Science in Elementary Education: Teacher Self-efficacy, Preparation and Student Achievement

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The purpose of this research was to assess individual elementary teachers' science teaching efficacy utilizing a mixed-methods, exploratory, concurrent case study design and to identify factors which contribute to the growth and development of teaching efficacy of teachers at Apex Elementary School (a pseudonym). The overarching question guiding this research was: What are the factors that influence science teaching efficacy of in-service teachers at the elementary level? Further questions addressed by this study were: To what extent does the number of years of teaching influence science teaching efficacy? To what extent does membership in a grade-level teaching team influence science teaching efficacy? A sample of 18 teachers responded to a demographic and 25-item Science Teaching Efficacy Belief Instrument (STEBI) survey that examined elementary teachers' overall feelings of science teaching efficacy (STE). Broken down into its components, the STEBI-A measures personal science teaching efficacy (PSTE) and science teaching outcome expectancy (TOE). Further data was collected through semi-structured interviews and classroom observations of two participants. Qualitative data analysis revealed four themes related to teachers' science teaching efficacy; socioemotional status as inhibitors to self-efficacy, limitations to teachers' science professional practice, school facility or technology factors not under teacher control, and building or district administration factors. ANOVA analysis and descriptive statistics of quantitative data yielded evidence of significant differences suggesting that participating in a grade-level teaching team can have some influence on teachers' STE. However, the number of years teaching did not have a significant contribution to STE. Furthermore, analysis per survey components, showed no indication that years of teaching experience nor participation in a grade-level teaching team influence teachers' PSTE or TOE.

Keywords: *Science teaching efficacy, personal science teaching efficacy, science teaching outcome expectancy*

Science is an essential component in early education as children develop an understanding of the natural world. In recent years, primary and secondary science curricula reform have placed high demands on teachers leaving many educators concerned. With an emphasis on cross-cutting concepts, practices in science, and core concepts, the 2016 Massachusetts Science and Technology/Engineering Framework Standards have created new demands on teachers' overall understanding of the discipline, particularly at the elementary level. Research indicates a strong correlation between Science, Technology, Engineering, and Math (STEM) education in elementary schooling with academic success in middle school, high school, and beyond (Keely, 2009; Kazempour, 2014; Keller, 2016; Morgan, Farkas, Hillemier & Maczuga, 2016). However, a breadth of research shows that elementary teachers are by-in-large unqualified or insufficiently trained to teach STEM subjects, particularly science, at the elementary level (Nowikowski, 2016). Numerous elementary educators lack the necessary Technological Pedagogical Content Knowledge (TPCK) to teach rigorous science curriculum. These inadequacies lead to low feelings of science teaching efficacy which can have adverse effects on student achievement in science (Tschannen-Moran, Hoy, A. W. & Hoy, 1998; Tschannen-Moran & Hoy, A. W. 2001; Goddard, Hoy, A. W., & Hoy, 2000; Tschannen-Moran & McMaster, 2009). Teaching efficacy beliefs refer to the level of confidence one has in their teaching ability and is reflected in their teaching practice. The primary purpose of this study was to assess individual teachers' science teaching efficacy using a mixed-methods exploratory, concurrent case study design to identify contributing factors toward the development of teaching efficacy amongst teachers at a rural, Massachusetts elementary school. The overarching question guiding this research was: What are the factors that impact science teaching efficacy of in-service teachers at the elementary level? Further questions addressed by this study were: To what extent do self-selected, science professional development courses influence teaching efficacy? Is there a correlation between the number of years teaching and teaching efficacy in science?

Theoretical Framework

Bandura's (1999) social learning theory provided the theoretical framework that informed this study, offering seminal knowledge pertaining to how an individual's perceived self-efficacy influences the development of teaching efficacy, particularly at the elementary level. Bandura (1982, 1997) asserted that perceived self-efficacy contributes to an individual's overall cognitive development and functioning and noted that the belief in one's abilities is not an attribute that is fixed, instead it is built through an organization of social, cognitive, and behavioral skills and serves a myriad of purposes. In 1982, Bandura asserted that four major tenets which contribute to the development of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and psychological arousal. Mastery experiences build efficacy through the resiliency to overcome obstacles through perseverance and sustained effort. Conversely, failing to complete a task or unsuccessfully completing a problem can undermine self-efficacy. Vicarious experiences, or observing others considered as role models as they successfully complete challenging tasks influence self-efficacy by perceived similarities to the success and resiliency of role models. Social persuasion involves verbal persuasion that an individual possesses the necessary tools to master activities and are likely to succeed rather than dwell on setbacks that arise. Finally, psychological arousal, or emotional states, directly impacts how an individual judges his/her capabilities and persistence in overcoming challenges. Bandura (1982, 1993) asserted that low self-efficaciousness ties heavily into the investment of cognitive efforts and acquisition of knowledge and skills.

Teacher efficacy specifically refers to a teachers' perception of his/her effectiveness to generate desired outcomes pertaining to student learning even when challenged with unmotivated or difficult students (Tschannen-Moran, et al., 1998; Tschannen-Moran & Hoy, A. W. 2001; Goddard, et al, 2000; Tschannen-Moran & McMaster, 2009). When applied to education, Bandura (1997) postulated that teachers' beliefs of their own instructional efficacy play a pivotal role in how they design and carry out educational experiences for their students. These perceptions are specific to the context of teaching and therefore, influence beliefs of an individual's capabilities to complete requirements of specific teaching tasks. Teachers with high levels of efficacy have a tendency to be more organized, willing to try new strategies, are resilient when faced with adversity and have a positive impact on student achievement as well as student efficacy and motivation (Henson, 2001).

Literature Review

Extensive literature have examined teacher efficacy beliefs using qualitative and quantitative methods particularly when new reform initiatives are in place. For example, although not expressly focused on teaching efficacy, Trygstad, Smith, Banilower, Nelson and Horizon Research Inc. (2013) investigated the preparedness and teaching beliefs of elementary science teachers at the implementation of the Next Generation Science Standards (NGSS, 2013). Results of the study showed that several factors, such as the importance that schools place on science content, district professional development focused on science, community attitude toward science, and how instructional material and resources are managed, contribute positively to elementary instruction. Conversely, the lack of targeted professional development and conflicting district initiatives inhibit effective science instruction and have an impact on teachers' pedagogical beliefs (Trygstad et al., 2013). Expanding on the impact of science educational reforms, Walen and Chang Rundgren (2014), completing their study in Sweden, demonstrated that teacher efficacy is not specific to one locale but is an international issue. Educational scholars such as Buss (2010), investigated elementary teachers' self-efficacy in teaching mathematics and science as compared to other content at the elementary level. Bergman and Morphew (2015) looked deeply into the elementary preparatory programs in an effort to identify factors which can increase teaching efficacy of pre-service teachers.

On the other hand, while relatively few qualitative studies on teaching efficacy were reported in the literature, however, such provided rich descriptions of the growth and development of teaching efficacy. Nowikowski (2016), studied pre-service teachers' perceptions of STEM activities and their correlation to teaching efficacy. Study findings showed that the majority of participants, even though having previous experience with STEM subjects and activities, did not see themselves as capable of effectively conveying STEM concepts or leading STEM activities. Harding (2016) highlighted the correlation between elementary teachers' lack of science content knowledge and negative attitudes about teaching science.

Mixed methods studies were more prevalent in the literature and provided a more detailed picture of teaching efficacy through a triangulation of blended rich descriptions with quantitative statistical analysis. For example, Mendon and Sadler (2016) sought to identify factors that influence pre-service elementary teachers' science teaching efficacy specifically as it pertains to teaching physical science content. Riggs (1991), utilizing the Science Teaching Efficacy Belief Instrument (STEBI) co-created with Enochs (1990), along with in-depth interviews, compared the differences in teaching efficacy between male and female pre- and in-service elementary science teachers. Again, focusing on pre-service elementary teachers, Mintzes, Marcum, Messerschmitt-Yates, and Mark (2013) assessed the effects of sustained PLCs on science teaching efficacy. Expanding on literature surrounding PLCs and teaching efficacy, Voelkel and Chrispeels (2017) noted "teacher efficacy was fostered during the PLC work of analyzing student data and work and deciding what interventions or instruction were needed to ensure students mastered learning goals" (p. 520).

Review of relevant literature pertaining to teaching efficacy included construct roots, definitions, measurements, collective teaching efficacy, the development of teaching efficacy through a variety of interventions, and the impact upon student achievement. There were a plethora of studies pertaining to the self-efficacy of pre-service teachers with a particular focus on elementary teachers' teaching efficacy. However, there was a shortage of studies that centered around elementary teachers' teaching efficacy while implementing the 2016 MA Science and Technology/Engineering Framework Standards. Results of this study added a new layer to existing research that concentrated on elementary teachers' teaching efficacy and provided insight into potential investigations in future studies.

Study Design

This mixed-methods, exploratory, concurrent case study aimed to examine teachers' science teaching efficacy within Apex Elementary School. Onwuegbuzie and Collins (2007) assert, "The exciting aspect of mixed methods sampling model is that a researcher can create more tailored and/or more complex sampling designs. . .to fit a specific research context, as well as the research goal, research objective(s), research purpose, and research question(s)" (p. 297). Case studies, as described by Creswell (2009) are "strategies of inquiry in which the researcher explores in depth a program, event, activity, process, or one or more individuals" (p.13). Exploratory in nature, as it sought to identify variables to examine further, this study utilized both quantitative and qualitative data techniques as a means to identify variables which contribute to teaching efficacy.

Samples

Two samples of participants were utilized: a qualitative sample and a quantitative sample. The qualitative sample was chosen from the pool of participants which included one third-grade and one fifth-grade teacher. Criteria for the qualitative sample included:

- Teaching at Apex Elementary School
- Willingness to participate in the study
- Full time employment (not job sharing)
- Teaching science as part of their teaching assignment

Quantitative data was gathered from a pool of 18 participants utilizing a demographic survey tool as well as the Science Teaching Efficacy Belief Instrument Part A (STEBI-A) to identify feelings of science teaching efficacy and outcome expectancy. The researcher collected and analyzed data concurrently, then triangulation was performed to reveal common themes across data.

Study Methods

Quantitative data was collected using the STEBI-A (Riggs & Enochs, 1990) to identify factors influencing elementary teachers' science teaching efficacy. Qualitative data was obtained via semi-structured interviews and classroom observations to understand the complex behaviors of teachers as they develop their teaching efficacy in science. Qualitative data, however, allows for a deeper understanding of underlying reasons, meanings, opinions, or beliefs of participants. Utilized together, quantitative and qualitative data provided a more comprehensive picture and broader perspective of the complex construct of teaching efficacy.

Strategies for data collection. The data collection process followed the policies set forth by the Office for Human Research Protections (OHRP, 2019) and was collected over a six-week period. Three differing data collection techniques were utilized. Quantitative data was collected through a 36-question survey, including demographic information and qualitative data collection from nine open-ended interview questions through an interview protocol as well as through classroom observations. Further, data was triangulated from surveys and interviews to provide evidence supporting the validity of potential findings.

Survey. The STEBI-A is a vetted survey tool designed by Riggs and Enochs (1990) to measure the personal science teaching efficacy and outcome expectancy of in-service elementary teachers. The foundation of the survey rests firmly upon Bandura's (1982, 1997) social learning theoretical framework as well as Gibson and Dembo's (1984) work relevant to teaching efficacy beliefs. The survey is Likert scale consisting of 25 items, with a five-point rating response: strongly agree (five points), agree (four points), uncertain (three points), disagree (two points), and strongly disagree (one point). During analysis, negatively-worded statements were reverse-scored to yield consistent values between positively and negatively worded items. Of the 25 items, 12 questions expressly measured science *teaching outcome expectancy* (TOE) while the remaining thirteen measured *personal science teaching efficacy* (PSTE).

Semi-structured interviews. Although a common set of questions was asked of all participants, interviews were semi-structured to allow for clarifying questions to be asked. Open-ended questions centered upon teachers' backgrounds into science, science experiences, science education, as well as generalized impressions about elementary education. Interviews were conducted at times and locations that were convenient for participants and took no longer than 45 minutes. All interviews were audio-recorded on a personal iPhone (with permission of the participants), and all recordings were transcribed utilizing a secure, online transcription service.

Observations. Two systematic classroom observations of one, volunteer participant were conducted. Observations took no more than 75 minutes and were held in a fifth-grade classroom at Apex Elementary School. Data was gathered through an interactive coding system and focused upon teaching efficacy and outcome expectancy.

Analytic Plan

Unit of Analysis. The central purpose of this study is to assess the overall self-efficacy of elementary teachers as they implement the 2016 Science and Technology/Engineering Curriculum Frameworks. The unit of analysis are teachers' reflections on their levels of self-efficacy as evidence through interviews, observations, and survey responses. The researcher collected and analyzed all evidential data concurrently, then triangulation was performed to reveal common themes across data.

Results

Findings are presented in the following sections: 1) Demographic information of participants, 2) Analysis of quantitative data collected from the STEBI-A and an 11-item demographic questionnaire, 3) Analysis of qualitative data gathered through interviews and observations.

Demographic Information

The population of this study consisted of grades three through five elementary teachers at Apex Elementary School who taught science as part of the regular teaching duties. Of the 27 potential participants, 18 teachers responded to the study survey. Of these participants, 50% taught third grade, 34% taught grade four, and 16% taught grade 5. Due to school dynamics, participants within the study were all white females. Although there was a wide distribution of ages of the participants, the majority were over 40 years old (56%); the rest were 39 and below. Years of teaching experience also varied greatly; however, almost one third had six to ten years of teaching experience, while 22% had 16-20 years of experience. Teachers with two years of experience or less and teachers with 26 years of experience each made up 16% of study participants, and teachers with 21-25 years of experience rounded out the study group at 11%. Finally, 94% of participants stated that they did not hold a degree (undergraduate or graduate) in science.

Analysis of Quantitative Data

Quantitative data analysis was aimed at assessing relationships between identified factors influencing elementary teachers' science teaching efficacy. Analysis includes Analysis of Variance (ANOVA) to calculate and compare mean scores for variables STE, PSTE, TOE, as well as Cronbach's Alpha to assess the reliability of survey items. Cronbach's alpha for the 25 items was .897, indicating a high level of reliability amongst survey items. As high reliability was established, data were analyzed in reference to the following research questions:

- To what extent does the number of years of teaching influence science teaching efficacy?
- To what extent does membership in a grade-level teaching team influence science teaching efficacy?

To determine if there were statistically significant differences in levels of science teaching efficacy (STE) amongst elementary teachers with differing years of teaching experience, descriptive statistics were calculated utilizing Microsoft Excel. Results of mean scores of responses indicated that for STE, educators with 16-20 and 21-25 years of teaching experience had nearly the same levels of agreement STE survey items (*M* = 3.68, *SD* = .62*; M* = 3.6, *SD* = .45). Teachers with zero to two years of teaching experience (*M* = 3.48, *SD* = .18) expressed higher levels of agreement than teachers with over 25 years of teaching experience (*M* = 3.20, *SD* = .80). Interestingly, teachers with six to ten years of experience expressed the lowest levels of agreement with survey items (*M* = 3.14, *SD* = .34). One would expect that years of experience would correlate to higher teaching efficacy, but this was not the case.

Descriptive statistics were also run to determine if membership in a grade-level teaching team influenced science teaching efficacy. Results show that grade four teachers expressed higher levels of agreement with STE survey items (*M* = 3.78, *SD* = .50) than grade three and grade five teachers who had nearabout the same levels of agreement (*M* = 3.18, *SD* = .26; *M* = 3.14, *SD* = .69),

To ascertain if there were significant differences in levels of PSTE and TOE per STEBI-A survey components amongst teachers with differing years of teaching experience, descriptives were again utilized. Results of responses indicated that for PSTE, educators with 21-25 years of experience had a higher level of agreement of PSTE (*M* = 3.69, *SD* = .55) as compared to teachers with 16-20 years of experience (*M* = 3.43, *SD* = .91). Teachers with zero to two years of teaching experience (*M* = 3.35, *SD* = .29) expressed a higher level of agreement than elementary educators with six to ten years of experience (*M* = 3.11, *SD* = .47). Surprisingly, teachers with 25 years or more experience had the lowest level of agreement with PSTE survey items in comparison to their peers (*M* = 2.95, *SD* = 1). These findings are counterintuitive as again, one would think that with increased years of experience, PSTE would be at higher levels.

Analysis of responses associated with TOE indicated that teachers with 16-20 years of teaching experience had the highest level of agreement with survey items (*M* = 3.93, *SD* = .53) than teachers with zero to two years of experience (M = 3.52, SD = .33). Further results showed that teachers with 21-25 years of experience had higher levels of agreement with TOE survey items (M = 3.5, SD = .35) than teachers with over 25 years of teaching experience (M = 3.47, SD = .55). Finally, teachers with six to ten years of experience scored the lowest on TOE amongst their peers (M = 3.22, SD = .26).

Finally, descriptive statistics were calculated see if there were any differences in beliefs amongst teachers of the different grade levels, indicating the influence that membership in a grade-level teaching team had on PSTE or TOE. The descriptive analysis showed that for PSTE, grade four teachers had a higher level of agreement to survey items (M = 3.77, SD = .06), compared to grade three teachers (M = 3.03, SD = .36). Further, teachers from grade three had agreement levels which were higher PSTE as compared to grade five teachers (M = 2.95, SD = 1.03). Additionally, descriptive analysis of science TOE showed grade four teachers stronger agreement levels (M = 3.79, SD = .46) compared to grade three teachers (M = 3.36, SD = .4) who had approximately the same level of agreement with TOE survey items as grade five teachers (M = 3.36, SD =.33).

ANOVA Analysis

To explore whether there were statistically significant differences between the mean scores in STE for teachers with differing years of experience and across grade levels, two one-way analysis of variance (ANOVA) were conducted. Further analysis breaks the STEBI survey into its components of PSTE and TOE and again, looks to reveal any statistically significant differences in mean scores. Delving further into data analysis provided insight into the influence that the number of years of teaching, as well as membership in a grade-level teaching team had on science teaching efficacy.

Testing assumptions

Before running ANOVA, three assumptions were tested to ensure compliance:

1. Levene's test was conducted to test the assumption of equal variances across groups of teachers with differing years of teaching experience. Levene's test indicated no significant differences for PSTE (p = .26) or TOE (p = .2) amongst the groups; therefore, the assumption was not violated, and equal variances are assumed.
2. Normality assumption: Participants' scores on the STEBI-A scale ranged from 59 to 115. To determine if the data set modeled a normal distribution, we used visual inspection of histograms displaying the distribution of scores as well as skewness and kurtosis values. To detect normality, acceptable ranges of skewness and kurtosis considered are (-1, 1) and (-3, 3) respectively (Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017). The histograms as well as skewness (.3801) and kurtosis (1.43) measures warrant the normality assumption.
3. Independence of observation: To ensure the accuracy of data, STEBI scores were taken once from each participant.

Results from ANOVA tests are shown in Tables 1and 2. ANOVA results showed no statistically significant differences in STE amongst the teaching experience groups F = (4, 13) = .90, p = .48 > 0.05. However, results from STE analysis showed statistically significant differences across grade levels indicating that membership in a grade level teaching team has some influence on teachers' STE, F = (2, 15) = 3.92, p = .04 < 0.05. (See Tables 1 and 2).

Table 1

One-way ANOVA summary comparing teachers years of teaching experience and its influence on STE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.929511111	4	0.23237778	0.909694	0.486886	3.179117
Within Groups	3.3208	13	0.25544615			
Total	4.250311111	17				

Table 2

One-way ANOVA summary comparing teachers' membership in a grade-level teaching team and its influence on STE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.459644444	2	0.729822	3.922838	0.042624	3.68232
Within Groups	2.790666667	15	0.186044			
Total	4.250311111	17				

Breaking down the STEBI-A into its components of PSTE and TOE, ANOVA results indicated no statistically significant differences in PSTE among the teaching experience groups $F = (4, 13) = .477$, $p = .75 > 0.05$. Further, no statistically significant differences were found for TOE between the groups, $F = (4, 13) = 1.85$, $p = .17 > 0.05$ (see Tables 3 and 4).

Table 3

One-way ANOVA summary comparing teachers' years of teaching experience and PSTE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.938108333	4	0.2345271	0.4779745	0.7514865	3.1791171
Within Groups	6.378691667	13	0.4906686			
Total	7.3168	17				

Table 4

One-way ANOVA summary comparing teachers' years of teaching experience and TOE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.2342028	4	0.308550694	1.853107	0.178938	3.179117
Within Groups	2.1645583	13	0.166504487			
Total	3.3987611	17				

Finally, one-way ANOVA analysis tests were run to test whether there were any statistically significant differences between means of responses on PSTE or TOE for participation in a grade-level teaching team. ANOVA results revealed no statistically significant differences in PSTE $F = (2, 15) = 3.496$, $p = .057 > 0.05$. Interestingly, although ANOVA results showed statistically significant results for STE for teacher membership in a grade-level teaching team when run on scores of the full STEBI-A, when broken down into its components, analysis did not show significantly significant differences for TOE across grade-level teaching teams $F = (2, 15) = 1.93$, $p = .18 > 0.05$ (See Tables 5 and 6).

Table 5

One-way ANOVA summary comparing grade level means for PSTE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.326444444	2	1.16322222	3.496411	0.056699	3.682320344
Within Groups	4.990355556	15	0.33269037			
Total	7.3168	17				

Table 6

One-way ANOVA summary comparing grade level means for TOE.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.459644444	2	0.729822	3.922838	0.042624	3.68232
Within Groups	2.790666667	15	0.186044			
Total	4.250311111	17				

Quantitative data analysis yielded multiple results. Evidence of significant differences suggested that participating in a grade-level teaching team can have some influence on teachers' STE. However, the number of years teaching did not have a significant contribution to STE. Furthermore, analysis per survey components, showed no indication that years of teaching experience nor participation in a grade-level teaching team influence teachers' PSTE or TOE.

Analysis of Qualitative Data

Transcribed teacher interviews and classroom observations addressed the following research question: What are the factors that influence the science teaching efficacy of in-service teachers at the elementary level? Data was coded utilizing an inductive, manual coding approach to allow for patterns within the data to emerge. Precoding revealed preliminary initial codes which were reviewed several times to glean initial codes. Initial coding of qualitative data revealed 94 open codes, which were extracted to address the study's questions focusing upon factors that influence elementary teachers' science teaching efficacy in teaching the 2016 MA Science and Technology/Engineering standards. Upon repeated examination of initial codes, 43 axial codes were abstracted into categories which developed from data and initially focused upon teachers' personal feelings, environmental factors, socioemotional factors, teachers' professional practice, institutional factors, and professional development. Through the cyclical process of reviewing codes, four themes related to teachers' science teaching efficacy emerged;

socioemotional status as inhibitors to self-efficacy, limitations to teachers' science professional practice, school facility or technology factors not under teacher control, and building or district administration factors. Each theme, described in detail below, was consistent with concepts identified in the literature on science teaching efficacy and either influenced teachers' personal teaching efficacy, or level of teaching efficacy. Codes and themes were member checked to establish credibility and accuracy of findings.

Theme 1: Socioemotional factors as inhibitors of self-efficacy. Several factors emerged through this study, particularly tied to teachers' socioemotional state as they prepare and teach science. Most of the socioemotional factors were constraints that inhibited the growth of teachers' personal self-efficacy. During interviews, teachers expressed feelings of anxiety and frustration in teaching science. For example, when asked if teachers feel prepared to teach science, a third-grade teacher, T2, replied:

> No, I don't feel prepared. I feel like, you know, it gives me a little bit of anxiety because I don't ever want to come into a classroom and not be…feel prepared, and feel the best, ready to go. And with all of the subject areas, I feel like I've mastered it pretty much, and I can deliver it and do the best I can. But with science, I feel like I'm just kind of hoping for the best, hoping I'm going to get through it and that they're [her students] going to be able to understand what I'm trying to say because, in all areas, I'm not 100% confident. (T2)

Teachers also expressed feelings of helplessness or a lack of confidence when it comes to teaching science. For example, a fifth-grade teacher, T1, stated that she was "Overwhelmed and underprepared. Year two, and I still don't know what I'm doing. I don't know what I'm doing" (T1). Teachers' feelings were exacerbated by notions that science is harder to teach than other subjects. T1 noted, "It is hard enough planning with a [book] series when you really don't know what you're talking about, never mind trying to find creative things to do with it" (T1).

During classroom visits, it was observed that low socioemotional levels impacted the quality and effectiveness of instruction. T1 was observed having difficulty conveying science content, which she reported being uncomfortable with. During an interview after the observation, T1 stated, "I think my anxiety is like, do I understand this [science content] enough so I can present it in the best possible way for them [students]?" According to Bandura (1997), teacher's self-efficacy is the foundation for performance expectations. Hence a teacher who believes they are more competent is likely to have greater control over the teaching and learning process. However, the opposite also holds as, in this case, low self-efficacy directly affects this teacher's impact on the science teaching and learning process. This ties into the assertion put forth by both teachers that science is a more difficult subject to teach than others. Their lack of belief in their abilities acts as a constraint to building science teaching efficacy.

Interestingly, interview data detected a transformational experience one participant had while participating in this study. The teacher reported elevated teaching practices by simply having a modicum of support.

> Well, by you just offering a little support, I was like, all right, maybe I do know a little bit of what I'm doing. Just a little more confidence. Oh, but the study, just making me aware that there are modifications. I don't have to exactly be by the book, that was so helpful (T1).

Finally, although quantitative data shows no statistically significant differences between the number of years teaching science and STE, qualitative data showed that, while implementing the new science curriculum, teachers report feeling like novice teachers despite their veteran teacher status. For example,T2 asserts, "All these changes have made teachers, like myself who has been teaching for many years, feel like they went from masters of their curriculum to brand new teachers" (T2). To counter these feelings of inadequacy, Duschal, Schweingruber, and Shouse (2007) assert that to teach science, educators need "sustained science-specific professional development in preparation and while in service" (p. 296). The authors further note that to fully support teachers, professional development should be centered upon science taught at the elementary level and should include not only recent research on how children learn science, but science pedagogy as well. More recently, the National Association for Science Teachers (2018) stress the importance of countering pre-existing anxiety, in teaching science, amongst elementary teachers by creating opportunities for teachers to “experience the same hands-on, engaging learning environments, and research-based best practices” (p. 3) which support student learning.

Theme 2: Limitations to teacher science professional practice. Another factor that seems to influence teachers’ science teaching efficacy is tied to teachers' science professional practice. NGSS and the Massachusetts Science and Technology/Engineering Framework Standards emphasize cross-cutting scientific concepts, practices in science, and core concepts, which places high demands on teachers' understanding of scientific content and pedagogy. Both in teacher interviews and classroom observations, data showed a disconnect between the new standards and new science pedagogy. For example, T2 asserted:

> It's always about, how do you take something and make it so that an eight-year-old can understand that concept? So, it's making sure that you understand the material enough. I don't feel like there's enough that's given to us as teachers to make us understand it before, now you need to present it so that somebody else understands it" (T2).

In the classroom, this disconnect leads to fragmented delivery of content and instructions as well as diminished levels of science activity design and implementation, which negatively influences students' cycle of scientific inquiry. It should be noted, however, that despite aforementioned feelings, a concerted effort to plan engaging lessons was detected. T1 reported that utilizing teacher preparation periods as well as personal time to plan, prepare, and practice science lessons. Prior studies have found that teachers who were weak in background content knowledge were more likely to have notably lower levels of self-efficacy than their peers with greater content knowledge (Riggs & Enochs,1991).

Theme 3: School facility and technology factors not under teachers' control. School facility and technology factors were also found to affect teachers' science teaching efficacy. The physical set-up of the room limited the ability of students to freely move about during science experiments as well as impacted the space needed to properly store and set up materials for scientific inquiry. Technological difficulties such as hardware issues and internet inconsistencies have also impacted science lessons. T1 reported that internet issues had affected past lessons inhibiting her from giving online assessments as well as the ability to print hard copies of assessments. These factors compound teacher frustrations, thus contributing to low self-efficacy. In examining the impact of school facilities on teacher efficacy and student learning, Penn State's Center for Evaluation and Education Policy Analysis (2019) reports that classroom space is paramount with current educational emphasis on 21st-century learning, which includes problem-solving, building communication skills, and cooperative group work. For teachers, classroom space is needed to reconfigure seating to facilitate the varying teaching techniques that align with 21st-century skills.

Theme four: Building or district administration factors. Administrative or school district factors influencing teachers' self-efficacy include the lack of support for science curricula implementation. T2 noted,

> There was a total change of all our science topics with no training on the topics. On top of it, the science curriculum came on the heels of math and reading/language arts curriculum overhauls. We never got to digest one subject change before a new subject and curriculum had been thrown at us. (T2).

Further data indicates that the rigidity to pacing guides set forth by administration inhibits remediation time for students who struggle with abstract science concepts. Teachers report feeling pressured to move on with curriculum even if their students do not grasp challenging science concepts.

Investigating teacher motivation, Ellis (1984) found that "teachers are primarily motivated by intrinsic rewards such as self-respect, responsibility, and a sense of accomplishment" (p. 2). He further reports on three ways administrators can support and motivate teachers; shared governance, inservice educational opportunities, and an evaluation process that is supportive and systematic. Similar to Ellis's findings, the present study indicated that teachers at Apex are frustrated with the lack of shared governance and revealed further that curriculum and implementation decisions are being made at the administrative level with little to no input from teachers.

Investigating the impact that science professional development (PD) courses had on teachers' self-efficacy, it was clear that teachers were overwhelmingly disappointed with the lack of science PD scheduled before the implementation of the 2016 MA Science and Technology/Engineering standards. As T2 Notes:

> I think that they could have done a much better job in preparing everybody for the experience [implementation]. You know what I mean? And yes, it might not have been perfect the first year or the first two, everything takes time. But to just throw a book and be like, "There you go, good luck" (T2).

Some data indicated that self-selecting PD creates a financial burden for teachers, and if they are on the top of the pay scale, no financial incentive to attend PD outside of district offerings. Because teachers feel as if they do not possess the skills necessary to teach science, they justify their feelings by placing blame on the district. This mindset hinders any potential science PD opportunities that the district might provide in the future.

Discussion

Findings of this study showed that, overall, Apex elementary teachers' socioemotional levels are low, which could have contributed to a diminished sense of science teaching efficacy and compromised their beliefs in their abilities to move forward and fully embrace new practices associated with the 2016 MA Science and Technology/Engineering standards. Perhaps due to the covert nature of socio-emotional factors, I argue that the district is unaware of teachers' low socioemotional levels, and the significant challenges teachers face daily, that directly impact their teaching practice. Therefore, I envision that the district is not affording them the empowerment to seek out science teaching self-efficacy growth opportunities either within the district or externally. Jennings (2015) asserts that "Most teacher training focuses on content and pedagogy, overlooking the very real social, emotional, and cognitive demands of teaching itself" (p. 1). Berdik (2019) reports, "teacher stress is growing, experts say, pushing educators out of the classrooms and hurting learning. On top of chronic underfunding for education and the continued pressure of standardized tests, there's also the unrelenting pace of newer education reforms" (p. 1). To help teachers recover from a state of low confidence, and hence, low TPCK, one fundamental recommendation of this study is the development of a science PLC that will provide teachers with a safe and collegiate environment where they feel free to express their tensions without judgement or ridicule. Summarizing literature on PLCs, Hord (1997) defines Professional Learning Communities as "teachers in a school and its administration continuously seek and share learning, and act on their learning. The goal of their actions is to enhance their effectiveness as professionals for the students' benefit…" (p. 6). The Apex District's PLC would consist of all science faculty within the district. Initially, the PLC would meet to unpack the 2016 MA Science and Technology/Engineering curriculum standards to understand the progression of the standards through each grade level. Future meetings would focus on analyzing data collected from state assessments as well as student work to identify content areas of weakness and come up with action plans to address those areas. The goal of the PLC would be to create smaller inquiry groups within the original group and pair up elementary teachers with upper-level science teachers. The purpose of these pairings is to support elementary teachers' growth in TPCK. Elementary teachers would have the opportunity to participate in observations of their upper-level counterparts and learning walks in other science classrooms throughout the district. Further, all members of the PLC would have the opportunity to attend science workshops and conferences to not only strengthen TPCK but help members stay abreast of new trends in science education.

Professional development opportunities such as the ones highlighted above allow for science collaboration not only at each grade level but district-wide as well. Fullen (1999) asserts, "The quality of relationships is central to success [of school improvement efforts]. Success is only possible if organizational members develop trust and compassion for each other" (Dana & Yendol-Hoppey, 2008, p. 28). Members of the science PLC will build meaningful relationships that will have positive impacts on teachers' TPCK, which will ultimately lead to increased feelings of science teaching efficacy.

Conclusions

Quantitative data analysis focused on the research questions, which sought to determine if the number of years teaching or the membership in a grade-level teaching team impacted STE, PSTE, and TOE. Data were analyzed using one-way ANOVA, and results showed no significant differences in mean values for STE, PSTE or TOE. It is, therefore, a conclusion that years of teaching experience does not impact PSTE and TOE. Further analyzed by ANOVA was the assumption that there were differences in STE, PSTE and TOE amongst teachers who participate in differing grade level teaching teams. Statistically significant differences were found in STE for teachers participating within a grade-level teaching team, however when broken into STEBI components, no statistically significant differences in PSTE and TOE were revealed; hence, grade level taught may have some impact on STE.

Qualitative findings derived from interviews and observations are consistent with Bandura’s (1982, 1997) social learning theory which emphasizes that perceived self-efficacy is not a fixed attribute but fluctuates through the organization of skills gained through a myriad of experiences. In the case of Apex Elementary, socioemotional factors, teachers’ science professional practice, school facility and technology, and administration or district-related factors directly influence teachers’ perceived self-efficacy. Findings from quantitative and qualitative data show that, regardless of years of teaching experience or grade level taught, Apex teachers experience low self-efficacy which inhibits them from embracing new curricula changes such as the implementation of the 2016 MA Science and Technology/Engineering standards. It is recommended that the district support teachers at a personal level through the creation of a science PLC. The PLC will create a safe space where teachers can recharge, be attentive to teachers' individual needs, negate feelings of isolation, and empower teachers leading to higher levels of personal self-efficacy.

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