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Abstract

In the United States, innovation and our economy seem to be lacking in comparison to other countries. Many cite the shortage of individuals interested in STEM careers as part of the problem. The following research article addresses how STEM programs may influence the efficacy and practice of curriculum integration as well as the mathematics and science instruction of teachers in elementary education. Data were collected using interviews and taped instruction from an elementary educator who graduated from a STEM-focused elementary program. This exploratory case study will aid in understanding how preservice programs focusing on STEM-integrated curriculum in elementary education can have a positive or negative influence on teachers' understanding and implementation of STEM-integrated curriculum.

Keywords: Curriculum integration; Preservice teachers; STEM; Teacher education

STEM (science, technology, engineering, and mathematics) is an acronym that citizens in the United States continuously hear from educational and political outlets, but what is it, and why has it gained increasing momentum throughout the years? According to Hill, Corbett, and St. Rose (2010), "the term 'STEM' refers to the physical, biological, and agricultural sciences; computer and information sciences; engineering and engineering technologies; and mathematics" (p. 2). However, in the context of the field of education, STEM goes beyond this conceptualization and looks more deeply into the process by which students gain early exposure to these particular disciplines (Duschl, Bismack, Greeno, & Gitomer, 2016). Given the high demand for STEM workers, if the United States hopes to continue to fill STEM-related jobs and maintain their competitive edge in innovation, it is increasingly important to expose students to STEM education in Grades K–12.

According to Langdon, McKittrick, Beede, Khan, and Doms (2011), "a STEM degree is the typical path to a STEM job, as more than two thirds of the 4.7 million STEM workers with a college degree has an undergraduate STEM degree" (p. 4). Furthermore, "STEM occupations are projected to grow by 17.0 percent from 2008 to 2018, compared to 9.8 percent growth for non-STEM occupations" (Langdon, McKittrick, Beede, Khan, & Doms, 2011, p. 1). Students who pursue STEM-related majors typically find themselves better equipped to perform these jobs; however, national and international assessments continue to illustrate that our country is not providing rigorous STEM preparation in K–12 schools. There is not just a lack of proficiency in STEM-related subjects on international assessments; there is also a lack of student interest in pursuing such careers (President's Council of Advisors on Science and Technology, 2010).

Conceptual Framework and Literature Review

Curriculum integration has become increasingly popular in the 21st century (Stohlmann, Moore, & Roehrig, 2012) and is the guiding framework for this study. Honey, Pearson, and Schweingruber (2014) define integration as "working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines" (p. 52). In problem-based learning, students work in real-world contexts to solve problems. According to the STEM Task Force (2014),

> Through problem/project-based learning situations, students weave together and communicate their understanding of STEM concepts. Concepts that were once taught in isolation become tangible and relevant to their daily lives. Integrated approaches to K-12 STEM education in the context of real-world issues can enhance motivation for learning and improve student interest, achievement, and persistence. These outcomes have the potential to increase the number of students who consider pursuing a STEM-related field. (p. 9)

For example, in a science classroom, students may be tasked with constructing an oven without electricity, a challenge that is faced by many worldwide (Honey, Pearson, & Schweingruber, 2014). Students will utilize processes and skills learned in engineering, the physical sciences, and mathematics to tackle this real-world issue (Honey et al., 2014). Even though problem-based learning and curriculum integration are two separate approaches to planning and instruction, both are often used in elementary STEM education. Because students are unlikely to see subjects in isolation in the real world, curriculum integration allows them to approach real-world settings that are applicable outside of the classroom. It ignites their ability to think critically and expand the application of their knowledge.

However, in order for this thoughtful planning and instruction in the context of STEM to occur, teachers need the proper professional development (PD) and training to afford their students these opportunities. In an empirical study, Darling-Hammond (2000) found a positive correlation between teacher-quality characteristics and student outcomes; states who provided their teachers with more opportunities to enhance their skills and teaching ability through PD had significantly higher student achievement, which coincides with student motivation. In an empirical study about motivation, Skinner and Belmont (1993) found that "children who experience their teachers as providing clear expectations, contingent responses, and strategic help are more likely to be more effortful and persistent" (p. 578). All three of these teacher characteristics rely on the education of teachers, in-service or preservice. Therefore, it is evident that teacher quality can have a positive influence on student motivation.

Some policies have attempted to enhance educational programs to ensure teacher effectiveness, including the No Child Left Behind Act of 2001 and the Common Core State Standards (Hanushek, Peterson, & Woessmann, 2014). Because of alarming statistics in international test scores in mathematics and science, President Obama also devised the "Educate to Innovate" initiative that designates goals and resources to improve STEM in K–12 and higher education (The White House: President Barack Obama, 2017). However, students from other countries still consistently outperform our students in international tests in all subjects, most notably in science and mathematics (Hanushek et al., 2014; Provasnik et al., 2016). Can preservice teacher education make a difference?

It is evident that there is a shortage of graduates in STEM fields; however, if children are not exposed to STEM-related curriculum at an early age, how can they be motivated to pursue STEM careers? Even though there are quite a few STEM-focused preservice teacher programs in middle and secondary education, there are very few programs that are specifically focused on elementary education. Some may argue that STEM is too complex a concept and framework to teach to younger children. However, there are frameworks that have been used to create lessons and activities for younger children, including Engineering is Elementary. It is imperative to not limit students' exposure to STEM based on their age. "Various research studies of undergraduate student experiences in choosing STEM professions (Russell, Hancock, & McCullogh, 2007; Russell, 1999) have noted that the best time to create a connection, awareness and interest in STEM fields would be the elementary years" (DeJarnette, 2012, p. 182). Conversely, if students are not exposed to STEM-related activities and instruction in their early education, any general interest in pursuing a STEM career may eventually wane with time. This is where classroom teachers can potentially have a positive influence on children's development. If elementary teachers are able to expose students to STEM-related curriculum, this exposure could hypothetically have the ability to spark a greater interest in mathematics and science and motivate them to continue to seek STEM-related opportunities. But, are preservice teachers properly prepared to take on this responsibility?

Purpose of the Study

Currently there is an abundance of literature about what STEM is, how it is important for the U.S. economy, how it is vital for future technological advances, and the lack of interest and motivation to pursue STEM careers in the United States. However, there is very little literature that discusses the influence that a STEM preservice teacher education program may have on a teacher's efficacy in STEM integration or in the teaching of STEM subjects in elementary education. The purpose of this case study was to examine the world of the participating teacher's experience within the STEM elementary education program, her current teaching experience as a graduate of such a program, and how she makes sense of her preservice STEM-focused elementary education program with her current teaching experience.

The following are the initial research questions that guided this study.

- How does training from a STEM elementary education program influence an elementary teacher's instruction and experiences as it relates to their current teaching practices?
- What is the teacher's experience with the STEM elementary education program?
- What is their experience teaching as a graduate of such a program?

The STEM Preservice Teacher Education Program

The STEM teacher education program that is discussed in this article, the Early Education STEM Program, required 27 hours of general education STEM coursework, including Calculus for Elementary Teachers, Conceptual Physics for Elementary Teachers, Materials in Engineering or Design Thinking, Biology, Chemistry, and other courses (DiFrancesca, Lee, & McIntyre, 2014). The program required students to take two methods courses in mathematics and two in science. The focus of these methods courses was on grade-level content and methodology; the first course focused on Grades K–2, and the second course focused on Grades 3–5 (DiFrancesca et al., 2014). The coursework also included a strong literacy foundation that included two courses focusing on reading and language arts as well as an engineering methods course focused on children's designs and inventions. Additionally, there were two courses that integrated STEM with other curricula as teachers planned lessons and units. Overall, the program required more mathematics and science content and pedagogy classes than most elementary education programs.

Methods

Research Design

In this study, we used an exploratory case-study approach to collect data on an elementary teacher's experiences from a STEM elementary education program and how those experiences relate to her experiences as a teacher. According to Yin (1994), a case-study design should be considered for a variety of reasons, such as (a) to answer *why* and *how* questions, (b) to investigate contextual attributes to the phenomenon that is being studied, or (c) when the line between the context and the phenomenon are unclear. For example, Baxter and Rideout (2006) studied the types of decisions that nursing students made and what factors influenced their decision making. They chose a case-study design because even though the decisions and decision making of nursing students was the focus of their study, it could not be removed from the context of the nursing school.

The goal of our study was to investigate the world of the participating teacher's experience with the STEM elementary education program, her current teaching experience as a graduate of such a program, and how she made sense of her preservice STEM-focused elementary education program with her current teaching experience. However, it is unclear how the STEM program affected these aspects and whether the teacher's experience and the context of her classroom affected these aspects as well. The case-study approach allowed us to investigate how a STEM-focused program can affect the efficacy and teaching experiences of an elementary teacher's STEM and curriculum integration instruction by collecting data from a semistructured interview and classroom observation. The first author is also a graduate of the Early Education STEM Program, which gave her a better understanding of the training that the participant received in her elementary education program.

Participant Information

The participant in this case study, Laura,[1] was chosen because she was a graduate of the STEM-focused teacher education program and because of her willingness to participate in the study. Laura is an African American female who was in her mid-20s at the time of the study. She was a fourth-grade teacher at an elementary school in a neighboring school district. She was a native to the state in which she taught and in which she attended the elementary education STEM-focused teacher preparation program. She taught in an inclusion classroom setting that had a class size of 23 students. Roughly 50% of her students had special accommodations or individualized education plans (IEPs). Her classroom was very diverse with a mix of genders, races, and cultures. The school in which she taught included Grades 3–6. In 2016, the year in which this study took place, the school qualified for Title I funding, which supports the education of students from low

[1] Laura is a pseudonym.

socioeconomic status backgrounds. The data collection for this study was conducted in Laura's classroom.

Data Collection Process

The data were collected from a semistructured interview and from observation of Laura's mathematics instruction. A select number of interview questions were adapted from the same protocol used for previous studies by researchers at North Carolina State University to create a STEM program in higher education, which was funded by the National Science Foundation. This protocol (i.e., questions to gain insight into teachers' STEM knowledge) has been developed over time and used with in-service teachers and preservice teachers. The interview lasted approximately 40 minutes and included follow-up questions.

Laura's science instruction was not observed during this observation due to the nature of her schedule and because she did not have control over how often or when she taught science. No observation protocol was used because we did not want to limit the scope of the observation. The observation lasted approximately 40 minutes. Both the observation and the interview were conducted in Laura's suburban fourth-grade classroom.

Data Analysis

The semistructured interview was transcribed verbatim, and the observation notes were converted from jotted notes to an in-depth narrative. After reading the transcript initially, we had an idea of the themes that ran through the transcript. Using the themes that emerged, we revised our initial research questions. Even though the data answered the research questions, an additional research question was added after reading the transcript: How do factors outside of your control affect your teaching? Also, the second initial research question was omitted because of redundancy with the first research question.

Large portions of the transcript were coded through the use of the program Atlas Ti. After developing initial codes, as well as inserting in vivo codes, we moved from a descriptive phase of coding to an analytical phase, grouping the more descriptive codes under families of analytical codes. We looked for repetitions of codes to generate themes across the data. The creation of code families allowed for us to view codes that were interconnected in order to form a general analysis of the data. The in vivo codes assisted in the cross-referencing of descriptive codes with the data to ensure validity. After creating initial codes as well as code families, we triangulated the data from the interview with the data from the observation to identify overlap in the themes (see the Appendix for initial codes and code families).

Strategies for Trustworthiness

Throughout the data analysis process, the research team compared and discussed findings (Shenton, 2004). Because constant comparative analysis was used, codes were constantly checked against categories and the qualitative data presented. Lastly, a layout of the research analysis was included to provide a clear and cogent idea of the coding procedure (Shenton, 2004).

Ethical Considerations

There was no inherent risk to the participant in this study. All data were stored on a USB file, which was locked in the primary investigator's office. All identifying information regarding the participant was removed, and the recordings and observations will be kept for research purposes only. This study was approved by an authorized internal review board.

Findings

After reading through the codes and in vivo codes, we identified themes, which were used to answer the following revised research questions.

1. How does training from a STEM elementary education program influence an elementary teacher's instruction and experiences as it relates to their current teaching practices?
2. What is their experience teaching as a graduate of such a program?
3. How do factors outside of their control affect their teaching?

In the following sections, we present a summary of the findings organized by theme.

Theme 1: Instructional Gains Acquired Through a STEM Program

Laura discussed the instructional gains that she acquired from her STEM program. She consistently discussed how her depth of mathematical knowledge aided her understanding of her students' misconceptions and allowed her to teach at a deep conceptual level: "I feel like just in the fact that I had, like a conceptual understanding of the math, it helped. Because I could take it down to the concrete level for the kids that need it." Laura articulated that she was confident in teaching mathematics. Even though her confidence level was low as a beginning teacher in other content areas, it was higher in mathematics due to her deep understanding of the mathematical concepts that she was required to teach. This mathematical preparedness and deep conceptual understanding was evident throughout the observation of her mathematics lesson. Laura pointed out that her STEM program offered classroom management training that assisted in her preparedness as a teacher. Laura also explained that she utilizes curriculum integration in various content areas; however, science and social studies are often "cut out" of their schedule due to the value placed on tested subjects.

Theme 2: Instructional Hurdles That She Has Encountered as a Teacher

This theme relates to the training that Laura felt she should have gained from her program but did not. Laura struggled in science instruction as a beginning teacher and said that she needed an immense amount of preparation prior to teaching science lessons in order to feel comfortable teaching the content. Laura explained that even though she did not understand science content as a whole, she had a deep understanding of specific science topics that were not applicable to her fourth-grade curriculum. Graduating from a STEM program, Laura initially did not understand how to use technology as an instructional tool but is now comfortable utilizing it in her classroom. She articulated that she did not use Engineering is Elementary (EIE), which is a process that Laura and her classmates were taught in her STEM program. Although she did indicate that she understands the usefulness of EIE, she did not think that it is practical. When asked about these specific instructional techniques, Laura expressed the following:

> I definitely don't use engineering so no on that side. But as far as like as science, technology and math, my science instruction can be stronger and better but I do integrate math into that and technology we use all the time. And I feel like my first year with the technology

> I was like "oh my gosh what is this. I have to use it all the time. There's all this pressure." But now I feel like I know how to use it as an instructional tool versus like a teacher, a second teacher, if that makes sense.

When Laura first started teaching inclusion at the beginning of her third year, she realized there were several things associated with the role of an inclusion teacher that she did not understand (i.e., paperwork, IEPs, and pullout).

Theme 3: Aspects of Teaching Outside of Her Control

Laura went into detail about the different aspects of teaching that were outside of her control, such as district requirements as well as the lack of curriculum resources that she was able to utilize as a beginning teacher. Laura also explained that she does not have as much control over her classroom schedule and instruction as she would like. Because she teaches in an inclusion setting, she has to create her schedule around the special education teachers that work with her students. She also has to use certain instructional activities and focus more on certain aspects of the content that are valued because of high-stakes testing.

Theme 4: Critical Reflection and Scrutiny

During her interview, Laura reflected critically on her own teaching and on the context in which she teaches. She discussed critical self-reflection and how she continually scrutinizes herself on certain aspects of her teaching, especially in content areas that require more preparation. She also referred to focusing on testing due to peer scrutiny involved with the public display of test scores at her school. It was evident that Laura was worried about appearing to be an effective teacher in front of her peers. She explained that she was nervous at the beginning of her inclusion teaching due to her students performing poorly on their end-of-grade tests the previous year. At their testing meetings, she wanted her peers to see her students' growth and not just their proficiency (or lack thereof): "So like I was overwhelmed about being judged without anyone knowing the whole picture. But, it went well. They actually talked about where they came from and noticed that 55 was great." Laura also explained how she had been overwhelmed with procedures in her new inclusion setting and thus started attending voluntary PD training to streamline the procedures in her classroom.

Theme 5: What STEM Means to Her

Laura expressed what STEM meant to her in the interview:

> Like really helping them get a conceptual understanding so they can have a good foundation. So, I feel like STEM in the elementary is like building a good foundation for them in science and technology and all that so that way they can be successful.

Laura articulated that STEM meant preparing students for 21st-century learning, developing deep conceptual understanding in the contents associated with STEM, and effectively utilizing technology.

Discussion

Reverting back to the guiding conceptual framework of curriculum integration, it was hard to determine whether curriculum integration was a prevalent strength of the STEM preparation program. Even though Laura expressed that she attempts to utilize curriculum integration throughout different content areas, it was not established in the observation of her teaching, in part due to the demands placed on her by her administration and school district by devoting the majority of instructional time to tested content areas at that grade level. Even though Laura alluded to curriculum integration, we were unable to determine whether the curriculum integration was a major facet of the STEM program and of her teaching using the collected data.

One clear strength of the STEM program was the deep content and conceptual instruction in mathematics that Laura received as a preservice teacher. This was clear throughout the interview and observation. For example, during the observation, students were working through different multiplication and division problems. According to Carpenter, Fennema, and Franke (1996),

> We start the discussion of multiplication and division by distinguishing among three basic problems. The three problems are related but differ in what is known and what is unknown. In a *multiplication* problem, the number of sets and the number in each set are given, and the solution requires that one find the total number. In a *measurement division* problem, one must find the number of sets when the total number and the number in each set are given. In a *partitive division* problem, the total number and the number of sets are known. The solution requires that the number in each set be found. (p. 7).

Laura provided several opportunities for students to work through these different types of multiplication and division problems that required different strategies to find a solution. The importance of this lies in the practice of problem solving because Laura is deliberately teaching students that there are different ways to solve problems utilizing the same operation, depending on what is unknown (Carpenter, Fennema, & Franke, 1996).

Laura also discussed how her confidence in mathematics instruction was relatively higher than her confidence in other content areas when she began teaching. Bandura (1986) suggests that self-efficacy, “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (p. 391), can affect how long they persist in attempting to complete a task or the energy that they invest in this specific task. Building on that work, Pajares and Miller (1994) conducted a study using “path analysis techniques to test Bandura’s (1986) hypotheses regarding the predictive and mediational role of self-efficacy in the area of mathematics” (p. 193). They found that students’ judgments about their capability to solve mathematics problems were predictive of their ability to solve those problems, suggesting that the higher someone’s self-efficacy is in a particular domain, the higher their performance is in that domain. Therefore, Laura’s higher self-efficacy in doing and understanding mathematics translates to her ability to teach, adapt, and diagnose during her instruction. Even though the data revealed several instructional gains from the STEM preparation program, the dominant and repetitive instructional gain supported by the data was that of deep mathematical conceptual understanding and its translation to Laura’s teaching.

Limitations

Even though the data collected showed clear patterns in Laura’s instructional practices and how these related to the STEM preparation program, there were limitations to the study and the data that are important to note.

Sample size. Because all of the data were collected from a single participant, it is difficult to say whether other graduates from a STEM preparation program had similar experiences to Laura’s.

Scope of data collected. Unfortunately, we were unable to observe Laura's science instruction. Even though it was discussed in the interview, it was not at the forefront of her instruction. This is likely due to limitations in Laura's instructional schedule and the lack of input in the subjects and content that she teaches on a daily basis.

Implications

One of the most profound implications of this study is the strong mathematical content and conceptual understanding that this particular STEM preparation program instilled in Laura. This particular program consisted of two K–5 mathematics methods courses. It is known that the mathematics content knowledge that preservice teachers possess is vital to their teaching success; however, pedagogical knowledge is of equal importance (Hill & Ball, 2004) and has been consistently deemed important in the field of teaching. As Hill, Rowan, and Ball (2005) explained, teacher knowledge has typically been measured by coursework or degrees attained, but there has been a new development in literature that has looked closer at teacher's knowledge in terms of the "ability to understand and use subject-matter knowledge to carry out the tasks of teaching" (p. 372), which was originally described by Shulman (1986).

For example, the development of fractional concepts is readily discussed in the literature, and there is an emphasis on the underlying key conceptual practices in early mathematics, which include measurement, patterns, number sense, and the development of algebraic thinking, just to name a few (Empson, 1999; Van de Walle, 2007). This is an area of mathematical knowledge that is readily taught in Laura's fourth-grade curriculum and an area in which she consistently expressed her deep understanding of the content and pedagogical knowledge throughout her interview. With K–5 mathematical instructional and content knowledge being noted as an area of weakness in elementary education (Hill & Ball, 2004), teacher education programs can expand the number of methods courses that preservice teachers are required to take as well as the scope of the content and pedagogical knowledge that is taught in these classes.

An additional implication of this study is the translation of curriculum integration throughout Laura's pedagogy. Although she was taught using a model that infused integration among multiple disciplines, it was not evident in her teaching observation. This is likely due to time constraints because she is encouraged to spend more time on tested subjects. Effective implementation of curriculum integration relies not solely on an individual's pedagogical education and self-efficacy but also the culture and context embedded within the school itself.

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Appendix

Table A1
Initial Codes and Code Families

Themes/memos	Codes	Behaviors	Frequency	In vivo codes
Instructional gains from program This refers to the knowledge that the participant felt like she gained in her teacher preparation program in order to assist her with the instruction of her students.	• Confidence in subject areas • Contribution to team • Curriculum integration • Diagnosing misconceptions • Mathematical conceptual understanding • Preparedness		29	"I feel like just in the fact that I had, like a conceptual understanding of the math, it helped. Because I could take it down to the concrete level for the kids that need it."
Instructional hurdles This refers to the instructional hurdles that the participant felt like she encountered during her teaching experience.	• No EIE • Struggles in science teaching • Struggles in the beginning of teaching • Role of inclusion • Technology use • Underpreparedness	Would laugh nervously talking about some of these aspects.	41	"I definitely don't use engineering so no on that side. But as far as like as science, technology and math, my science instruction can be stronger and better but I do integrate math into that and technology we use all the time. And I feel like my first year with the technology I was like "oh my gosh what is this. I have to use it all the time. There's all this pressure." But now I feel like I know how to use it as an instructional tool versus like a teacher, a second teacher, if that makes sense."
Aspects of teaching out of her control This refers to the decisions made that are not within the teacher's control.	• District requirements • Lack of curriculum resources • Schedule • Valued due to testing • Negative PD • Positive PD	Would laugh nervously talking about some of these aspects.	30	"Um, well we have a little bit of say but since I am inclusion this year I had almost zero say because I have to teach reading when the EC teacher is available and I have to teach math when she is available and then I have a couple kids that go out for certain interventions and that block of time had to be flex time so they could go out, then so mine is kind of rigid this year . . . ."
Critical reflection and scrutiny This refers to the participants (teachers) critical reflection of her education program and instructional practices and to the judgment and/or interaction with coworkers that sometimes influences the participant.	• Passion in math led to degree choice • Underpreparedness • Preparedness • Contribution to team • Judgment of peers • Voluntary PD		19	"This is like hard. Umm okay (takes sheet of paper and pen off table) (Thinks about where to start). Okay, so like—my first—I'm very critical of myself, so not like good at all." "So like I was overwhelmed about being judged without anyone knowing the whole picture. But, it went well. They actually talked about where they came from and noticed that 55 was great."
What STEM means to her This refers to what STEM means to the participant in an elementary setting and the overall definition of STEM.	• Technology use • STEM as conceptual understanding • Mathematical conceptual understanding		17	"Like really helping that get a conceptual understanding so they can have a good foundation. So I feel like STEM in the elementary is like building a good foundation for them in science and technology and all that so that way they can be successful."