An Investigation into Teacher Candidate Self-Efficacy as a Result of a STEM Professional Development School Program

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Abstract: With shortages in the STEM workforce, it is important to foster children’s interest in STEM subjects at early ages. New teachers must be prepared to engage learners in STEM experiences upon their entry into the profession. This study investigated the impact of a STEM professional development school (PDS) on teacher candidate (candidate) self-efficacy. Embedded within an introductory educational technology course, the PDS engages candidates in planning, teaching, and evaluating integrated STEM lessons to elementary students throughout the semester. Data were collected from PDS and non-PDS candidates enrolled in different sections of the same course. A teaching self-efficacy survey was used to measure candidate self-efficacy at the beginning and end of the semester. Data were analyzed using descriptive and inferential statistics. Findings indicated statistically significant increases over time with medium effect sizes for both PDS and non-PDS candidates, however, only PDS candidates experienced a calibration of their beliefs.

Introduction

Currently there are not enough STEM workers to fill STEM jobs in the U.S. (Fayer, Lacey, & Watson, 2017; National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007; Xeu & Larson, 2015). By 2026, 3.5 million computing-related jobs will be available, but most will go unfilled as there will only be enough graduates from US colleges and universities to fill approximately 17 percent of those positions (National Center for Women and Information Technology, 2018). As schools and teacher education programs have attempted to better prepare and increase K12 student interest in STEM disciplines, efforts have primarily occurred in secondary school settings, which likely is too late to adequately interest learners in STEM (Gibson, 2012). Additionally, many teachers lack the knowledge, skills, self-efficacy, and beliefs needed to effectively implement quality STEM learning experiences for their students (Barr & Stephenson, 2011). As teacher education programs have worked to better prepare teacher candidates (candidates) for teaching integrated STEM lessons, most effort has been on the integration of Science and Mathematics, with technology and computational thinking often overlooked (Herschbach, 2011; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). Therefore, a critical issue facing teacher education is how to prepare candidates to effectively teach integrated STEM lessons where educational technology and computational thinking have a central role. The purpose of this study was to expand the literature by investigating the influence of a STEM professional development school (PDS) program on the beliefs that candidates maintain about their ability to develop and teach integrated STEM lessons (i.e., self-efficacy).

Integrated STEM
There is no agreed upon definition of integrated STEM Education in the literature, although it has been defined as the combination of two or more STEM disciplines within a single learning experience (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Honey, Pearson, & Schweingruber, 2014). These experiences tend to be mostly design-based where engineering-oriented activities become the catalyst for problem-solving as part of an authentic issue or context (Honey et al., 2014; Kelley & Knowles, 2016). The integration of STEM subject areas has also been found in both the Common Core State Standards for Mathematics and the Next Generation Science Standards, which recommend learners engage in asking questions, modeling, planning and carrying out investigations, analyzing and interpreting data, computational thinking, developing innovative solutions, and communicating results (Honey et al., 2014).

There are several benefits of integrated approaches to teaching STEM, such as increased content relevancy and learner engagement as concepts are connected across disciplines (Frykholm & Glasson, 2005; Koirala & Bowman, 2003; Jacobs, 1989). Researchers have also found that in integrated STEM experiences, learners engage more in critical thinking, problem-solving, creativity, and are more successful at retaining what they have learned while also becoming more self-reliant and technology literate (Ellis & Fouts, 2001; Ge, Ifenthaler, & Spector, 2015; King & Wiseman, 2001; Morrison, 2006; Smith & Carr-Kidwell, 2000). Bragaw, Bragaw, and Smith (1995) found that the integration of Math and Science content led to positive student attitudes towards both subjects, while Guthrie, Wigfield, and VonSeck (2000) found students were more motivated to engage in learning.

Although there are several benefits to teaching integrated STEM lessons, Armoni (2012) raised a concern that younger children may struggle to learn due to the demands of abstract thinking often found in STEM learning experiences. Perhaps more problematic, however, is the lack of knowledge, skills, self-efficacy, and beliefs teachers have about STEM disciplines. Multiple researchers have argued this is due to the limited exposure to STEM during initial teacher preparation (e.g. Corcoran, 2009; Eilks & Markic, 2011; Weiss, Bamlower, McMahon, & Smith, 2001). Therefore, it should come as no surprise that teachers have lower confidence and negative beliefs about STEM subjects (Appleton, 2003; Dembo & Gibson, 1985; Epstein & Miller, 2011; Sterling, 2006; Weiss et al., 2001), especially in the context of integrated STEM where technology and computational thinking are emphasized as those areas have rarely been the focus of integrated STEM efforts (Herschbach, 2011; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). It is imperative that teacher education programs better prepare candidates by exposing them to integrated STEM learning experiences and do so in ways where technologies and computational thinking have a central role.

**Candidates’ Self-Efficacy & Teaching with Technologies**

Teachers’ lack of confidence and subsequent resistance to integrated STEM with a technology and computational thinking focus should be expected given the lack of emphasis on STEM instructional practices when their beliefs systems were developed (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013; Collins & Halverson, 2009; Parette, Quesenberry, & Blum, 2010). Confidence, or self-efficacy, is a fluid belief that changes as a result of everyday experiences (Bandura, 1977, 1986, 1997). As individuals experience success and failures while completing a task, they gain knowledge that allows them to better judge how well they can complete a specific task (Bandura, 1997; Brown & Lent, 2006; Lent, Brown, & Hackett, 1994; Usher & Pajares, 2008). Self-efficacy is most strongly influenced by personal experiences where mastery in a task can be achieved, but can also be influenced by other experiences, such as (a) vicarious experiences where others, including their successes or failures in a given activity, can be observed, (b) persuasion where feedback can support and convince individuals they are capable of completing a task, and (c) emotional reactions where arousal can drive individuals’ beliefs about needing to be successful (Bandura, 1977, 1986, 1997). Typically, when individuals have higher self-efficacy beliefs, they are more motivated to engage in novel experiences, even if they prove to be more complex and difficult (Bandura, 1997; Gonida & Leonardi, 2011; Klassen, 2006; Schunk & Pajares, 2009). However, the process of calibration, by which individuals iteratively align their perceived abilities to better reflect their actual abilities (Bandura, 1986, 1997), can prove to be beneficial in promoting conceptual change (e.g., “I’m not really as good as I thought I was; I need to learn more”; Siwatu & Chesnut, 2014) and establishing initial beliefs about ability (e.g., “this isn’t that hard; I can do this with a little more work”; Wheatley, 2002).

A teacher’s self-efficacy can be described as the beliefs that a teacher maintains about his or her ability to plan and teach a lesson to meet specific learning targets (Gavora, 2010). Teacher self-efficacy has been consistently found to promote teacher longevity and commitment to the profession, culturally responsive practices, and accommodations for special needs students (Chesnut, 2017; Chesnut & Burley, 2015; Chesnut & Cullen, 2014; Lam, 2015; Siwatu, Chesnut, Alejandro, & Young, 2016; Siwatu, Putnam, Starker, & Lewis, 2015). Research in teacher integrated STEM self-efficacy is quite sparse. In one of the few studies available, a professional development institute that culminated in the implementation of integrated STEM lessons by practicing teachers found teachers’ self-efficacy had increased at statistically significant levels (Knowles, 2017). In this study, how self-efficacy
developed followed differing trajectories, where Science teachers experienced significant growth initially, while Technology teachers experienced significant growth in their self-efficacy after implementing an integrated STEM lesson. Given the overall lack of studies detailing approaches to teacher integrated STEM self-efficacy development, including the impact of those approaches, it is logical to examine how self-efficacy develops in contexts other than STEM. One area of specific interest is candidate self-efficacy development in PDS programs.

Professional Development Schools

Emerging from situated learning experiences (Lave & Wenger, 1991) where candidates learn through embedded field- or place-based experiences, PDS programs are formed as part of university and school partnerships where both institutions agree to work together in the preparation of new and current teachers (Castle, Fox & Fuhrman, 2009; Castle, Fox, & O’Hanlan Souder, 2006; Long & Morrow, 1995; Mourlam & Montgomery, 2015; Tusin, 1992). There are several design elements that characterize PDS programs, but perhaps most important of which are having a shared vision and clear communication among stakeholders, in addition to other aspects such as professional learning opportunities for all partners, and a commitment to innovation and reflection (Goodlad, 1993; Heil, 1986; Killion, 2011; National Association for Professional Development Schools, 2008; Nelson, 1986; Williams, 1986). When successful PDS partnerships exist, candidates are positively impacted in multiple areas, such as licensure exam pass rates, self-efficacy, teacher professionalism, and pedagogical knowledge (Castle et al., 2009; Castle et al., 2006; Houston, Hollis, Clay, Ligons, & Roff, 1999; Levin & Rock, 2003; McDermott, Gormley, Rothenberg, & Hammer, 1995; Reinhartz & Stetson, 1999). In one study, candidates appeared to take more ownership of their learning through their use of more personal possessive adjectives: “almost as if the non-PDS teacher candidates were practicing for the real thing while the PDS teacher candidates were doing the real thing” (Castle et al., 2009, p. 66). Given the success of PDS programs in contexts other than STEM education, and that to the best of the authors’ knowledge no STEM PDS currently exists in the extant literature, the following research questions guided this study: (a) to what extent do candidate self-efficacy beliefs change during the course of a semester for those enrolled in the PDS program and those not enrolled in the PDS program? and (b) to what extent does participation in the PDS program influence candidate self-efficacy beliefs at the end of the semester, controlling for prior self-efficacy beliefs?

Methods

This study took place at ABC University, a medium-sized research university in the midwestern region of the US with an approximate undergraduate teacher education program enrollment of 450 students. The university is in a community of approximately 10,000 people with an annual K12 enrollment of approximately 1,300 students in the public-school system. While most children in the community are Caucasian (76%), there is a relatively high number of Native American students (10%), as well as students from economically disadvantaged families (30%).

The STEM PDS Program

The STEM PDS program was implemented in an introductory educational technology course typically taken by freshman and sophomore level candidates seeking initial teacher certification in elementary education. Candidates enrolled in the course are typically also concurrently enrolled in separate field experience and foundations of American education courses. In this course, candidates learn about a variety of educational technologies (i.e. iPads, interactive whiteboards, Google Drive, etc.) and how they can be used during instruction to support student learning. This course has a specific focus on the integration of educational technologies through graphical-based coding with the other STEM subjects, in addition to other topics such as digital citizenship and media literacy. Built upon design-based learning experiences, the PDS program has also been designed to support candidate engagement in mastery and vicarious experiences, and persuasive feedback from peers and their professor as they learn about integrated STEM teaching approaches that they then implement as they plan, teach, and evaluate integrated STEM lessons to elementary school students throughout 12-weeks of the semester.

Candidates engage in a variety of activities within the PDS program designed to impact their self-efficacy, in addition to their knowledge and beliefs about integrated STEM (see Figure 1.). Typically, candidates plan and teach four integrated STEM lessons that they will teach throughout the semester. Candidate lessons are designed to be collaborative, problem- and design-based experiences for elementary learners. Each lesson includes content from at least two of the STEM subject areas, and are aligned with state content standards and ISTE Standards for Students. In the sections that follow, the process through which candidates progress as they engage in lesson planning, implementation, and evaluation is described.

Figure 1. STEM PDS Elements
Lesson modeling & practice. Candidates first engage in the STEM PDS through lesson modeling and practice as part of problem-based learning experiences related to the STEM lessons they will teach to elementary students. This occurs intensively in the first four weeks of the course, then periodically throughout the remainder of the semester. As part of lesson modeling, candidates take on the role of elementary student and vicariously learn about an integrated STEM instructional practice by watching their professor model all aspects of the lesson. As part of this experience, there are opportunities for candidates to develop mastery of the targeted elementary content standards, the modeled teaching strategies, and the technology tools used in the lesson. Mastery experiences exist in the form of practicing each component of the STEM lesson through a problem-based learning instructional approach. For example, in a STEM lesson where candidates teach third graders to create interactive posters similar to a museum exhibit on world climates, the professor first introduces and explains each part of the lesson before candidates complete the lesson as though they were the elementary student. In this lesson, candidates, and eventually third graders, are asked to: (a) research world climates using reliable online resources, (b) compile and present key information about two world climates on a poster, (c) create original artwork of plants and animals located in the climate, as well as graphs comparing weather data from each climate, (d) code a computer animation to share information about their climate using the online coding application Scratch, (e) use a technology called Makey Makey that creates an interactive connection between the poster and the Scratch animation using with areas on the poster that conduct electricity (e.g. aluminum foil “buttons”), and (e) present their final products and what they learned to peers. The professor walks candidates through each part of the lesson by showing examples, demonstrating technology, and facilitating small and large group discussions. As candidates complete the STEM lesson, they apply prior knowledge from earlier course units. In the example lesson on world climates, this would include content knowledge about media literacy and computational thinking topics candidates learned in prior units, such as identifying trustworthy sources, citing sources, and debugging a computer program. This results in multiple pathways for learning to achieve the same learning objective and ultimately forms the foundation for candidate lesson plans. It is through this problem-solving that candidates’ knowledge of course themes are reinforced.

Lesson planning. At the beginning of the semester, candidates are introduced to lesson planning through multiple in class activities. This begins with a broad overview of constructivist and constructionist learning theories, the components of a lesson plan and their function, and an opportunity to review and deconstruct exemplar lesson plans. Then, in teaching teams of two, after lesson modeling has concluded, candidates create their own lesson plan to be used when they teach elementary students. Candidate lessons are required to use an engineering design process to structure the learning process elementary students progress through. A lesson plan template is provided to support candidates due to their lack of experience creating lesson plans. The following information is provided: (a) targeted South Dakota content standards, (b) learning objectives, (c) suggested materials and equipment, and (d) broadly stated recommended activities, such as a lesson opener or a key activity like researching world climates. Candidates then design the instructional sequence by selecting and organizing activities that align and fit with lesson content topics and technologies. It is through this lesson design process that candidates engage in mastery experiences where their knowledge, self-efficacy, and beliefs are developed.

Professor feedback. Lesson plans are reviewed by the candidates’ professor before candidates teach. Substantial feedback is given to each candidate regarding lesson design to: (a) identify any gaps within the instructional sequence, (b) ensure content topics are adequately addressed, (c) determine the suitability of questioning and formative assessment strategies, and (d) to evaluate lesson technology integration. In doing so, the professor is able to motivate candidates by confirming successful practices demonstrated in lesson plans and persuade candidates to change specific areas of their lesson planning by addressing any misconceptions they may have that would ultimately lead to an unsuccessful lesson. Candidates then make lesson revisions and resubmit their lessons for additional feedback. This feedback-revision process continues until the professor believes candidates are prepared as evidenced through well designed lesson plan.

Lesson implementation. Candidates, in teaching teams, teach their one-hour lessons to small groups of elementary learners following a co-teaching framework where one candidate leads instruction and the other observes. Elementary student groups typically range in size from 3-5 students depending on total grade level enrollment. During lesson implementation, candidates serve as lead teachers for elementary students while inservice teachers are available to support both candidates and elementary students. This often occurs with special elementary student learning needs or classroom management related issues. During lesson implementation, the professor observes candidates teaching their lessons, providing support as needed. Each lesson is taught twice to different groups of elementary learners where candidates alternate between lead teacher and peer observer weekly.

Peer observation. During lesson implementation, in teaching teams one candidate observes for lesson strengths and weaknesses, learner engagement and understandings of the content, as well as any aha moments for future lesson use. Observing candidates also assist in the lesson as needed. Often this includes answering elementary
student questions, retrieving any additional materials and equipment needed to complete the lesson, and troubleshooting any technology issues that occur.

**Reflective dialogue with peers & professor.** Each week after the one-hour lessons conclude, candidates engage in reflection and dialogue about their performance beginning with a reflective journal entry. Candidates’ journaling encompasses lesson successes, concerns, and questions. Teaching teams then discuss the peer observer’s notes to reflect on the overall success of the lesson, including any necessary lesson revisions. Finally, as a class, the professor poses multiple discussion prompts for candidates to openly reflect on, such as lesson success, classroom and behavior management, and lesson difficulties. Discussion concludes with the professor providing feedback from observations, noting individual candidate successes and areas for growth shared by all candidates. Reflective dialogue sessions with candidates provides the opportunity to both motivate them by reaffirming their interactions with elementary students, while also assisting with the development of their knowledge and beliefs as they are encouraged to try new strategies to better meet the needs of the learners and lesson objectives.

**Data Collection & Analysis**

Following Institutional Review Board (IRB) approval for existing data use, self-efficacy data were collected from a program evaluation survey used by the School of Education for accreditation and program renewal. The survey, which is completed at the beginning and end of the semester for all candidates, includes items from a teacher self-efficacy survey instrument (Skaalvik & Skaalvik, 2010). The teacher self-efficacy survey consists of six dimensions, including (a) instruction, (b) adapting education to individual students’ needs, (c) motivating students, (d) keeping discipline, (e) cooperating with colleagues, and (f) coping with changes and challenges. Each dimension included four items for a total of 24-items where candidates responded using a 7-point scale ranging from “Not certain at all” (1) to “Absolutely certain” (7). The survey was not modified from the original, which underwent construct validity testing through confirmatory factor analysis and structural equation modelling. Reliability testing in the original instrument resulted in alphas ranging from .81 to .90 for each dimension (Skaalvik & Skaalvik, 2010). Cronbach’s alpha was used to confirm reliability, resulting in an alpha of .97 for both the pre- and post-survey.

All analyses were conducted in R (R Core Team, 2019; v. 3.6.1) using a variety of base and add-on libraries available through the Comprehensive R Archive Network (Hornik, 2012). To answer the first RQ concerning the growth of candidate self-efficacy during the semester for those enrolled in and not enrolled in the PDS program, descriptive statistics for pre- and post- semester measures were calculated, along with paired samples t-tests. Cohen’s d effect sizes were calculated for each paired samples t-test using psych package (Revelle, 2018; v. 1.8.12) in R. To answer the second RQ, concerning the influence of the PDS program on candidate self-efficacy beliefs, after controlling for prior self-efficacy beliefs, a hierarchical regression was conducted predicting post-semester self-efficacy beliefs starting with prior self-efficacy beliefs, then adding the PDS program binary indicator (i.e., 0 = Non-PDS, 1 = PDS), and then allowing these predictors to interact, as would be introduced in a moderation analysis.

**Participants**

Participants (N = 71) were recruited from three sections of an introductory educational technology course taught in the School of Education at ABC University. Candidates in one section of the course (N = 24) participated in the PDS program embedded at a local elementary school (henceforth referred to as PDS), while candidates in the other two sections (N = 47) participated in just the lecture and lab-based learning experiences in their sections of the course taught on the campus of ABC University (henceforth referred to as non-PDS). Candidates enrolled in the PDS were primarily female (18) and were sophomores (15), juniors (7), or seniors (2), and identified as Caucasian (21), Hispanic (1), Hispanic and Caucasian (1), or African American and Caucasian (1). All candidates in the PDS were traditional college age, between the ages of 18 and 22. PDS candidates were primarily elementary education majors (21), nine of whom were also double majoring in special education. There was also one secondary education major, one physical education major, and one student that did not identify a major. Half of PDS candidates were also enrolled in a separate field experience course.

There were freshman (3), sophomore (40), junior (3) and senior (1) level candidates enrolled in the non-PDS sections of the course. Non-PDS candidates were primarily Caucasian (44) with one candidate identifying as both African American and Caucasian, one candidate identifying as Asian, and one candidate identifying Native American and Caucasian. Non-PDS candidates were mostly female (34) and generally traditional college age except for two candidates (one 26 years-old, one 29 years-old). Non-PDS candidates were majoring in elementary education majors (26), five of whom were also double majoring in special education, secondary education (16), and physical education (3). There was also one candidate that was a nursing major. Of the 47 non-PDS candidates, 32 were enrolled in a separate field experience course.

**Results**
Analysis of candidate responses on the teaching self-efficacy survey indicated that candidates in both the PDS and non-PDS sections had a moderate sense of self-efficacy at the beginning of the course (see Table 1). Those in the PDS were slightly higher (mean = 5.45) than their peers not enrolled in the program (mean = 5.27), but not significantly different ($t_{69} = 0.86, p(>|t|) = 0.390$).

| Group    | Pre- M (SD) | Post- M (SD) | Mean Diff | df  | t     | p(>|t|) | d  |
|----------|-------------|--------------|-----------|-----|-------|--------|----|
| PDS      | 5.45 (0.78) | 5.96 (0.67)  | 0.51      | 23  | 2.15  | 0.042  | 0.70|
| Non-PDS  | 5.27 (0.88) | 5.79 (0.70)  | 0.53      | 46  | 4.21  | 0.001  | 0.66|

Table 1. Self-efficacy beliefs before and after coursework

Responses at the end of the semester, indicated that the self-efficacy scores of candidates in both groups increased significantly, with medium effect sizes. As Figure 1A illustrates, candidates experienced parallel increases in their self-efficacy in both groups from the beginning of the semester to the end. Results of a paired-samples t-test indicated that for candidates in both groups, their reported increase in their self-efficacy was statistically significant with medium effect sizes.

To understand individual trend differences, a hierarchical regression was used. Table 2 summarizes the results. The first model was developed to predict candidate self-efficacy beliefs after coursework using responses collected prior to coursework. This model was not statistically significant ($F_{(1, 69)} = 3.971, p(>F) = 0.051$), and only accounted for 5% of the variance in self-efficacy beliefs after coursework. In the second model, the binary PDS variable was added as a predictor of self-efficacy beliefs after coursework. This model was not statistically significant ($F_{(2, 68)} = 2.265, p(>F) = 0.112$), only accounting for 6% of the variance in self-efficacy beliefs after coursework. The addition of PDS as a predictor only slightly improved model fit with the data ($\Delta SS = 0.27$), but was not statistically significant ($F_{SS} = 0.64, p(>F) = 0.423$). While one would typically stop the hierarchical regression when model additions fail to improve fit, the results from the prior analysis (i.e., significant gains in self-efficacy beliefs for both groups) made us question if the PDS was influencing the trajectory of the relationship between self-efficacy beliefs before and after coursework. In the third model, the interaction between the binary PDS and self-efficacy beliefs prior to coursework was added as a predictor of self-efficacy beliefs after coursework, to determine if being involved in the PDS moderated the gains in candidates’ self-efficacy beliefs. This model was statistically significant ($F_{(3, 67)} = 4.239, p(>F) = 0.008$), accounting for 16% of the variance in self-efficacy beliefs after coursework. The addition of the interaction significantly improved model fit ($\Delta SS = 3.27, F_{SS} = 7.74, p(>F) = 0.007$).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Residual SS</th>
<th>$\Delta SS$</th>
<th>F-value</th>
<th>p(&gt;F)</th>
<th>R$^2$</th>
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<tr>
<td>Pre Self-Efficacy</td>
<td>31.86</td>
<td></td>
<td></td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td>Pre Self-Efficacy + PDS</td>
<td>31.59</td>
<td>0.27</td>
<td>0.64</td>
<td>0.427</td>
<td>.06</td>
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<tr>
<td>Pre Self-Efficacy + PDS + (PDS*Pre Self-Efficacy)</td>
<td>28.32</td>
<td>3.27</td>
<td>7.74</td>
<td>0.007</td>
<td>.16</td>
</tr>
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</table>

Table 2. Hierarchical regression with model fit statistics

Results from the final model suggest that the relationship between self-efficacy beliefs before coursework and self-efficacy beliefs after coursework is moderated by participation in the PDS. These findings are summarized in Table 3 and illustrated in Figure 1B. For Non-PDS students, self-efficacy beliefs prior to coursework were significantly and positively associated with self-efficacy beliefs after coursework ($b = 0.342, SE = 0.108, \beta = 0.420, p(>|t|) = 0.002$). Conversely, self-efficacy beliefs prior to coursework were significantly and negatively associated with self-efficacy beliefs after coursework for the PDS students, with an unstandardized shift in the slope of $b = -0.568 (SE = 0.204)$ and a standardized shift in the slope of $\beta = -0.696 (p(>|t|) = 0.007)$. While results from the first RQ demonstrate that both PDS and Non-PDS make overall gains in self-efficacy beliefs, the overall trajectory is moderated by involvement in the PDS. More specifically, a candidate who had lower self-efficacy beliefs at the beginning of the semester continued to have a relatively low self-efficacy beliefs at the end of the semester. Even though there may have been statistically significant gains for non-PDS candidates, candidates retained the same relative positions in their distributions, pre- and post-coursework. Conversely, candidates with a relatively low appraisal of their self-efficacy beliefs initially ended the course with relatively high levels of self-efficacy, while those candidates starting high ended relatively lower in their respective distribution of scores.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>b (SE)</th>
<th>95% CI</th>
<th>(\beta)</th>
<th>t</th>
<th>p(&gt;\mid t\mid)</th>
</tr>
</thead>
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<tr>
<td>Intercept</td>
<td>3.989 (0.578)</td>
<td>[2.835; 5.144]</td>
<td>6.899</td>
<td>&lt; .001</td>
<td></td>
</tr>
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</table>
participation in a STEM PDS program can be understood. Doing so would likely prove valuable for programs
question in future research using a longitudinal design so that a more complete understanding of candidates'
as well as other areas of their development such as their knowledge and dispositions, as they progress through their
program may help candidates more accurately understand their beliefs regarding their ability to teach. This begs the
becoming candidates had more realistic appraisals of their self-efficacy beliefs, with some becoming
planned, taught, and evaluated their own integrated STEM lessons with a strong educational technology focus, PDS
overall for PDS candidates their self-efficacy remained relatively high). Therefore, at the end of the semester, having
adjusted their self-efficacy appraisals accordingly (some candidates adjusted down while others adjusted up, but
they were better able to understand their abilities teaching integrated STEM lesson in an authentic context and
undergo calibration in their beliefs (see also, Bandura, 1986, 1997). That is, as candidates participated in the PDS,
remained generally low in their self-efficacy compared to their peers in the Non-PDS), PDS candidates appeared to
trajectory (candidates who initially indicated low self-efficacy increased at a statistically significant level but
used to predict post-coursework self-efficacy beliefs. While non-PDS candidates remained consistent in their
coursework self-efficacy beliefs, the binary PDS variable (i.e., 0 = Non-PDS, 1 = PDS), and their interaction were
differences in candidate self-efficacy beliefs for those enrolled and not enrolled in the PDS program. As the results
indicated, both PDS and non-PDS candidates experienced statistically significant increases in their self-efficacy
from the beginning of the semester to the end. This is an important result, because it shows that participation in a
STEM PDS with an emphasis on educational technology can increase candidate self-efficacy in ways similar to a
traditional university classroom experience in educational technology. The results in this area are similar to those
from other studies where candidates have reported increases in their self-efficacy beliefs as a result of their
participation in a PDS program (Levin & Rock, 2003; Reinhartz & Stetson, 1999). Given the lack of studies on PDS
programs focused specifically on integrated STEM and educational technologies, additional research needs to be
conducted within these contexts to fully understand changes in candidate self-efficacy beliefs, and the practices
through which their beliefs are developed across different contexts and settings. This study detailed some of those
practices, but still represents only one approach with a limited sample in a unique context.
The first research question this study investigated was whether there were any statistically significant
differences in candidate self-efficacy beliefs for those enrolled and not enrolled in the PDS program. A hierarchical
regression showed differences between the two groups when pre-coursework self-efficacy beliefs, the binary PDS variable (i.e., 0 = Non-PDS, 1 = PDS), and their interaction were used to predict post-coursework self-efficacy beliefs. While non-PDS candidates remained consistent in their trajectory (candidates who initially indicated low self-efficacy increased at a statistically significant level but remained generally low in their self-efficacy compared to their peers in the Non-PDS), PDS candidates appeared to undergo calibration in their beliefs (see also, Bandura, 1986, 1997). That is, as candidates participated in the PDS, they were better able to understand their abilities teaching integrated STEM lesson in an authentic context and adjusted their self-efficacy appraisals accordingly (some candidates adjusted down while others adjusted up, but overall for PDS candidates their self-efficacy remained relatively high). Therefore, at the end of the semester, having planned, taught, and evaluated their own integrated STEM lessons with a strong educational technology focus, PDS candidates had more realistic appraisals of their self-efficacy beliefs, with some becoming more confident and others becoming less confident. This is an important finding because it demonstrates that participating in a STEM PDS program may help candidates more accurately understand their beliefs regarding their ability to teach. This begs the question, how does experiencing this calibration early in a candidate’s program of study impact their self-efficacy, as well as other areas of their development such as their knowledge and dispositions, as they progress through their degree program, in particular their methods coursework and clinical experiences? Researchers should explore this question in future research using a longitudinal design so that a more complete understanding of candidates’ participation in a STEM PDS program can be understood. Doing so would likely prove valuable for programs

Table 3. Results from final model predicting self-efficacy beliefs after coursework

Table 1. Illustrates the moderated relationship between pre- and post-coursework self-efficacy beliefs due to PDS.

Figure 1A illustrates parallel growth in self-efficacy beliefs from pre- to post-coursework. Figure 1B
illustrates the moderated relationship between pre- and post-coursework self-efficacy beliefs due to PDS.

Discussion

The first research question this study investigated was whether there were any statistically significant
differences in candidate self-efficacy beliefs for those starting with different levels of self-efficacy based on their
enrollment in the PDS program. A hierarchical regression showed differences between the two groups when pre-
coursework self-efficacy beliefs, the binary PDS variable (i.e., 0 = Non-PDS, 1 = PDS), and their interaction were
used to predict post-coursework self-efficacy beliefs. While non-PDS candidates remained consistent in their trajectory (candidates who initially indicated low self-efficacy increased at a statistically significant level but remained generally low in their self-efficacy compared to their peers in the Non-PDS), PDS candidates appeared to undergo calibration in their beliefs (see also, Bandura, 1986, 1997). That is, as candidates participated in the PDS, they were better able to understand their abilities teaching integrated STEM lesson in an authentic context and adjusted their self-efficacy appraisals accordingly (some candidates adjusted down while others adjusted up, but overall for PDS candidates their self-efficacy remained relatively high). Therefore, at the end of the semester, having planned, taught, and evaluated their own integrated STEM lessons with a strong educational technology focus, PDS candidates had more realistic appraisals of their self-efficacy beliefs, with some becoming more confident and others becoming less confident. This is an important finding because it demonstrates that participating in a STEM PDS program may help candidates more accurately understand their beliefs regarding their ability to teach. This begs the question, how does experiencing this calibration early in a candidate’s program of study impact their self-efficacy, as well as other areas of their development such as their knowledge and dispositions, as they progress through their degree program, in particular their methods coursework and clinical experiences? Researchers should explore this question in future research using a longitudinal design so that a more complete understanding of candidates’ participation in a STEM PDS program can be understood. Doing so would likely prove valuable for programs

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seeking to implement PDS programs in STEM or educational technology, in addition to propelling the field forward in this area.

**Limitations**

A limitation of this study is the candidates’ self-selection into the PDS program. Candidates were allowed to sign up for any section of the course, although elementary education majors were encouraged to enroll in the PDS given the grade level candidates in this section would be teaching. However, due to candidate self-selection that resulted in non-equivalent groups, it is difficult to draw conclusions regarding the differences between PDS and non-PDS candidates. Researchers should attempt to better control for this in future research. A limitation of this study was the use of a generic teaching self-efficacy survey to measure candidate confidence in integrated STEM education. Additionally, this instrument was initially developed for Norwegian teachers and may not be suitable for use with U.S. educators. Due to the lack of available integrated STEM self-efficacy survey instruments, researchers should address this limitation by developing instruments that assess candidates’ beliefs related to the integration of STEM disciplines, rather than using generic teaching focused or disciplinary STEM focused instruments. Another limitation of this study is the context in which the study occurred. This study occurred in the Midwestern region of the U.S. and results may not be similar to those in other contexts and regions of the world. A final limitation of the study is the composition of the sample, which was primarily female and Caucasian. Candidates from other demographic groups may experience the PDS program differently and subsequently report different levels of self-efficacy. Therefore, researchers should seek more diverse samples in future research.

**References**


