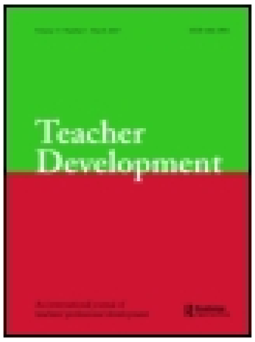

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Teaching efficacy: exploring relationships between mathematics and science self-efficacy beliefs, PCK and domain knowledge among preservice teachers from the United States

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This mixed-methods study investigated the relationships among preservice teachers' efficacy beliefs, pedagogical content knowledge (PCK) and their domain knowledge (DK) as related to mathematics and science teaching. Quantitative results revealed that participants' PCK was significantly correlated with their mathematics and science efficacy beliefs. Additionally, participants' mathematics and science DK did not predict their mathematics and science personal efficacy beliefs, however, their PCK score predicted participants' outcome expectancies. Interview analysis revealed five inter-related key themes, labeled as: *Previous academic experiences*, *Mathematics and science PCK beliefs, Personal efficacy, Outcome expectancies* and *Emotions*. These common themes describe participants' views of their quality teacher training and thinking about planned instruction. Educational implications are discussed in relationship with study findings.

Keywords: STEM education; teaching beliefs; teaching knowledge; preservice teachers

Introduction

Recent reforms calling for improved mathematics and science teaching emphasize the role of changes not just in teachers' practices but changes in their philosophies of teaching (Smith and Southerland 2007). The reform recommendations in the US, Australia and UK for instance (ACE 2001; Duschl, Schweingruber, and Shouse 2007; Millar and Osborne 1998; NAS 2006; NRC 2000, 2011, 2012) aim at improving the way mathematics and science is taught and assessed in schools. The reform suggests changes to mathematics and science teaching, emphasizing active learning through the use of constructivist, inquiry-based instructional approaches. Additionally, rather than teaching isolated science and mathematics units focused on mastering content, students need to learn more problem solving skills, scientific inquiry, how to pose questions and formulate hypotheses (Richardson and Liang

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2008). In addition, attention to learning trajectories as students progress through school is critical to effective student learning (Corcoran, Mosher, and Rogat 2009). Concerns about the quality of elementary science education exist in many countries, leading researchers to focus on teacher preparation and teachers' pedagogical content knowledge (Appleton 2003).

Reform recommendations for mathematics teaching, similarly to science teaching, suggest that teachers engage students in multiple experiences, active learning and emphasize conceptual understanding (Hill, Rowan, and Ball 2005; Marrongelle, Sztajn, and Smith 2013). However, when reform recommendations in mathematics teaching are presented to teachers their understanding of how to implement them hampers the necessary changes in teachers' classroom practices. The different interpretations of mathematics reform are problematic because teachers interpret it according to their personal perspectives, their past experiences and their cognitive schemas about what is effective teaching (Skott 2001).

Over the past 20 years science reform initiatives have been introduced and developed in the US, UK, Ireland and Australia, where the educational system experienced a shift in focus to science, mathematics and technology education. National UK reports (i.e. Royal Society 2010, 2011) point out that many students lose interest in mathematics and science during secondary school, which oftentimes results in insufficient uptake into undergraduate degrees in STEM. A shortage of middle and secondary mathematics and science teachers exacerbates the problem (Royal Society 2011). At the elementary level, teachers report feelings of inadequate science and mathematics preparation and low mathematics and science teaching efficacy (Sharp, Hopkin, and Lewthwaite 2011; Sharp et al. 2009). In Ireland, among the main STEM reform recommendations were to prioritize the science, mathematics and technology curriculum, increase the practical work in schools, increase the number of science laboratories in secondary schools and improve the standard of laboratory equipment in schools (Kennedy 2012).

One common goal in the process of reforming the educational system in many countries, especially in the STEM fields, is to better train teachers, to provide adequate professional development and start students' STEM education and the foundation of their scientific literacy as early as possible (see Figure 1).

Teaching beliefs

Research shows that teachers' beliefs play a pivotal role in how they interpret their pedagogical knowledge, how they conceptualize their teaching tasks and subsequently how they enact their teaching decisions (i.e. Kagan 1992; Mansour 2009; Pajares 1992). Teachers' pedagogical actions, their instructional approaches and their attributions about student abilities are solidly grounded in their personal beliefs (Swars et al. 2007). Research suggests that teachers' classroom actions are based on a cognitive schema about teaching that was develop throughout their schooling years (Clark and Peterson 1986; Saban 2003).

Despite a history of reform initiatives in elementary science and mathematics teaching, most elementary teachers are not adequately prepared to teach mathematics and science, and they hold negative views toward teaching mathematics and science (i.e. Borko and Whitcomb 2008; Huinker and Madison 1997). Additionally, elementary teachers do not feel confident about their mathematics and science teaching (Skamp and Mueller 2001).

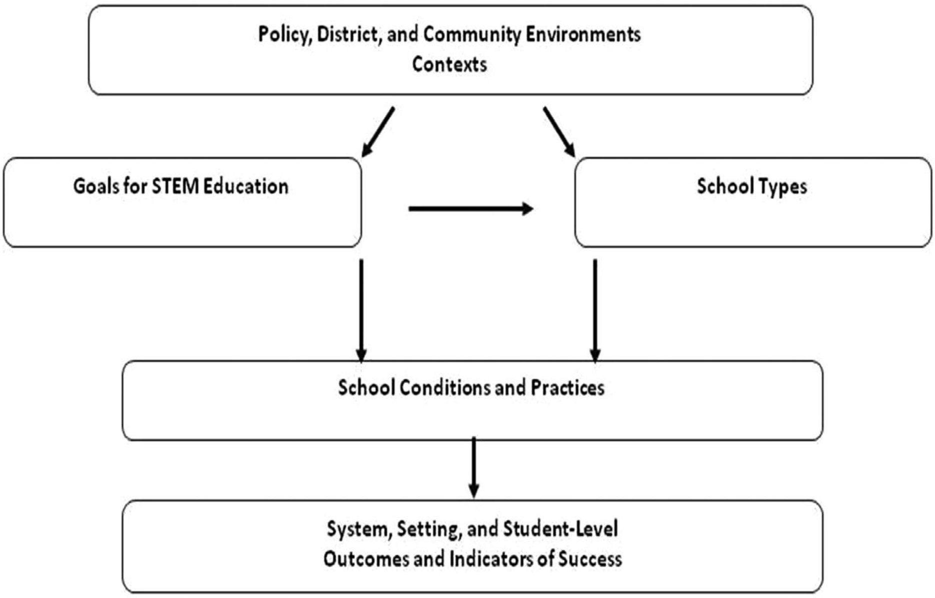

Figure 1. K-12 STEM Framework (NAS 2006).

Science teaching efficacy beliefs

Using Bandura's (1977) theory that efficacy in one's ability to perform and meet outcome expectations will result in task engagement, Enochs and Riggs (1990) developed the Science Teaching Efficacy Beliefs Inventory (STEBI), which measures personal science teaching efficacy and science teaching outcome expectancy. Longitudinal research has shown that elementary preservice teachers' efficacy beliefs may manifest themselves in the implementation of poorly designed science lessons that utilize 'meaningless and excessive use of effort and time' (Hechter 2011, 188). Elementary teachers' low science teaching self-efficacy has been attributed to their own lack of understanding in science and insufficient experiences with good science teaching (Bleicher 2007).

The need to improve elementary teachers' science teaching efficacy has been addressed in numerous studies (e.g. Bleicher 2007; Hechter 2011). Bleicher (2007) described the impact of a preservice elementary science methods course focused on conceptual understanding through hands-on science learning experiences. As a result, there was a significant pre/post increase in conceptual science understanding and efficacy. Additional factors that have been shown to impact science teaching efficacy are the use of mastery and vicarious learning experiences during a science methods course (Bautista 2011), prior science learning experiences and the number of postsecondary science courses completed (Hechter 2011).

Mathematics teaching efficacy beliefs

Building on the seminal work of Enochs and Riggs (1990) in the development of STEBI, the Mathematics Teaching Efficacy Belief Instrument (MTEBI; Enochs, Smith, and Huinker 2000) was developed to assess teachers' efficacy beliefs about mathematics teaching. Reasons for lower levels of teaching efficacy in mathematics include past mathematics performance (Bates, Latham, and Kim 2011; Phelps 2010) and mathematics anxiety (Swars, Daane, and Giesen 2006). Research concerning past mathematics performance suggests that teachers with higher perceptions of their mathematics ability and actual performance reported higher levels of mathematics teaching efficacy (Bates, Latham, and Kim 2011). This aligns with Bandura's (1997) social cognitive theory that defines factors contributing to personal beliefs as mastery experiences, persuasion by a significant other, vicarious experiences and physiological arousal. Past and current mathematics performances serve as mastery experiences for which teachers construct their beliefs about teaching mathematics. In addition to past performance in mathematics, other research by Swars, Daane, and Giesen (2006) found significant negative correlations between preservice teachers' level of mathematics anxiety and mathematic teaching efficacy. Furthermore, mathematics methods coursework has been shown to have significant impact on preservice teachers' mathematics teaching efficacy (Huinker and Madison 1997).

Study purpose

This mixed-methods study investigated the relationships among preservice teachers' mathematics and science teaching efficacy beliefs, their pedagogical content knowledge (PCK) and their domain knowledge (DK). In addition to survey data which measured teachers' efficacy beliefs, PCK and DK in mathematics and science, we captured, via interviews, participants' reflections on their mathematics and science teaching preparation, and their mathematics and science teaching efficacy beliefs. Our study responds to the need for more studies conducted at the elementary level exploring teachers' mathematics and science beliefs and practices. Elementary grades are recognized as a crucial period for the development of students' basic scientific literacy and attitudes toward mathematics and science. Contributions from this study can help enhance our understanding of elementary teachers' thinking and enacting of mathematics and science practices in their classrooms and the existing relationships between teaching self-efficacy and knowledge. The key research questions addressed by the current study were the following:

(1) What are the relationships between participants' mathematics and science efficacy beliefs, their PCK and their DK?
(2) Do PCK or DK predict teaching efficacy in mathematics and science?
(3) How do participants describe their STEM teacher education experiences and their efficacy?

Methodology

Design, participants and procedures

In the current study both quantitative (survey) and qualitative (interviews) data were collected, and the study employed was a sequential explanatory mixed-methods design (Creswell et al. 2003), which consisted of collecting quantitative data and then qualitative data to help explain or elaborate on the quantitative results. In a sequential explanatory design, collection and analysis of quantitative data is followed by the collection and analysis of qualitative data (Tashakkori and Teddlie

2003), with priority being given to the quantitative data; the qualitative data help further explain the results from the quantitative data and analysis.

Participants ($N = 55$) were preservice teachers enrolled in an Elementary Education teacher preparation program with a STEM focus at a large research university in the United States. All participants were females (55 females, 100%), seniors (last year of their teacher preparation program) and the age range was 21–22 years old. Also, the vast majority of participants were predominantly white ($n = 51$, 92%). The demographics of participants are typical of a population enrolled in the Elementary Education teacher programs in the US. Additionally, all participants in the current study were high academic achievers (GPA mean = 3.62, out of 4.0) and had finished with their coursework in teacher preparation at the time of the study.

Data sources

Data were collected using surveys (phase one) with all participants ($N = 55$) and interviews (phase two) with survey participants who volunteered for phase two of the study ($n = 40$).

Quantitative data: survey

The administration of the survey was conducted in one testing session (90 minutes total) outside of participants' classes. The survey instruments were comprised of three measures which are described next.

Diagnostic of Teacher Assessment Mathematics and Science (DTAMS, Bush et al. 2006) measured elementary preservice teachers' mathematics and science PCK and DK. In the current study, to measure mathematics PCK and DK, we used two subscales from DTAMS, namely *Life Science Test* (LST) and *Physical Science Test* (PST). Similarly, to measure mathematics PCK and DK, we used two subscales from DTAMS, namely the *Whole Numbers Test* (WNT) and the *Rational Number Test* (RNT). Psychometric properties of the DTAMS instrument (i.e. validity and reliability) are discussed in Bush et al. (2006). In the current study, to establish evidence of validity and reliability of the measure, we ensured content and construct validity by reviewing the test items with a group of teacher educators and researchers, and also piloted the test items with a group of undergraduate preservice teachers, a similar population with the study sample. Additionally, we calculated internal reliability scores for the subscales; for the WNT, Cronbach's alpha = .73, for the RNT, Cronbach's alpha = .80, for the LST, Cronbach's alpha = .67, and for the PST, Cronbach's alpha = .71, indicating thus good reliability scores.

Science Teaching Efficacy Beliefs Instrument (STEBI, Enochs and Riggs 1990) was used to measure elementary preservice teachers' efficacy beliefs about their science teaching.

Mathematics Teaching Efficacy Beliefs (MTEBI, Enochs, Smith, and Huinker 2000) was used to measure elementary preservice teachers' mathematics teaching efficacy.

Instrument development and psychometric properties of the STEBI and MTEBI instruments (i.e. validity and reliability) are discussed in the original studies of Enochs and Riggs (1990), and Enochs et al. (2000). In the current study, evidence of the validity and reliability of STEBI and MTEBI was established by reviewing the survey items with a group of teacher educators and researchers, and piloting the instrument with a sample of preservice teachers, a similar population to the study participants. Additionally, the internal reliability scores calculated for the sample in this study indicate good reliability of the two instruments (Cronbach's alpha = .87 for STEBI and Cronbach's alpha = .83 for MTEBI).

Data from the survey was entered in SPSS and quantitative data analysis consisted of correlational analysis and regression analysis. Results from these analyses are presented in detail in the Results section.

Qualitative data: interviews

In-depth, semi-structured interviews lasted from 50 to 60 minutes and were conducted with survey participants who volunteered for the second phase of the study, the interview ($n = 40$). We invited all 55 survey participants to take part in phase two of the study (interview) and 40 responded to our invitation. Interview questions aimed at measuring participants' perceptions of their teacher preparation program, beliefs about mathematics and science teaching, and their mathematics and science teaching efficacy. Interview transcripts were analyzed by using an inductive approach. Three primary coders were involved in organizing and coding the interview data. In our data analysis we used *open* coding (finding primary categories from the data) and *axial* coding (exploring the inter-relationship of categories), two coding techniques that we borrowed from grounded theory (Creswell 2013). In the first stage, open coding, all interviews were independently read by each coder and in a second stage, axial coding, coders compiled their codes and built a coding scheme. By constant comparisons five major themes were identified, labeled as: *Previous academic experiences*, *Mathematics and science PCK beliefs, Personal efficacy, Outcome expectancies* and *Emotions*.

Results

Relationships among participants efficacy beliefs, PCK and DK

Significant correlations were found between elementary preservice teachers' science PCK (time 1) and science outcome efficacy (time 2, $r = .61$, $p < .05$). Additionally, significant correlations were found between elementary preservice teachers' science PCK (time 1) and mathematics outcome efficacy (time 1, $r = .38$, $p < .05$).

Also, study results showed that participants' mathematics and science outcome expectancy beliefs (time 1) were significantly correlated ($r = .85$, $p < .05$) with outcome expectancy beliefs (time 2). Significant correlations were as well found ($r = .61$, $p < .05$) between participants' science personal efficacy (time 1 and time 2). These findings (Table 1) suggest that participants' DK, PCK and efficacy beliefs are strongly interconnected and influence each other.

Variables predicting participants' efficacy beliefs

Multiple regression analysis indicated that generally, participants' mathematics and science DK did not predict participants' mathematics and science teaching personal efficacy beliefs or their outcome expectancies, however, participants' PCK science overall score (time 1) predicted participants' score (time 2) in science outcome expectancy beliefs ($R^2 = .03$, F (1, 51) = 1.96, $p < .05$). Additionally, study results showed that participants' previous efficacy beliefs (time 1) were more likely to

Table 1. Correlations among variables of interest.

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Science PCK Time1	–	.02	.96*	.20	.59*	.14	.09	.18	.16	.38*	.04	−.00	.19	.35
2	Science PCK Time2		–	.23	.94*	.18	.44*	−.00	.05	−.06	−.15	.24	.19	−.17	−.99
3	Science DK Time1			–	.26	.62*	.18	.09	.17	.11	.27	.03	.00	.12	.29
4	Science DK Time2				–	.14	.54*	.03	.09	−.12	−.17	.22	.24	−.15	−.12
5	Science Total Score Time1					–	.07	.09	.07	.22	.25	.16	−.06	.32	.36
6	Science Total Score Time2						–	.06	.15	−.05	−.12	.28	.32	−.11	−.09
7	PMTE Time1							–	.80*	.22	.12	.68	.49	.37	.19
8	PMTE Time2								–	.14	.18	.49*	.48*	.19	.17
9	MTOE Time1									–	.58*	.10	−.26	.85*	.56*
10	MTOE Time2										–	−.10	−.15	.58*	.86*
11	PSTE Time1											–	.80*	.29*	.00
12	PSTE Time2												–	−.16	−.09
13	STOE Time1													–	.61*
14	STOE Time2														–

Note: PMTE = Personal Mathematics Teaching Efficacy; MTOE = Mathematics Teaching Outcome Expectancy; PSTE = Personal Science Teaching Efficacy; STOE = Science Teaching Outcome Expectancy.
*$p < .05$

predict their future efficacy beliefs (time 2). For instance, elementary preservice teachers' (time 1) mathematics personal efficacy beliefs predicted their (time 2) mathematics personal efficacy beliefs (R^2 = .65, F (2, 27) = 25.36, $p < .00$). Also, elementary preservice teachers' (time 1) science personal efficacy beliefs predicted their (time 2) science personal efficacy beliefs (R^2 = .61, F (2, 25) = 20.38, $p < .00$). Similarly, elementary preservice teachers' (time 1) mathematics outcome expectancy beliefs predicted their (time 2) mathematics outcome expectancy beliefs (R^2 = .36, F (2, 26) = 7.45, $p < .00$) and likewise, elementary preservice teachers' (time 1) science outcome expectancy beliefs predicted their (time 2) science outcome expectancy beliefs (R^2 = .37, F (2, 26) = 7.87, $p < .00$) (Table 2).

Participants' views of teacher education and teaching beliefs

Across all interviews, five inter-related key themes appeared to be common to all participants and were labeled as: (1) *Previous academic experiences* (i.e. previous mathematics and science experiences), (2) *Mathematics and science PCK beliefs* (i.e. their PCK readiness), (3) *Personal efficacy* (i.e. perceived ability to teach), (4) *Outcome expectancies* (i.e. targeted goals) and (5) *Emotions* (i.e. emotions associated with teaching). The five themes are described below along with participants' narrative accounts. To provide rich descriptions of participants' perspectives on each theme, we selected quotes from the interviews, the most representative data being captured this way to illustrate an idea, or a category described in the qualitative results (Table 3).

Previous academic experiences

When talking about their previous mathematics and science academic experiences, participants generally discussed their schooling experiences by describing either strong or weak preparation in science and mathematics, or describing their memories of how mathematics and science was presented to them. More than half of the interview participants (22 out of 40) mentioned the lack of science memories, or described traditional teaching strategies. One participant illustrated this idea by describing her science memories: 'I can remember being in elementary school and vaguely remembering science at all. It was you have a workbook and you read out of your workbook and then you write down what your book says in your workbook.'

Table 2. Predictors for science and mathematics teaching self-efficacy beliefs.

Science Variables	*B*	SE	*Beta*	*t*	*p* <
Science PCK Time1 (predictor of Science Outcome Expectancy Time2)	97.38	.224	.444	1.99	0.05*
Science Personal Efficacy Time1 (predictor of Science Personal Efficacy Time2)	516.47	.113	.789	6.98	.00**
Science Outcome Expectancy Time1 (predictor of Science Outcome Expectancy Time2)	169.49	.174	.559	3.20	.00**
Science Personal Efficacy Time1 (predictor of Science Personal Efficacy Time2)	826.49	.142	.909	6.38	.00**
Science Outcome Expectancy Time1 (predictor of Science Outcome Expectancy Time2)	287.09	.204	.648	3.17	.00**

*$p < .05$; **$p < .01$ (multiple regressions).

Table 3. Major themes.

Theme	Categories	Description
I. Previous academic experiences	(a) Memories of K-5 mathematics and/or science	• Difficulty in remembering meaningful learning in mathematics and/or science • Memories of how mathematics and science were taught
	(b) Weak academic mathematics and/or science experiences	• Lack of mathematics and science preparation • Difficulty in translating the mathematics high-level content (i.e. calculus) to K-5 curriculum and teaching • Lack of experience with informal/outdoor science activities and/or mathematics
	(c) Strong academic mathematics and/or science experiences	• Strong mathematics and science preparation • Enriching experiences with informal mathematics and/or science activities
II. PCK Beliefs	(a) College coursework (mathematics and/or science) influenced their thinking about mathematics and science teaching	• Coursework and methods courses influenced or changed the way they think about mathematics and science teaching • Need to better understand the K-5 curriculum and standards and what is expected of students
	(b) College field experiences (math and/or science) influenced their thinking about mathematics and science	• Relevant K-5 field experiences • Use of formative assessment • Support from mentors
III. Personal Efficacy	(a) Science teaching efficacy (b) Mathematics teaching efficacy	• Content mastering • Curriculum changes (i.e. new standards in science) • Sufficient or insufficient teaching practice • Personal interest (or lack of interest) in mathematics or science

(*Continued*)

Table 3. (*Continued*).

Theme	Categories	Description
IV. Outcome Expectancies	(a) The impact they would have on student learning (mathematics and/or science)	• Confident in planning lessons for developing conceptual understanding versus procedural knowledge • Their students will be able to apply knowledge (in practice, in real life)
V. Emotions	(a) Positive emotions about mathematics and/or science teaching	• Feel excited, determined, happy
	(b) Negative emotions about mathematics and/or science teaching	• Feel overwhelmed, anxious, unhappy

When talking about the quality of their previous academic experiences, a relatively higher number of participants (20 out of 40) expressed the idea that they had weak academic experiences in mathematics and science, compared to those who expressed in their interviews that they had strong academic experiences in mathematics and science (11 out of 40). The lack of strong academic preparation seemed to be contributing to feelings of low personal efficacy in science or mathematics teaching. One participant illustrated this view by explaining her science experiences:

> In science you talk a lot about teachers maybe lacking that confidence in the content knowledge and that's why they avoid it. Math can be cut and dry so you're like I know it or I don't know it, but science has a lot more discussion and it's a lot more in depth; it's such an abstract thing. It has so much more potential than what it traditionally looks like and what I guess I grew up with. Science falls in the background; with science I always felt kind of intimidated.

Another participant illustrated the same idea when talking about her mathematics learning experiences; asked to discuss the subject areas where she felt least confident to teach, she said:

> My math experiences when I was younger was very sequenced in steps. It was here's how you do it, go practice. I was shown all different types of ways to practice. When I was younger, it was here's your book, do 10–25. I never really liked math. It didn't come naturally to me. I always had to work really hard at it. So that's probably my least favorite and least confident – because I don't enjoy it.

Participants also acknowledged the significant role their K-5 previous academic experiences played into their thinking about how they will teach mathematics and science, and shaped their expectations about the quality of teaching. Here is one example from an interview:

> We never really did science when I was in elementary school, we didn't. I can remember maybe putting a balloon over a bottle and putting maybe baking soda in the bal-

> loon, that's really, honestly, that is all I remember. And so I just expected not to really have to teach science, and now they're pushing for it.

Another participant expressed a similar idea by describing her mathematics experiences based on a traditional teaching approach and how her views of mathematics teaching changed only because of the methods courses she took during the teaching preparation program:

> With math, I was taught a totally different way, like memorization, multiplication tables. Coming in, I didn't have that methods course, I would teach the same way. But now, they gave us a whole different way to go about math and workshops and manipulatives we can use and the resources we can bring into the classroom. That definitely changed. I think the way we learned was the old school way and it's no research behind.

Mathematics and science PCK beliefs

Interview records about participants' mathematics and science PCK beliefs revealed that the methods courses in their teacher preparation program and their field experiences were the two main factors that contributed the most to the development of their PCK. The vast majority of participants (37 out of 40) acknowledged the positive impact of their methods courses. Participants' descriptions of their learning experiences in the methods courses were most of the time enthusiastic and appreciative. One participant illustrates this point by saying:

> The STEM – having that STEM title to our program changed my old-fashioned ways of how I had seen things done. I saw a lot of lecturing when I was younger and I didn't see as much hands-on, I didn't see as much of the creative, engineering type. I of course did not see the technology. So seeing that has brought all different ideas into my mind. I have way more background with these things I was previewed to in my classes. So having that STEM, taking the engineering course was absolutely awesome. Working so hard in the science and the math stuff changed my way – I can use science and math to teach any other subject. Having that STEM focused changed my outlook on all of it.

Participants also recognized that they do not expect to learn all the content they would need to teach in elementary school during their mathematics and science college coursework, and that in their methods courses they learned valuable learning skills as future researchers and lifelong learners. Here is an example from an interview: '[The teacher preparation program showed that] you have to do a lot of research and how to find good research … You can't expect kids to understand if *you* don't understand completely.' Another participant described her realization, 'I had to do a lot of research before I would teach science to make sure I knew.'

Furthermore, when talking about their methods courses participants also recognized how their thinking about teaching changed because the coursework challenged and addressed the common misconceptions they held about teaching strategies or terminology (i.e. hands-on is not the same as experiments). Here is an illustrative quote:

> One thing that's changed [from the program] is thinking about experiments. If I get the kids up and going, then they're learning something and that's not actually true. They actually have to have structure and there has to be questioning and higher level

> thinking. You can't just throw an activity in front of a kid and expect them to know everything.

Another important element in participants' development of their PCK, according to their interviews, was their K-5 field placement. The majority of participants (28 out of 40) stated that their field placement was crucial for their learning about mathematics and science teaching. Participants described their field experiences as extremely helpful and relevant for their teacher preparation. One participant illustrates this point by comparing the methods courses and field placement:

> The field experience with the methods course [helped her teaching development]. I would say all of it, I can't really pick one thing, but if I had to pick, the field experience, being in the classroom, you can be in a college classroom and they can tell you all you want, they can feed you all this information, tell you all these ideas, but until you're actually trying to implement them or until you're watching other people actually implement them, it doesn't become real. And so the field experience, I learned so much just being in a classroom with kids and a teacher.

Personal efficacy

Across interviews, participants expressed different levels of mathematics and science teaching efficacy. Although all participants took two methods courses in both mathematics and science teaching during their teacher education program, the range of their efficacy varied. When talking about their science teaching efficacy, more participants (19 out of 40) expressed low science teaching efficacy beliefs compared to those who expressed high teaching efficacy beliefs (16 out of 40). Feelings of low science efficacy were generally associated by the participants with lack of personal interest in science, lack of strong science knowledge and lack of effective models in K-5 science teaching, or lack of value placed on science teaching at the elementary level. One participant illustrated this idea by saying:

> [Not confident]. Science once again. Just because I can easily take a science lesson and teach it, but I'm just not as confident in the content. With some science topics I am, but not across the board. I feel in order to be an expert on the science topic I'd have to do a whole lot more research than a math topic, so it's just more work for me which is fine, you have to do what you have to do, it just doesn't come as easy to teach science.

For those who expressed high science efficacy beliefs, science was described as fun, they have a personal interest in it, and they possess the knowledge and skills to teach it. One participant explained, 'Science I feel really confident in because we had the two methods courses about it. I was able to learn how to teach science, how to teach it through inquiry. Kids love science so much.' Among participants with high science efficacy, some described their developing efficacy in science as related to their recognition of applications of science in their world. One explained, 'I used to say "I don't see how science connects to my daily life," and now I can't go a day without thinking about or seeing how science connects with my daily life.'

When talking about their mathematics teaching efficacy, more participants expressed high mathematics teaching efficacy beliefs (17 out of 40) in their interviews compared to those who expressed low teaching efficacy beliefs (10 out of 40). Participants with low efficacy beliefs, generally talked in their interviews about the fact that they never enjoyed learning math, they lack mathematics knowledge, and had difficulties in relearning math in their methods courses – how math was presented in K-5 was very different than how math was taught in their methods courses. Here is an illustrative quote:

> I am not a math person. I never liked math, I've never really been good at math. I feel like I've put a lot more effort into math, therefore I don't feel as comfortable. It's very much because it's my weak spot, therefore I don't feel confident. To me, it doesn't matter how well I've been prepared, it's still my lack of mathematical knowledge liking that makes me uncomfortable with it. I'm very prepared by [university] as far as math goes, I know where to go to get the resources that I need, but just because I don't like math, it's where I feel the least confident.

Among those who felt efficacious in their mathematics teaching, they generally talked about the fact that they had strong mathematics knowledge, or they had a talent and personal interest for mathematics, or had inspirational former teachers. Also, they mentioned that their methods courses helped to improve their mathematics teaching efficacy because they re-learned math in these courses. While their previous experiences had been procedural and memorization based, the mathematics methods courses helped them conceptually understand mathematics. One participant expressed this idea: 'So I think learning how to teach math conceptually was the biggest thing for me. Learning how to teach something, instead of just saying, "Here are the steps. This is what you do to get this answer."' Another participant felt that rather than focusing on the high-level mathematics content in her college courses, the methods courses have helped her develop 'a much better understanding of the content and how to break it down into the basics for the students.' These experiences increased participants' mathematics teaching efficacy:

> I don't think it will be as hard for me anymore because I felt we were so well prepared. Before it kind of freaked me out a little bit because math wasn't always my favorite subject. But I know it doesn't have to be my favorite subject to teach it well and as long as my bases are covered and I can come up with new ways to explain things I stay enthusiastic about it.

Outcome expectancies

An interesting theme in participants' interviews that emerged was related to their views of the impact they would have on their future students' learning and lives. While only a small number of participants (15 out of 40) talked about the outcome expectancies, data revealed that these participants briefly described future learning goals and mentioned the desire to promote curiosity about the world among their students and to support students' basic mathematics and science literacy. Participants envisioned how they could support their students to begin to examine the world around them and ask questions about what they see going on in their everyday lives and be able to apply their knowledge to real-life situations. One participant said, 'When I was in elementary school I don't remember doing science at all. I love to teach science and the kids love science. It's the stuff that they see every day and they like too so they are curious about things which is good. Keeps their curiosity alive.' Another participant gained insight in science teaching from science methods courses and her outcome expectancies benefited from example science lessons modeled in class:

> This whole inquiry-based thing, I'd never really heard of it, it just seemed like it would be so much a handful to let them do their thing for a few minutes and then go back and try to redirect their thoughts. But it really helps them; they're constructing their own knowledge and making their own meaning.

Improvement in outcome expectancies for student mathematics learning was evident in participants' interviews. While discussing her increased mathematics teaching efficacy, one participant stated, 'My kids are going to learn and they are going to do well …. I know I can do this, it might not be my best subject, but I'm going to be effective teaching it.' Learning how to prepare her lessons and improve her own understanding of the topics was key for making her feel like she could help her students succeed.

Emotions

Emotions were referred to during the interview when participants talked about their efficacy (or lack of) in teaching mathematics and science. Positive and negative emotions were mentioned alike, such as excitement about starting a new career soon, but nervousness and anxiety about providing quality teaching and aligning their teaching to new standards in mathematics and science. Not all participants described emotions in their interviews as related to mathematics and science teaching; only 22 mentioned positive emotions and only 13 mentioned negative emotions as related to mathematics and science teaching. Many of the negative emotions that were described reflected the initial fear of teaching mathematics or science. 'I always hated science. When I was in school growing up I hated science, it was hard for me. I didn't like it, I didn't get it. I know that sounds bad being a teacher.' The negative feelings (i.e. being overwhelmed) were described when talking about their preparation in the general education courses. As generalists, elementary teachers have to teach all subject matters, so participants recognized the fact that peers who major in science or mathematics education for instance are specialized in one area and might have stronger domain knowledge:

> I guess I was just worried the most about it and coming into the program they helped me fall in love with science, they showed us all the different things I can do and now I love doing it in the classroom.

While discussing mathematics teaching, past experiences seemed to greatly influence participants' attitudes towards mathematics teaching. For many of the interviewees, these feelings had remained constant through much of their school experiences. Significant changes in their attitudes towards mathematics teaching occurred while in the two mathematics methods courses, which focused on re-learning mathematics conceptually.

Discussion and conclusion

The aim of the current study was to explore elementary preservice teachers' efficacy beliefs as related to their mathematics and science PCK and DK, as well as their views about the STEM training in the teacher education program. Research suggests that changes in teachers' beliefs are a crucial precursor to real change in teachers' instructional practices, especially when they need to adopt reform recommendations in order to meet the quality teaching standards imposed by the state (Smith and Southerland 2007; Thomson and Gregory 2013).

Findings from our study show that relationships between preservice teachers' efficacy beliefs, PCK and DK are complex and interconnected. Quantitative analysis revealed that participants' PCK and efficacy beliefs correlate to a high degree and influence each other. Also quantitative findings indicated that participants' mathematics and science DK did not predict their teaching efficacy beliefs, however, their mathematics and science overall PCK score (time 1) predicted participants' efficacy beliefs, more exactly, their (time 2) outcome expectancies.

These findings may suggest that PCK could be more important for the development of preservice teachers' mathematics and science efficacy beliefs than their DK, or that their PCK is a better indicator of their teaching efficacy beliefs compared to their DK. Interestingly (and maybe unfortunately), DK is most of the time the main focus of teacher education programs and professional development programs for teachers. Developing teachers' DK is evidently important, but even more important is the development of their PCK that may increase their mathematics and science teaching efficacy, and help implement successful teaching strategies. Recent findings (i.e. Buss 2010; Hill, Rowan, and Ball 2005) pinpoint to the increased attention that teacher education programs need to place on developing preservice teachers with strong PCK and subsequently a specialized mathematics and science DK (especially at the elementary level). Researchers of primary preservice teachers in Australia (Appleton 2003; Appleton and Kindt 2002) described the importance of PCK development through preservice teachers' experiences in the coursework. Appleton and colleagues recommend that teacher educators make efforts to provide positive science teaching experiences to preservice teachers, which is crucial for the their development of PCK. Additional research from the Netherlands (Velthuis, Fisser, and Pieters 2014), Australia (Palmer 2006) and the UK (Jarvis and Pell 2004) showed that general science course content as well as the methods courses that preservice teachers took during their teacher training had an impact on increasing their efficacy especially in their early years of training. In addition, exposure to science teaching experience in their K-5 field placements contributed to higher levels of participants' personal self-efficacy for science teaching. This is important to notice, given the fact that research shows that elementary school teachers tend to avoid teaching science for many reasons including weak or absent models for effective elementary science instruction (Tilgner 1990).

Furthermore, our results show that elementary preservice teachers' previous efficacy beliefs are more likely to predict their future efficacy beliefs than their mastery of DK and PCK. Findings from other studies conducted with K-12 students (i.e. Eccles 1983; Wigfield and Eccles 2002) revealed that participants' efficacy beliefs were strong predictors of student achievement compared with test scores or course grades. These studies consistently showed that student self-perceptions of their efficacy beliefs (i.e. perceived abilities and expectancies for success) were the strongest predictors of subsequent grades in mathematics and English and were better predictors of students' later grades than were students' previous grades.

Other studies found that preservice teachers' efficacy beliefs are strong predictors of learners' effort and persistence in professional and academic domains. Watt and Richardson (2008) in a study of Australian preservice teachers showed that participants' ability beliefs and persistence were predictors of their teaching motivation and professional commitment. Charalambous and Philippou's (2010) study conducted in Cyprus showed that teachers' efficacy beliefs about implementing reform in their instruction affect their task choices and consequently fuel concerns about how to translate reform into their classroom teaching.

The qualitative results in our study augmented the quantitative results and revealed the complexity of participants' thinking about their teaching practices and efficacy to implement quality science and mathematics teaching in their future classrooms. Participants generally expressed in their interviews the importance of gaining solid pedagogical preparation during the teacher education program in order to be able to teach at higher levels to their students. Research shows that elementary teachers most often leave their teacher education programs with limited mathematics and science PCK and DK, but are required to adopt reform STEM initiatives and adequately prepare their students for national tests (Hill, Rowan, and Ball 2005; Hill, Schilling, and Loewenberg Ball 2004). Australian researchers have found that more science DK does not necessarily support preservice teachers' understanding of reform, or their ability to adopt reform in teaching (Skamp and Mueller 2001). Additional findings (Palmer 2006) with Australian preservice teachers suggest that PCK was the main source of efficacy for preservice teachers and not DK. In a study of preservice teachers from Cyprus (Charalambous, Philippou, and Kyriakides 2008) findings revealed that participants' efficacy beliefs were developed mainly via social cognitive learning, such as experimentation with teaching, and interaction with mentors, tutors, peers and students.

In preparing teachers to effectively meet the challenges posed by reform initiatives to prioritize quality science and mathematics teaching in the elementary classrooms, it is important to acknowledge the crucial role teachers' beliefs (i.e. efficacy beliefs) play in bringing about necessary reform-based pedagogical strategies (Lumpe et al. 2012; Smith and Southerland 2007). Teachers need to feel capable of successfully implementing reform strategies in their classroom, and one way to accomplish this goal is to create and promote adequate professional training to elementary teachers in mathematics and science teaching. Because the elementary teachers are trained as generalists, their mathematics and science PCK and DK might be weaker compared with their counterparts, middle and secondary teachers, who are trained and are specialized in one content area only (e.g. mathematics or science or history).

Implications, future research and limitations

Study implications can be helpful for both, the teaching practice and the research regarding elementary teacher preparation. Findings from our study can help teacher educators, researchers, and policy makers in better comprehending elementary teachers' specialized preparation (i.e. PCK and DK), their views about the teacher preparation program, and their mathematics and science teaching efficacy beliefs. Additionally, findings from our study can help policy makers think about the types of support that elementary teachers need *during* and *after* their four years of college preparation, in order to be successful in their mathematics and science teaching once they are in the profession. Current reform calls in the US, UK and Australia aim at improving teacher practices once they are in the field, but as well aim at improving their teacher preparation during college (e.g. Palmer 2006; Sharp, Hopkin, and Lewthwaite 2011).

Some of the limitations of our study are related to demographics; all participants were white females, trained in a traditional teacher education program (four-year college degree program) at a large university. Their views about teaching could be different than other teacher candidates educated in a non-traditional teacher training program (i.e. small, private colleges or alternative teacher certification programs). Future research should seek the support of multiple disciplines and methods to better evaluate teacher preparation programs and the impact of program preparation on teachers' classroom practices once they are in the field.

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