teaching Self-Efficacy of Pre-Service Teachers

Many studies have examined the impact of methods courses, professional development, extra science courses, or other science learning experiences on STSE of pre-service teachers (Avery & Meyer, 2012; Bergman & Morphew, 2015; Lumpe, Czerniak, Haney, & Beltyukova, 2012). For example, Morrell and Carroll (2003) administered the STEBI-B (used in most of the studies of STSE in this literature review) to students before they engaged in the aforementioned interventions and after. No changes in their STSE during the science courses or students' teaching were found, however significant gains were demonstrated for students in the science methods course likely due to the design of the course. Similarly, Settlage, Southerland, Smith, and Ceglie (2009) also found high levels of STSE, but given that students already possessed high confidence in their abilities, the authors found that students did not modify their instructional practices over time. Menon and Sadler (2017) suggest that students benefit the most by taking science courses with inquiry based teaching strategies, although low STSE students benefit from proper pacing of the courses. Similarly, through ethnographic research, Jung and Tonso (2006) found that pre-service teachers responded positively to non-threatening, hands-on experiences providing implications for course design for the future. Knaggs and Sondergeld (2015) note that positive impacts from these interventions are likely due to modelling the instructor's method of teaching.

In order to understand and resolve public issues, society needs to be scientifically literate. This means that individuals need to be informed and develop a scientific background. Science teachers play an essential role in educating society about how the world works. Al Sultan et al (2018) argued that pre-service teachers enter the teaching field with low self-efficacy beliefs. In their study, 49 pre-service elementary teachers in an introductory or advanced science methods course completed a survey assessing their scientific background. They also completed the Test of Basic Scientific Literacy (TBSL), Science Teaching Efficacy Belief Instrument (STEBI-B), and Beliefs about Teaching (BAT) as further assessment. Al Sultan et al found that pre-service elementary teachers had satisfactory scientific literacy levels and in both methods classes, the participants demonstrated higher self-efficacy in teaching biology and lower self-efficacy in teaching physics. The authors also found a positive relationship between scientific literacy and self-efficacy in advanced pre-service elementary teachers because of the amount of exposure to scientific courses.

Science is often not a priority in elementary classroom instruction, although with the adoption of the Next Generation Science Standards (NGSS) in most of the United States, increased focus on teaching science through inquiry will need to be integrated into the curriculum. Accordingly, Grinell and Rabin (2017) developed a study with the goal to motivate 59 pre-service elementary teachers in a science methods course to spend a significant amount of time teaching science in their future classrooms, even if they have demonstrated low STSE. The findings from their study indicated that helping pre-service teachers find the connections between science knowledge and ethics helps shape their beliefs in a way that can motivate them to improve their level of science knowledge. By improving their knowledge of science, they can teach their students more often and more effectively. At the end of the semester, almost every participant was better able to discuss the ethics and equity in the context of science teaching. As noted previously, many pre-service elementary education teachers have low levels of proficiency and interest in science, which can lead to a failure to make science a priority in the curriculum (Cervato & Kerton, 2017). Interventions such as requiring extra science courses in the pre-service teacher curriculum, participating in authentic science experiences using inquiry based activities (Avery & Meyer, 2012), and providing supportive settings in which the pre-service teacher is provided consistent and constructive feedback can improve self-efficacy and science knowledge (Knoblauch & Hoy, 2008).

In-Service Teachers' Science Self-Efficacy

In-service teachers have more work experience in the field, but that does not mean they are comfortable when it comes to teaching science topics. Lumpe et al (2012) investigated whether there was an effect on elementary students who are educated by confident teachers who believe in their own abilities. The researchers also investigated whether a summer professional development program, focusing on science content knowledge, for 450 elementary science teachers would affect their beliefs about teaching. During the school year, teachers were provided with support to help with professional development and science content. Both teachers and principals received additional professional development. The researchers measured the teachers' knowledge of science concepts before and after the program. They then compared the teachers' knowledge to that of 580 fourth graders and 1,369 sixth graders, using the Ohio state achievement test for science. The results showed that the program increased the positive beliefs the science teachers had about their own teaching. The researchers also found that teacher STSE and at the number of professional development hours they attended contributed to student achievement.

Unsurprisingly, in-service teachers can also benefit positively from an increase in exposure to content-specific knowledge. Swackhamer, Koellner, Basile, and Kimbrough (2009) researched the effects of content-specific courses in math and science over a five-year period on 277 teachers' self-efficacy. At the end of each course, the teachers were asked to complete a self-efficacy survey (STEBI- B), although only 88 teachers completed the survey. The results showed that the mean scores of teachers who took more than four of the courses had a significantly higher Science Teaching Outcome Expectancy (STOE) and levels of efficacy than the teachers who took fewer than four of the courses. STOE describes the general factors that teachers believe will impact student science ability. The teachers initially had low STSE due to their perceived low level of content knowledge. While the literature on in-service and pre-service teacher science self-efficacy is large, few studies compare the STSE of in-service to that of pre-service teachers, nor have any studies compared the relationship between STSE and science content knowledge among these two groups.

Science Misconceptions and Content Knowledge Among Teachers

Research has suggested that students hold many misconceptions when it comes to science concepts and content (e.g., Bar, Brosh, & Sneider, 2016; Tompo, Ahmad, & Muris al, 2016). Educators, elementary teachers in particular, often focus on those misconceptions to guide their teachings. However, research suggests that educators also hold science misconceptions, and these misconceptions negatively impact their teaching. Several studies have shown that teachers and students tend to hold the same misconceptions and that they are mostly in the physical sciences (Burgoon, Heddle, & Duran, 2011; Bursal, 2012; Stein, Larabee & Barman, 2008).

Similar to the present study, Kirik (2013) examined the relationship between STSE, participation in extracurricular activities, science content knowledge, number of science and methods courses taken, as well as classroom management and efficacy beliefs. Seventy-one secondary science education majors and 262 pre-service elementary teachers participated in the study. The results indicated that there was a small significant relationship between science knowledge and outcome expectancy. Both groups had positive STSE, although secondary science majors had higher STSE than elementary majors.

Although studies have investigated the impact of different types of interventions on both content knowledge and STSE, none have assessed both constructs among both pre-service and inservice teachers. Many of the interventions were methods courses taken by all elementary education teachers, or were one-time programs offered over a period of time. This study extends the previously conducted research by examining a longer term intervention: a graduate degree intended to train elementary teachers to be STEM specialists. The authors hypothesize that teachers in (or have graduated from) the STEM graduate program possess greater STSE and content knowledge over other in-service teachers.

Methods

This study sought to answer the following research questions:

- To what extent is there a relationship between STSE and science content knowledge?
- Is there a difference in both constructs among pre-service and in-service teachers?
- Is there a difference in both constructs among teachers training to be science/STEM specialists and those who are non-specialists?

Participants

After receiving Institutional Review Board approval to conduct this study, in-service and pre-service elementary teachers were emailed an invitation to participate in the study which included a link to a science self-efficacy survey and science content knowledge survey.

Participants included undergraduate pre-service teachers enrolled in a teacher education program at a large private university on Long Island, NY, and in-service teachers enrolled in graduate programs in the same university. Some participants had recently graduated from the graduate program, which is a master's degree in elementary STEM education in which students are trained to be STEM specialists. Additionally, elementary teachers in partner districts with the university were invited to participate in the study.

Measures

In order to measure STSE, the STEBI-B was administered. The STEBI-B is one the most frequently used measures of STSE. It is relatively brief and has demonstrated reliability and construct validity consistently. The STEBI-B was developed by Riggs and Enochs (1990) to assess the science teaching self-efficacy of pre-service teachers. Because we administered the survey to both pre-service and in-service teachers, we chose the STEBI-B as opposed to the STEBI-A which was intended for in-service teachers only. The STEBI-B includes 23 items on two subscales: Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE). The PSTE primarily assesses the degree to which participants believe that they, as educators, can impact student achievement in science, whereas the STOE demonstrates participants' beliefs about the general factors that might impact a student's science achievement. Items were answered using a 5-point Likert scale from strongly agree to strongly disagree. Two items in particular tend to cross-load onto both factors and to exhibit low loadings. Bleicher (2004) revised the wording of the scale, although as reported below those two items still proved problematic in this study as well. Those two items are "The low science achievement of some students cannot generally be blamed on their teachers" and "Increased effort in science teaching produces little change in some students' science achievement" (Bleicher, 2004, p. 391). Riggs and Enoch (1990) reported an internal consistency reliability, using Cronbach's alpha (CA), with a score of .76, while Bleicher (2004) found a CA of .72.

The Science Beliefs Test was administered to assess the science content knowledge of teachers. The Science Beliefs Test was developed by Larrabee, Stein, and Barman (2006). The test was intended to be administered via computer and includes a 44 item true/false test that was constructed based on common misconceptions that teachers, and people in general, have about life science, earth science and physical science concepts. The items on the test reflect knowledge that the average adult should possess about science concepts. The original version of the test asks participants to explain their answers so that the researchers could determine whether participants actually understood the concept being tested. For this study, we only asked participants to mark whether they believed a statement to be true or false.

Larrabee et al determined the internal consistency reliability, using Kuder-Richardson, to be a value of .77. They also determined test-retest reliability was .776. We report our own reliability statistics for both measures below. The online version of the Science Beliefs Tests may be found here https://www2.oakland.edu/secure/sbquiz/.

We also added additional questions about whether participants were pre-service, in-service, secondary or elementary level, in the STEM MA graduate program (the program at our institution in which elementary teachers are trained to be science specialists) or whether they were employed as science specialists. We also asked about the highest educational level attained. After data were collected and coded, they were analyzed using SPSS v. 23.

Results

Participants

A total of 144 participants took the survey, although only 109 of those surveys were completed. The 35 participants who did not complete the surveys, did not complete the Science Beliefs portion of the survey. Of the 109 participants, 82 were in-service teachers, while 27 were pre-service. Of the 82 in-service teachers 28 had been trained as STEM specialists. We did not ask participants about their gender or ethnicity. Because most of the participants were graduates of our institution's program, we were aware that at least 90 percent of participants were white females. Eight participants were special education teachers, and 13 were employed as elementary STEM specialists.

Reliability and Validity of the Measures

The full STEBI-B demonstrated a reliability of a CA of .856, while the subscale STOE had a CA of .685, and the PSTE had a CA of .896. These values show that the scale demonstrated good reliability. Principal components analysis using varimax rotation revealed six factors demonstrating eigenvalues greater than 1, with the entire model explaining 64.5 percent of the variance. When forcing the items into two factors (representing the two subscales), all of the items, other than 10 and 13, loaded onto the two appropriate factors explaining 39.5 percent of the variance. However, items 10 and 13 loaded at .258, which is below the .5 cutoff. These two items had been noted as problematic previously by Riggs and Enochs (1990).

Science Teaching Self-Efficacy Scores

STSE total and subscale scores were computed for each group. Comparisons among groups were also calculated. The mean STSE total score was 48.48 (standard deviation of 9.14). As can be seen in Table 1, there were few differences among groups in STSE total scores between STEM MA students and non-STEM MA students. Pre-service teachers ($n = 27$) did demonstrate higher STSE scores than in-service teachers trending significant where $p = .06$, $F = 3.459$ (1, 282.7). In general, when considering the different range of scores for each subscale, participants STOE (with a range of 0-65) scores were lower than their PSTE (a range of 0-50) scores. The average STOE score for all participants was 23.97; for the PSTE the mean was 24.58.

Table 1: Mean total and subscale scores on STSE and Science Beliefs for all groups.

	Range of scores possible	Pre-service (n = 27)	In-service (n=82)	STEM MA (n= 81)	Non-STEM MA (n= 28)	Total (n = 109)
STSE mean Total Score	0-115	51.34	47.55	49.29	48.29	48.48
STOE	0-65	24.59	23.77	24.10	23.93	23.97
PSTE	0-50	26.58	23.88	25.07	24.34	24.58
Science Beliefs Total	0-44	24.74	25.04	25.04	24.93	24.99
Life Science	0-11	6.81	6.76	7.00	6.70	6.78
Physical Science	0-16	9.93	10.13	10.18	10.01	10.1
Earth Science	0-14	7.67	7.85	7.68	7.85	7.80

When looking at the differences between participants on their current teaching status: pre-service teacher, in-service general elementary, and in-service STEM elementary teacher, those employed as STEM elementary teachers scored significantly lower than general education teachers on the STEBI-B, at the $p < .05$ level. STEM elementary teachers had a mean score of 41.23, while general education teachers had a mean score of 49.10. When compared to pre-service teachers, STEM elementary teachers scored significantly lower at the $p < .001$ level, where pre-service teachers had a mean score of 51.34.

Science Beliefs Test scores

The mean raw score on the Science Beliefs Test was 24.99 out of 44. When converted to a percentage, the mean total score was 56.73%. There were no significant differences between pre-service and in-service teachers on the Science Beliefs test or any of its subscales. The same is true for STEM MA students as compared to non-STEM MA students. There were also no differences between STEM teachers, general education teachers on the Science Beliefs Test. Students tended to get a little more than half of the questions correct on all of the subscales.

Students tended answer life science questions correctly more often with a percentage of 62 correct. In the physical sciences, on average they scored 59 percent correct, although students in the STEM MA program scored higher at 64 percent. Students scored the lowest on the Earth science questions at an average of 49 percent correct for all participants. (See Table 2).

Table 2: Scores on Science Beliefs converted to percentage correct for all groups.

	Range of scores possible	Pre-service (n = 27)	In-service (n=82)	STEM MA (n= 81)	Non-STEM MA (n= 28)	Total (n = 109)
Science Beliefs Total	0-44	54%	57%	57%	57%	57%
Life Science	0-11	61%	61%	64%	61%	62%
Physical Science	0-17	58%	60%	64%	59%	59%
Earth Science	0-16	48%	49%	48%	49%	49%

Analysis of responses to individual Science Beliefs Test items showed that on many items half of the respondents answered the questions correctly. For example, question two states "Plants use oxygen." Only 50 percent of participants indicated that this statement was true. Another trend that we noted was that a large majority of the participants (75 percent) chose the incorrect answer to the question 1 which stated that "The only essential constituents that plants need in order to grow are: water, light and nutrients from the soil or medium in which they exist." The correct answer to this question is false, because plants also need air, as at least half of the participants indicated in their answer to question 2. In another example, question 13 states, "An astronaut is standing on the moon with a baseball in his/her hand. When the baseball is released, it will fall to the moon's surface." Only 29.13 percent of participants accurately responded that this statement was true.

We also sought to determine whether there was a relationship between science content knowledge and STSE. A Pearson's Product Moment correlation showed a negative, moderate, significant relationship between STSE and total Science Beliefs score was $r = -.281$ $p<.01$. Further analysis shows that the Science Beliefs scores was, negatively related to the PSTE subscale $r = -.297$. Overall, these results suggest that the higher a participant's science teaching self-efficacy, the lower their content knowledge.

Discussion

This study sought to determine whether, and to what extent, there is a relationship between science content knowledge (as measured by the Science Beliefs Test; Larrabee et al, 2006) and science self-efficacy. We also sought to determine if there were differences on these measures between in-service and pre-service teachers, as well as between graduate students (who are in-service teachers) training to be science specialists (in the STEM MA program) and those not in the STEM MA program. We found that there were differences between pre-service and in-service teachers on the STSE scores. Results were not significant at the $p < .05$ level, but they were trending towards significance at $p = .06$. There was very little difference on science content knowledge between any of the groups we studied. However, we did find a significant negative relationship between STSE and science content knowledge, particularly for one subscale of the STEBI-B. These results indicate that as Personal Science Teaching Efficacy beliefs go up, science content knowledge goes down, meaning that teachers who believe they are able to teach science effectively tended to have lower science content knowledge. These results indicate that elementary school teachers and those training to be teachers have low content knowledge. They carry the same misconceptions as that of the general public. Further, it is problematic when teachers believe they are effective science teachers but have low content knowledge. Although research notes that teacher self-efficacy is positively related to student achievement (Zee & Koomen, 2016), other researchers noted that teachers with high self-efficacy may be resistant to changing instructional practices because they already have confidence in their pedagogical efficacy (Tschannen-Moran, Hoy, & Hoy, 1998). Most relevant to this study, research conducted by Settlage et al, (2009) of pre-service teachers found that the participants already had high self-efficacy at the pre-test. Since they lacked uncertainty in their teaching abilities they were not open to expanding their knowledge to improve their pedagogical practices. It is important to note that Riggs and Enoch (1990) did not indicate a cut-off score by which to determine whether a participant had high or low STSE. Given that the maximum score one can attain is 115 and that the mean score was 48, we can surmise that the respondents in this study had average STSE.

One positive explanation for the high STSE scores of the pre-service teachers, is that pre-service teachers have been found to become more interested in science through methods courses, which increases confidence in students' ability to teach science topics (Grinell & Rabin, 2017; Menon & Sadler, 2017). By adding additional science courses to pre-service teachers' education programs, pre-service teachers have been found to increase their scientific knowledge and STSE (Avery & Meyer, 2012).

In-service teachers can also benefit from continued teacher training (Lumpe et al, 2012; Swackhamer et al, 2009). One explanation for why in-service teachers had lower STSE is that in-service teachers may be more aware of the subjects they are not the strongest in teaching because of their years of experience. In-service teachers can increase their STSE by participating in more continued teacher training that will provide them with more hours of exposure to the scientific content knowledge that they may not know as well as other subjects.

As reported in the literature, it is not uncommon for in-service elementary school teachers to have low content knowledge is science. Interestingly, our results showed that elementary STEM teachers (that is elementary teachers who only teach science) had significantly lower STSE even though their science content knowledge was on par with the other groups. Their low STSE may be due to the fact that they are "in the trenches" teaching science every day and are aware of their lack of content knowledge, thus propagating low STSE.

Additionally, although we found few difference in respondents' knowledge about life science, Earth science and physical science, other researchers found that most teachers had the highest self-efficacy in teaching biology and the lowest self-efficacy in teaching physics (Al Sultan et al, 2018). Similarly, Burgoon et al (2011) found that students and teachers have the most misconceptions in the physical sciences. In this study, however, participants scored lowest in Earth science concepts.

At the institution in which this study took place, elementary school teachers (both pre-service and in-service) may participate in a program where they train to be science specialists in the STEM MA program. They take additional science and math methods courses, engineering design courses, and often science content courses. Surprisingly, there were no differences between those who were in this program and those who were not studying to be science specialists. One explanation for these results are the uneven group sizes. There were only 28 students in the STEM program.

Limitations

The most significant limitation to this study was the sample size. A sample of 109 participants does not make this research generalizable to other groups of elementary teachers. This limitation is a common issue among studies of STSE and science content knowledge. Our sample strategies had mixed results, while all participants who were invited to take the survey who were students at the institution (all pre-service teachers and all in-service STEM MA students) participated, there was a low return rate for the in-service teachers invited who were not at the institution. Many participants chose not to complete the surveys likely because they were very long. Future research should employ a random sampling strategy and incentive programs to encourage participation.

There are also ethical issues to consider in the development of this research that are related to the limitations. Because elementary school teachers are known to have low self-efficacy in science and mathematics, it may have been uncomfortable to take a 44 question test on the subject and not receive the correct answers once the survey was completed and submitted. Additionally, it would be helpful for teachers to be aware of the topics in which they could improve knowledge. Given that there is a negative relationship between knowledge of science and confidence, it would be beneficial to both the teacher-participants and their current and future students if teachers are provided with the results of the research. These issues can be remedied by offering professional development to teachers who participated in the study.

Implications and Recommendations

Self-efficacy levels of teachers can affect their ability to be effective in the classroom. Teachers can work towards improving their levels of self-efficacy by allowing themselves to continue to learn through content-specific and inquiry-based courses. Although in-service teachers have more years of teaching than pre-service teachers, in-service teachers need just as much continued education in order to be more successful in the classroom. Universities do, and should continue to develop programs for pre-service teachers that will provide them with more learning experiences in science-based courses so that future teachers can increase their levels of self-efficacy which will lead to their future students to also be more successful in the learning process. Further, relationships between universities and schools can facilitate the improvement of teachers' self-efficacy (Petersen & Treagust, 2014). Future research should expand efforts to collect larger samples of elementary teachers and to connect teacher knowledge to student knowledge. Further, research investigating interventions for improving elementary science content knowledge are needed.

Conclusion

It is important for pre-service teachers to be motivated to take on the responsibility of providing their students with quality science instruction. When teachers do not have high self-efficacy about their ability to teach science, they are less likely to want to dedicate instructional time to science. Teachers can be motivated to have higher self-efficacy in science if they are able to understand ethical issues that probe their interest and create a desire to share the knowledge and importance to their students.

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