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Elementary Preservice Teacher Preparation to Teach Mathematics and Science in an Integrated STEM Framework

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Abstract: A mixed-methods research design with a sequential, explanatory approach was used to investigate the extent to which successful completion of integrated mathematics and science methods of instruction courses related to elementary preservice teachers' attitudes toward and confidence in teaching integrated STEM lessons. Participants (n = 24) were enrolled in their final two semesters of a teacher preparation program at a four-year public university leading to dual certification in elementary (K-6) and special education. Quantitative data were collected using the STEM Attitudes Questionnaire and the STEM Confidence Questionnaire and administered as a pre, post, and delayed post measure. Qualitative data were obtained from focus group participants and open-ended questions added to the delayed post-measures. Results indicated an overall positive change in attitudes and confidence over the 11-month period but no statistically significant difference in the participants' attitudes toward or confidence in teaching integrated STEM lessons. Important implications for the numerous stakeholders of STEM education are presented.

Keywords: *Elementary STEM Education; Teacher Preparation; Attitudes; Confidence*

Introduction

To advance America's discovery and innovation in the Science, Technology, Engineering, and Mathematics (STEM) disciplines, the efforts to improve STEM education have become a priority (President's Council of Advisors on Science and Technology [PCAST], 2010). The publications of the Common Core State Standards for Mathematics (CCSSM; National Governors Association Center for Best Practices [NGACPB], 2010) and the Next Generation Science Standards (NGSS; Achieve, 2012) both include an increased focus on real-life applications and practices of mathematics and science concepts in K-12 classrooms. This, along with the inclusion of engineering design in the NGSS (Achieve, 2012), supports an integrated approach to learning in both the K-12 mathematics and science curricula through the integration of STEM content, allowing students to use mathematics and apply scientific inquiry skills in real-life problem-solving contexts to develop more meaningful knowledge and understanding of the world around them (Al Orime & Ambusaidi, 2011).

Whereas the idea of STEM integration in the early grades is gaining support on the national scene, there remains a deficit in the provision of STEM education in elementary schools (Barcelona, 2014; Kurup et al., 2017). The responsibility for developing elementary preservice teachers' content knowledge and pedagogical knowledge for teaching integrated STEM content lies within teacher preparation programs (TPP). Engaging preservice teachers (PST) in STEM learning and teaching practices allows them to make connections across STEM disciplines, thus increasing their content knowledge, pedagogical content knowledge, and confidence for teaching integrated STEM lessons (Barcelona, 2014; Kurup et al., 2017).

Furthermore, as the attitudes teachers have toward a subject influence their own instructional practices, an important factor in STEM education is improving PST' attitudes toward an integrated approach to teaching mathematics and science, leading to understanding and teaching integrated STEM in their future classrooms (Corlu et al., 2015). PST' attitudes toward integrated STEM teaching are also significantly impacted by explicit integrated STEM instruction in TPP (Kurup et al., 2017; Radloff & Guzey, 2017). Additionally, embedding explicit instructional strategies for STEM integration situated in authentic learning experiences may increase PST' knowledge of and confidence in teaching meaningful integrated mathematics and science content through best practices, not to the detriment of either discipline but to the promotion of both (Al Orime & Ambusaidi, 2011). This study describes the experiences of 24 elementary PST participating in integrated mathematics and science methods courses and related field placements – as learners and educators – and the impact of these experiences on their attitudes and confidence related to teaching integrated STEM lessons in the elementary classroom.

Literature Review

Mathematics and Science Integration

Effective integrated instruction requires teachers to have a deeper knowledge of how to correlate the different content areas. This includes constructing lessons or units that complement and support content and learning skills in at least two subject areas. The integration of mathematics and science provides an avenue for students to develop a more meaningful understanding and value of the important connections between and real-life applications of mathematics and science. (Frykholm & Glasson, 2005; Furner & Kumar, 2007). Huntley (1998) developed the Mathematics/Science Continuum framework based on the five categories describing interactions between mathematics and science defined by participants at the 1967 Cambridge Conference (Education Development Center, 1969). Presented in the Mathematics/Science Continuum is the transformation of the discrete categories into continuous categories representing the extent of interaction between mathematics and science during instruction. The five categories include *mathematics for the sake of mathematics*, *mathematics with science*, *mathematics and science*, *science with mathematics*, and *science for the sake of science*. Separate approaches to teaching mathematics and science are at the ends of the continuum. Movement toward the middle of the continuum represents an "increased infusion of one discipline (mathematics or science) into the teaching and learning of the other discipline (science or mathematics)" (Huntley, 1998, p. 321). In the middle of the continuum is the complete integration of mathematics and science, in which activities or units are designed so that both disciplines interact resulting in student learning of more than just the content of each subject.

Providing rich experiences for preservice teachers to develop both content and pedagogical knowledge for teaching connected mathematics and science within teacher education programs allows preservice teachers opportunities to connect mathematics and science in hopes that the same reform instruction would be implemented in their future classrooms. Furthermore, as methods of instruction courses within teacher preparation programs highly impact preservice teachers' self-efficacy in teaching, embedding integrated mathematics and science teaching may lead to an increase in preservice teachers' self-efficacy in teaching meaningful integrated mathematics and science lessons in the classroom (Frykholm & Glasson, 2005; Furner & Kumar, 2007).

Integrated STEM Education

Integrated STEM education provides opportunities for students to actively construct, contextualize, and connect STEM concepts in a social environment that is both learner-centered and knowledge-centered and can be described as the purposeful combination of some or all of the STEM disciplines into one class, unit, or lesson, with real-life application (Moore & Smith, 2014). STEM integration also includes STEM-related teaching practices outlined in the NGSS (Achieve, 2012), CCSSM (NGACPB, 2010), and the Mathematics Teaching Practices (NCTM, 2014). Characteristics of STEM education also includes students participating in active and inquiry-based learning, working cooperatively in small groups, while solving problems situated in real life. Following the 5E model of teaching (Bybee et al., 2006), teachers act as facilitators of student-centered learning allowing sufficient time for students to initially explore the phenomena under investigation, resulting in a more in-depth understanding of the STEM content. (Bybee, 2013; Navy & Kaya, 2020).

Potential benefits of integrated STEM learning experiences at the elementary school level have been identified in the literature (Barcelona, 2014; Kermani & Aldemir, 2015, Navy & Kaya, 2020). Barcelona (2014) found that student achievement at the elementary level was higher when students were engaged in integrated STEM learning, enhancing student learning and student attitudes as they are engaged in real-life, problem-solving learning contexts. Furthermore, providing early access to an understanding of the foundations of STEM learning within elementary classrooms may increase interest in and preparation of students to enter STEM careers (Kermani & Aldemir, 2015) as learning is made more relevant and at a deeper level of understanding for the students (Navy & Kaya, 2020).

Despite the potential benefits, effective implementation of integrated STEM education has been met with barriers and challenges at different levels. Teacher-related barriers have been identified in the literature that include insufficient content knowledge in STEM fields and the pedagogical strategies that could assist them in making meaningful and appropriate connections between or among the subjects (Frykholm & Glasson, 2005; Nadelson et al., 2013). Additionally, teachers bring their own beliefs to the classroom, including their experiences as learners of STEM subjects, predisposed to the teaching of mathematics and science in isolation as independent subjects in schools and curricula (Frykholm & Glasson, 2005; Moore & Smith, 2014). Teachers may also perceive authentic integration as impractical as they feel the pressure of high-stakes tests which are designed with mathematics and science segregated, focusing on single content-specific knowledge, not practices or applications of knowledge. Moore and Smith (2014) also identified barriers for STEM integration including a lack of technology-related and other material resources, the scarcity of research-based integrated STEM curricula, and a lack of alignment of mathematics and science content standards. Furthermore, with the emphasis on numeracy and literacy, the amount of time teaching science and other content outside of mathematics and literacy has declined resulting in fewer opportunities for elementary teachers to increase their STEM content knowledge and heighten their perceptions of STEM teaching and learning so they may effectively implement integrated STEM education into their classrooms (Nadelson et al., 2013).

Elementary STEM Teacher Preparation

Integrated skills and knowledge in STEM fields, developed through early experiences in primary school, are crucial for the development of 21st-century competencies. Future teachers play an important role in the development of these competencies and must have strong knowledge of both content and pedagogy in order to teach STEM lessons and make meaningful connections among STEM disciplines (Berlin & White, 2012; Epstein & Miller, 2011; Kurup et al., 2017). With an emphasis on the need for developing 21st-century skills in K-12 students, TPP must be the starting point with embedded experiences ensuring explicit connections are made among the STEM disciplines preparing PST to teach integrated STEM lessons (Corlu et al., 2015; Kurup et al., 2017; Riegle-Crumb et al., 2015).

In order for teachers to effectively teach STEM content, both their STEM content knowledge and teaching strategies for integrated STEM lessons must be improved; thus, teacher educators must be concerned with goals of integrated STEM teaching practices (Pimthong & Williams, 2021). Shulman's (1986) concept of pedagogical content knowledge (PCK) outlines important aspects of teaching with understanding including implementation of appropriate pedagogical strategies, assessment of student needs, knowledge of the curriculum, and the ability to develop conceptual understanding of concepts within the discipline. Within TPP, opportunities are needed for PST to develop an understanding of effective strategies for teaching integrated STEM lessons, leading to increased PCK for teaching integrated STEM content (Epstein & Miller, 2011; Pimthong & Williams, 2021).

In addition to knowledge for teaching STEM content, PST enter TPP with beliefs in their abilities and attitudes towards their skills in teaching STEM content effectively (Maher et al., 2013). The theory of planned behavior (Ajzen & Fishbein, 1980) emphasizes how a person's behavior is shaped by his or her knowledge, attitudes, values, subjective norms, and perceived behavioral control. According to Corlu et al. (2015), poor attitudes of PST toward mathematics and science may negatively affect their ability to learn and effectively teach the content in both subjects. By examining their own attitudes, concerns, and beliefs toward STEM education, PST may develop positive perceptions of STEM education and an awareness of how their future students will be impacted by positive experiences engaging in integrated STEM lessons (Maher et al., 2013). Throughout TPP, including more exposure to integrated STEM teaching and learning, focusing on real-life experiences, may enhance integrated STEM teaching and learning experiences in the PST' future classrooms (Barcelona, 2014; Kurup et al., 2017; Radloff & Guzey, 2017).

As a social cognitive theory, self-efficacy conceives a set of beliefs about a teacher's capacity to positively influence student learning including personal mastery experiences (Bandura, 1978; Tschannen-Moran & Hoy, 2001). According to Kurup et al. (2017), positive beliefs and understandings about STEM education can lead to more confident and competent teachers, connecting STEM learning to the daily lives of their students and equipping them with 21st-century skills. Additionally, PST need specialization in STEM practices and procedures including integrated teaching throughout their TPP (Kelley et al., 2020). Thus, participation in inquiry-based content and methods courses – including an integrated approach to teaching mathematics and science – may lead to enhanced attitudes toward and confidence in teaching integrated STEM content (Johnson et al., 2021; Corlu et al., 2015).

Field placements also play a pivotal role in determining the extent to which integrated STEM lessons are planned and implemented (Kurup et al., 2017). As PST more often experience segregated mathematics and science curricula, this lack of exposure to integrated teaching may result in PST feeling unprepared to teach integrated STEM lessons (Kurup et al., 2017). Thus, TPP need to offer PST an opportunity to observe and implement effective and authentic STEM practices in their field placements in classrooms with teachers who are committed to curriculum integration and in which integrated STEM lessons are prevalent (Barcelona, 2014; Kurup et al., 2017; Radloff & Guzey, 2017).

The purpose of this study was to investigate the extent to which successful completion of integrated mathematics and science methods of instruction courses related to elementary preservice teachers' attitudes toward and confidence in teaching integrated STEM lessons. This mixed-methods study was guided by the following questions:

Among elementary PST participating in integrated mathematics and science methods of instruction courses:

1. …to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?
2. …to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

Research Design

A mixed-methods, sequential, explanatory design was used to explore changes in elementary preservice teachers' attitudes toward and confidence in teaching integrated STEM lessons over the course of their final two semesters of a teacher preparation program. Both quantitative and qualitative data were collected over an 11-month period to gain a better understanding of the phenomena under investigation. Initial (pre) administration of the questionnaires in January was followed by a second (post) administration of the questionnaires in April. Collection of qualitative data through semi-structured interviews in May was followed by the final (delayed post) administration of the questionnaires with additional open-ended questions in November. Data were analyzed and triangulated to establish corroboration of the quantitative and qualitative data.

Participants

Participants included 24 elementary PST at a four-year public university situated in an urban city in the southeastern United States and majoring in K-6 Teacher Education, leading to an opportunity to attain initial teaching certification in both Elementary Education and K-6 Collaborative Teaching (Special Education). A power analysis was conducted in *G*Power* to determine the recommended sample size (Faul et al., 2013). Using standard power ($\beta = 0.80$), alpha level of 0.05, and a medium effect size ($f^2 = .25$), the recommended sample size was 28, which aligned with the suggested minimum sample size requirement for a multivariate analysis of variance (MANOVA) of at least 20 cases (Hair et al., 2010). Throughout the three phases of the study, data were collected from 34 elementary preservice teachers. Of the 34, 94% (N = 32) participated in the pretest, 94% (N = 32) participated in the posttest, and 83% (N = 30) participated in the delayed posttest. Incomplete data in the delayed posttest was attributed to lack of enrollment in the Tier 4 Internship semester of four participants and lack of completion of the questionnaires by two participants. The two preservice teachers who did not participate in the pretest were different from the two who did not participate in the posttest, resulting in only 72.2% (N = 26) of the preservice teachers participating in all three quantitative data collection time points. As a result of further data screening, two participants were eliminated from the study due to pattern responses. Both participants recorded the same score for each item even though both positively worded and negatively worded items were included. Thus, data provided by a total of 24 participants were used in this study. All participants were females (23 White and 1 African American) with ages ranging from 21 to 36 (M = 23.88, SD = 4.40).

To provide further explanatory power to the quantitative results, a purposeful sample of the participants in the quantitative phase was selected for the qualitative phase of this study (Creswell & Plano Clark, 2011; Johnson & Christensen, 2008). Following the posttest, 11 participants were selected to participate in a focus group based on their high level of engagement and interest in planning of and participation in integrated STEM lessons. Of the 11, four responded to the solicitation email with all being White females. Participation was voluntary with no incentives offered.

Context

The K-6 program in this study is unique as the PST are prepared, through coursework and field experiences, for general education and special education settings. To build a sense of school culture and community (Kelley et al., 2020), the elementary preservice teachers remain in the same school placement for the final three semesters of the program, including the Tier 3 methods of instruction and Tier 4 internship semester. Furthermore, in effort to better prepare elementary PST to teach integrated STEM, the mathematics and science methods of instruction courses were revised to include integrated mathematics and science pedagogy using a variety of co-teaching strategies. Both methods of instruction courses, taught as separate courses, continued to include many content-specific learning experiences. However, authentic and intentional integrated mathematics and science learning activities were included in joint class sessions to offer the elementary

PST an opportunity to experience integrated STEM education as learners and educators.

The Standards for Mathematical Practice (NGACPB, 2010), the Mathematics Teaching Practices (NCTM, 2014), and the Science and Engineering Practices (Achieve, 2012) guided PST engagement and learning through multiple integrated STEM lessons co-taught by the mathematics methods instructor, the science methods professor, and the special education professor in joint class sessions. The focus of these four co-taught lessons included: purposeful team teaching using faculty content expertise during participation in an integrated mathematics and science activity, use of observation data as formative assessment during participation in an integrated STEM activity, exploration of mathematics and science content standards and learning progressions through a lens of teaching all learners, and team lesson planning feedback from content expertise faculty including accommodations in STEM learning.

To deepen their experience, the preservice teachers – working in teams of four – were required to collaboratively plan an integrated STEM lesson focused on specific grade-level aligned mathematics and science content standards that were purposefully selected by the course instructors to allow for authentic mathematics and science integration. Using the Mathematics/Science Continuum model (Huntley, 1998) as the theoretical framework, the teams developed a *mathematics and science* integrated lesson that falls in the middle of the continuum. Implementation of active, inquiry-based learning using a hands-on approach for both the mathematics and science content, student engagement in real-world problem solving guided by the 5E model of instruction (Bybee et al., 2006), and appropriate accommodations were required components. After the initial draft of the lesson plan was completed, each team met with and received individual feedback from the content expertise faculty to ensure the mathematics and science content was accurate and effective pedagogical strategies aligned with mathematics and science integration. Following the feedback session, the team lesson plans were presented to both the faculty and their peers during one joint class session, providing additional feedback used to further refine their integrated STEM lessons. Building on the team planning experience, the PST used both mathematics and science content standards in their K-6 grade level placements, based on district-level pacing guides, to individually plan and implement integrated STEM lessons as a three- to five-day learning segment during the final two weeks of the semester. The individual integrated learning segment also used the Mathematics/Science Continuum model (Huntley, 1998) as the theoretical framework on which the PST developed *mathematics and science* integrated lessons. During the following internship semester completed at the same school, the participants were not required to plan and implement integrated STEM lessons unlike during the methods semester. However, they were required to teach all subjects for a minimum of 10 consecutive days, with the opportunity to teach integrated STEM lessons.

Instruments

Quantitative Data

The STEM Attitudes Questionnaire, adapted from the Survey of Attitudes Toward Statistics-36 (SATS-36) (Schau, 2003a), was used to measure participants' attitudes toward teaching mathematics and science in an integrated STEM framework. The STEM Attitudes

Questionnaire consisted of 34 items that assess six components of attitudes: Affect, Cognitive Competence, Value, Difficulty, Interest, and Effort. Participants responded to each item using a 7-point Likert-type scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*. Table 1 describes each component and provides sample items from the STEM Attitudes Questionnaire that were modified to reflect a focus on integrated STEM education. The structure, original scale, and scoring method of the original instrument were maintained. Prior to scoring, responses to the 19 negatively worded items were reversed so that a higher numbered response corresponds to more positive attitudes. Each component score was determined by calculating each component's item response mean, and the composite attitudes score was determined by calculating the mean of all the item responses.

Table 1

STEM Attitudes Questionnaire: Components, Definitions, and Sample Items

Component	Definition	Sample Item
Affect (6 items)	Elementary preservice teachers' "feelings concerning" teaching integrated STEM lessons	"I will like teaching mathematics and science in an integrated STEM framework."
Cognitive Competence (6 items)	elementary preservice teachers' "attitudes about their intellectual knowledge and skills when applied to" teaching integrated STEM lessons	"I am capable of learning how to teach mathematics and science in an integrated STEM framework."
Value (9 items)	elementary preservice teachers' "attitudes about the usefulness, relevance, and worth" of teaching integrated STEM lessons	"Teaching mathematics and science lessons in an integrated STEM framework should be a required part of my professional teacher preparation."
Difficulty (7 items)	elementary preservice teachers' "attitudes about the difficulty" of teaching integrated STEM lessons	"Integrating mathematics and science in a STEM framework is complicated."
Interest (4 items)	elementary preservice teachers' "level of individual interest" in teaching integrated STEM lessons	"I am interested in being able to plan and teach lessons that integrate mathematics and science."
Effort (4 items)	"amount of work" the elementary preservice teacher devotes to teach integrated STEM lessons	"I plan to persevere in planning and teaching integrated mathematics and science lessons.

Note. Adapted from *The Importance of Attitudes in Statistics Education* by C. Ramirez, C. Schau, & E. Emmioglu, 2012, p. 61. www.evaluationandstatistics.com

The STEM Confidence Questionnaire was adapted from the Self-Efficacy to Teach Science in an Integrated STEM Framework (SETIS) instrument (Mobley, 2015). The STEM Confidence

Questionnaire – used to measure participants' confidence to teach mathematics and science in an integrated STEM framework – consisted of 30 self-report items that assess three factors of confidence: Social, Personal, and Material. Participants responded to each item using a 4-point Likert-type scale ranging from 1 = *Cannot do this at all* to 4 = *Very confident I can do this*. Table 2 describes each of the three factors and provides sample items from the STEM Confidence Questionnaire that were modified to reflect a more general focus on science and mathematics. The structure, original scale, and scoring method of the original instrument were maintained. Each factor score was determined by calculating the mean of the item responses within each factor, and the overall confidence score was determined by calculating the mean of the item responses.

Table 2

STEM Confidence Questionnaire: Factors, Definitions, and Sample Items

Factor	Definition	Sample Item
Social *"others-oriented"* (10 items)	elementary preservice teachers' confidence in their ability to teach mathematics and science in an integrated STEM framework "related to aspects of self-efficacy that were not entirely within the teachers' control"	**Choose your level of confidence in your ability to** "Earn acceptable teacher-evaluation/performance scores while teaching science and mathematics in an integrated STEM framework."
Personal *"self-oriented"* (5 items)	elementary preservice teachers' confidence in their ability to teach mathematics and science in an integrated STEM framework "related to aspects of self-efficacy that are within the control of the individual and theoretically immune from outside influence"	**Choose your level of confidence in your ability to** "Use my understanding of integrated STEM in a way that allows me to teach science and mathematics effectively."
Material *"peripherally-oriented"* (4 items)	elementary preservice teachers' confidence in their ability to teach mathematics and science in an integrated STEM framework "related to aspects of self-efficacy that reside outside of individual or social control"	**Choose your level of confidence in your ability to** "Access technology to teach science and mathematics from within an integrated STEM framework."

Note. Adapted from *Development of the SETIS instrument to measure teachers' self-efficacy to teach science in an integrated STEM framework* (Doctoral Dissertation) by M. Mobley, 2015, p. 99.

Reliability for both questionnaires at each of the three time points was established through item analysis using Cronbach's alpha (1951). Item analysis for the STEM Attitudes Questionnaire revealed a range of reliability coefficients which included the components of Affect (.84 to .87), Cognitive Competence (.72 to .81), Value (.70 to .84), Difficulty (.52 to .71), Interest (.89 to .92), and Effort (.48 to .79). The reliability analysis supported the prior analyses performed on the original SATS-36 components with single administration (Nolan et al., 2012). The reliability coefficients for the three factors within the STEM Confidence Questionnaire were all above .80 for the pre, post, and delayed posttests supported by the prior analyses in the development of the original SETIS instrument (Mobley, 2015). Content validity for both questionnaires was established through an expert panel of four teacher education professors with STEM backgrounds who conduct research on STEM integration. The panel reviewed the items for relevance and made suggestions for alternative wording of unclear or confusing items.

Qualitative Data

Upon initial quantitative data analysis, research-based questions for the focus group interview protocol were developed by the Tier 3 methods faculty to provide additional insight into changes in attitudes toward and confidence in planning and teaching integrated STEM lessons, including barriers and challenges related to integrated STEM teaching, during the methods semester. Additionally, open-ended questions were added to the instruments for the delayed post administration to allow the participants to explain in greater depth how their attitudes toward and confidence in teaching integrated STEM lessons had changed over the two semesters and describe barriers and challenges faced during the internship semester. Both the focus group interview protocol and the open-ended questions were reviewed by experts in the field to establish validity and provide suggestions for alternate wording to ensure the questions were clear and concise.

Data Collection and Analysis

Quanitative Data

Participants completed both questionnaires at three different time points during this study—pretest (January), posttest (April), and delayed posttest (November). Participants completed the pretest and posttest online during an on-campus class meeting at the beginning and the end of the methods semester. The delayed posttest was administered online during the final three weeks of the participants' internship. Links to the questionnaires were emailed to the participants with instructions to complete within two weeks. A follow-up email, at the end of two weeks, reminded participants to complete the questionnaires within one week.

Descriptive statistics, including measures of central tendency, were used to initially describe, summarize, and interpret the data noting any possible trends. As research suggests a relationship between teacher attitudes and confidence (Tschannen-Moran & Hoy, 2001), a multivariate analysis of variance (MANOVA) with repeated measures was used to identify statistically significant main and interaction effects of time (pre, post, delayed post) for the scales associated with attitudes and confidence. All assumptions were tested and none were violated.

Qualitative Data

Upon completion of the methods semester, semi-structured interviews with four participants were conducted within a focus group. The audio file from the focus group interviews was transcribed, and multiple cycles of coding were employed to identify emerging themes using the qualitative software Quirkos. The constant comparative method (Glasser & Strauss, 1967) was implemented to analyze qualitative data obtained from the focus group interviews and the written responses to the open-ended questions. After multiple cycles of open coding, six initial themes emerged: perceptions of STEM integration, characteristics of STEM integration, barriers to STEM integration, STEM content knowledge, classroom teacher support, and modeling of lessons. Further analysis was conducted to identify significant overlaps between several themes resulting in three major categories: experiences preservice teachers believed impacted their attitudes, experiences preservice teachers believed impacted their confidence, and barriers to and challenges faced related to integrated STEM lessons.

Results

Quantitative Data

Based on the normal sampling distribution of scores, paired-samples *t* tests, using a two-tailed 95% confidence interval, were conducted to determine if there were any overall statistically significant differences from pretest to posttest in the participants' attitudes toward and confidence in teaching integrated STEM lessons during the methods semester and to inform subsequent data analysis of the delayed post measures. Shown in Table 3, the findings revealed a statistically significant difference (p = .001) in the participants' confidence in teaching integrated STEM lessons from the beginning (M = 3.00, SD = 0.57) to the end (M = 3.37, SD = 0.41) of the Tier 3 methods semester.

Table 3

Changes in Preservice Teachers' Attitudes and Confidence During the Methods Semester

	Pretest	Posttest			
	M (SD)	*M (SD)*	*t* statistic	Significance	Effect size
Attitudes	5.07 (0.66)	5.28 (0.64)	-1.855	*p* = .076	r = .36
Confidence	3.00 (0.57)	3.37 (0.41)	-3.655	*p* = .001	r = .37

Results from the MANOVA with repeated measures revealed no statistically significant effect of time on the participants' attitudes towards or confidence in teaching integrated STEM lessons. However, although not statistically significant, findings revealed positive changes in the participants' attitudes in each of the components except Effort over the two semesters. While the data showed an overall positive change in the participants' attitudes over the two semesters, the scores from post (M = 5.28, SD = 0.64) to delayed posttest (M = 5.21, SD = 0.71) decreased throughout the internship semester. Within four of the subscales (Affect, Cognitive Competence, Value, Difficulty), there was a slight increase in reported attitudes; however, the decrease in attitudes within the Interest and Effort subscales contributed to the overall decrease throughout the internship semester. Within the subscale of Effort, there was a statistically significant effect of time on the elementary preservice teachers' attitudes towards teaching integrated STEM lessons, $\Lambda = 0.67$, $F(4, 17) = 5.37$, $p = .01$. The results of the analysis of the STEM Attitudes Questionnaire, by the six components of attitudes to and the composite attitudes scores, are shown in Table 4.

Table 4

Changes in Preservice Teachers' Attitudes Toward Teaching Integrated STEM Lessons

	Pretest	Posttest	Delayed Posttest
Component	*M (SD)*	*M (SD)*	*M (SD)*
Affect	4.53 (1.17)	5.13 (1.07)	5.15 (1.18)
Cognitive Competence	4.96 (1.00)	5.17 (0.99)	5.39 (0.87)
Value	5.44 (0.92)	5.66 (0.71)	5.68 (0.89)
Difficulty	3.33 (0.79)	3.49 (0.74)	3.57 (0.96)
Interest	5.85 (0.89)	6.03 (0.68)	5.93 (0.82)
Effort	6.28 (0.61)	6.21 (0.62)	5.70 (0.90)
Composite	5.07 (0.66)	5.28 (0.64)	5.21 (0.71)

The results of analysis of the STEM Confidence Questionnaire by the factors of confidence in teaching integrated STEM lessons and the overall confidence scores revealed positive changes in the participants' confidence in all of the factors over the two semesters, as shown in Table 5. Although a positive change in the participants' confidence over the two semesters was revealed, the overall confidence scores from post (M = 3.37, SD = 0.41) to delayed posttest (M = 3.30, SD = 0.48) decreased throughout the internship semester.

Table 5

Changes in Preservice Teachers' Confidence in Teaching Integrated STEM Lessons

	Pretest	Posttest	Delayed Posttest
Factor	*M (SD)*	*M (SD)*	*M (SD)*
Social	3.02 (0.57)	3.27 (0.39)	3.28 (0.48)
Personal	2.86 (0.57)	3.34 (0.50)	3.29 (0.48)
Material	3.14 (0.66)	3.49 (0.47)	3.41 (0.58)
Overall	3.00 (0.57)	3.37 (0.41)	3.30 (0.48)

Qualitative Data

Qualitative data analysis revealed factors associated with the participants' integrated STEM experiences related to three major themes: experiences preservice teachers believed impacted their attitudes, experiences preservice teachers believed impacted their confidence, and barriers to and challenges faced during implementation of integrated STEM lessons. The first two themes represent those aspects of preparation and experiences that the preservice teachers believed impacted their attitudes and confidence. Several responses indicated positive changes in attitudes toward teaching integrated STEM lessons:

> I see how it can help students truly understand how to learn and show them why we need to know things. Many students ask, "Why do I need to know this?”, and by having them see how science and math intertwines, the students will understand why we need both science and math.

Some responses spoke to the influence of integrated STEM experiences on student learning such as, “My attitude towards STEM has improved greatly after witnessing the way it changes student learning… they see how it makes the real-life connection and purpose,” and, “I know not every lesson will be suitable for integration, but utilizing STEM integration can create deeper conceptual understandings of the lessons.” Others reflected on how integration of STEM concepts seems work intensive, though worthwhile:

My attitude toward teaching STEM lessons has changed over the Tier 3 and 4 semesters. I learned that it takes strong discipline to understand concepts and the procedure on how I would teach the students. It is a lot of work but very rewarding to student learning!

The participants also described experiences over the two semesters that positively influenced their confidence in teaching integrated STEM lessons. During the methods courses, the participants attributed the increase in their knowledge of and confidence in planning and teaching integrated STEM lessons to the faculty’s modeling of co-taught integrated lessons, with comments such as, “I think every day seeing it modeled. Y'all consistently even when you're teaching a lesson and not necessarily, you're like, ‘Oh but in a classroom you could do this.’” As the opportunities to teach integrated STEM lessons increased, the participants were able to gain more confidence stating, “I feel more confident and excited to teach them (STEM lessons) in Tier 4 (internship) because I have observed and taught more STEM lessons,” and, “Experience in the classroom has created a greater confidence in my skills; the CT I was fortunate to be with were wonderful resources for me to learn from.” Overall, increased confidence was reflected in responses such as, “It has changed tremendously. I am less intimidated by STEM,” and, “At the beginning, I was very intimidated by trying to pull in math, but now I am much more confident; it was a lot easier now than it was at the beginning.” A sense of excitement in actualizing STEM integration was also conveyed in comments such as, “After being in my methods classes, seeing it taught, and teaching it myself, I feel excited about teaching integrated STEM lessons.”

Barriers and challenges related to the difficulty and implementation of integrated STEM lessons were identified including a lack of resources, teacher support, and time. Responses such as, “I have been able to teach some integrated lessons but not many due to available and affordable resources,” and, “No access to supplies,” provided evidence of the material barriers participants faced in teaching integrated STEM lessons. Participants also faced challenges in planning integrated lessons due to the lack of STEM curricula and the misalignment of the mathematics and science content standards in the pacing guide as noted by comments such as, “Standards did not align for both math and science to produce a STEM lesson,” and, “There's a little bit more work in the sense that you've got to figure out what will connect and where to thoroughly teach it.”

A lack of teacher support in the field placement also contributed to the difficulty in implementing integrated STEM lessons:

> There is not a teacher at my school (that I am aware of) who is teaching any kind of STEM or integrated lesson. I feel it would be very difficult to do this without getting backlash from my fellow grade level teachers.

Other responses including, “There were not many opportunities to do integrated lessons in the second-grade classroom I was in because the cooperating teacher did not want to focus on science and social studies” were indicative of the lack of teacher support in the classroom.

The participants expressed additional concerns about the time demands of planning STEM instruction given the workload associated with other content areas, as well as the time in the classroom needed to effectively implement the lessons. “It takes so much time to plan,” and, “You’re only there two days a week...the time is hard” spoke to the demands of extra time needed to plan integrated lessons. Additionally, comments such as, “Some of the activities I couldn't even do because there was no time,” and, “There hasn’t been much opportunity to teach STEM lessons” were indicative of the factors hindering the sustainability of preservice teachers implementing integrated STEM lessons.

Discussions

The findings of this study illuminate experiences that impacted the participants’ attitudes toward and confidence in planning and implementing integrated STEM lessons, as well as barriers to and challenges faced. Over the final two semesters of the program, an increase in composite attitudes indicated improved changes in participants’ attitudes toward teaching integrated STEM lessons prior to and completion of integrated mathematics and science methods of instruction courses. These findings are consistent with previous research suggesting that PST’ attitudes toward STEM education were enhanced after participating in inquiry-based methods of instruction courses (Riegle-Crumb et al., 2015) and engaging in authentic integrated STEM teaching experiences (Thibaut et al., 2018). Participants’ attitudes were also enhanced as they recognized the positive impact of integrated STEM lessons on student learning (Value subscale) resulting in deeper conceptual understanding of both the mathematics and science content (Navy & Kaya, 2020). However, while the data revealed an overall positive change in the participants’ attitudes over the two semesters, attitudes decreased slightly at the completion of the internship semester. These results are consistent with Berlin and White (2012) as the elementary preservice teachers may have developed a more realistic understanding of integrating mathematics and science.

Thomas (2014) also found that a significant amount of variability in teachers’ attitudes toward STEM education was predicted by several factors including school support, perceived practicality, financial support, and designated time for vertical and grade-level alignment of the content standards to make the integration more authentic. As part of the requirements for the teacher preparation program, the participants in this study spent one half of their internship in a regular education classroom and the other half in a special education classroom. Thus, the opportunity to experience integrated STEM teaching and learning may have been limited based on the two placements.

As mentioned in the responses to one of the open-ended questions in this study, the participants who did not experience integrated STEM teaching did not have an opportunity for their attitudes to change during the internship semester.

Similarly, data revealed an overall increase in participants' confidence in teaching integrated STEM lessons over the final two semesters in the TPP. The qualitative data supported the quantitative results in that 83% of the participants reported increases in overall confidence to teach integrated STEM lessons over the two semesters. The participants' confidence in teaching integrated STEM lessons increased with each new opportunity to plan and teach integrated lessons in the classroom. Many were intimidated by integrated STEM teaching at the beginning of the Tier 3 semester but gained more confidence as their time in the elementary classroom increased significantly during the internship (Tier 4) semester. These results were supported by previous findings that teachers' self-efficacy is significantly improved through personal mastery experiences including cycles of implementation of and reflection on integrated STEM lessons (Bandura, 1978; Kelley et al., 2020). Furthermore, embedding integrated mathematics and science teaching in the methods of instruction courses may lead to an increase in PST' self-efficacy in teaching meaningful STEM lessons in the classroom (Frykholm & Glasson, 2005; Riegle-Crumb et al., 2015).

While the elementary preservice teachers reported positive attitudes toward and fairly high levels of confidence in teaching mathematics and science in an integrated STEM framework, responses to the open-ended questions revealed specific barriers to effective planning and implementation of integrated STEM lessons. During the Tier 3 semester, the participants had multiple opportunities to plan, revise, and reflect on their individual and team integrated mathematics and science lessons with the program faculty, their peers, and their cooperating teachers. As the three-day integrated STEM learning segment was a required component of the methods courses, planning these lessons was a priority of the participants, as well as supported by the cooperating teachers. Unfortunately, during the internship semester, there was no required integrated STEM lesson component. As supported by previous research, the participants recognized an emphasis on numeracy and literacy in the elementary classroom, which left limited time to teach science or integrated STEM lessons and was reflected by the decrease in time teaching STEM-related disciplines (Nadelson et al., 2013; NAE & NRC, 2014).

As revealed in related studies, the participants also recognized the immense discipline and work (Effort subscale), it takes to plan and implement effective integrated mathematics and science lessons (Berlin & White, 2012). During both semesters, the perceived difficulty (Difficulty subscale) in planning integrated lessons was attributed to the misalignment of mathematics and science content standards based on the local school district's pacing guides, supporting the need for the mathematics and science curriculum to be aligned and coherent to ensure STEM education is implemented in the classroom (Johnson et al., 2021; Moore & Smith, 2014). Furthermore, due to state high-stakes testing that occurred during the internship semester, the participants were not encouraged or supported to teach integrated lessons as the tests were designed with mathematics and science segregated into content-specific knowledge (Moore & Smith, 2014). These findings support research that suggests a need for TPP to include STEM education in their coursework and to also provide field placements with teachers who are dedicated to integrated STEM education and supportive of PST in their planning and implementation of such lessons. In such classrooms, PST would have the opportunity to observe, plan, and implement effective and authentic STEM lessons leading to the implementation of the STEM practices in their future classrooms (Kurup et al., 2017; Radloff & Guzey, 2017).

Conclusion and Limitations

In this study, several key issues have been highlighted that warrant consideration by the numerous stakeholders of STEM education. Within TPP, providing PST with meaningful experiences as a learner and educator in integrated STEM methods courses, may positively influence their attitudes toward and confidence in promoting STEM education in the elementary classroom (Johnson et al., 2021, Corlu et al., 2015). Additionally, increasing the quantity and quality of the STEM content coursework required may lead to PST who are better equipped to understand and interpret the content and practice standards, increasing their ability to integrate the mathematics and science standards and create authentic learning experiences (Pimthong & Williams, 2021; Radloff & Guzey, 2017). Results also have important implications at the school and district levels. Field placements with teachers that modeled integrated STEM lessons and collaboratively planned STEM lessons with the PST led to enhanced attitudes toward and greater confidence in teaching STEM lessons. Thus, a strong partnership with schools, placing PST in classrooms where integrated STEM lessons are prevalent, is vital to the development of positive attitudes and self-efficacy toward implementing STEM education (Kurup et al., 2017; Thibaut et al., 2018).

Future studies are warranted to add to the existing body of research including an exploration of the relationship between the attitudes towards STEM education of the PST and those of their cooperating teachers. Results of this research could lead to field placements with experienced and supportive teachers that value and implement integrated STEM lessons providing PST more opportunities to plan and implement effective STEM integrated lessons. Additionally, investigating the content of an integrated STEM methods of instruction course may assist in identifying appropriate textbooks, as well as other STEM resources that should be included in such courses, assisting TPP with program course additions and possible redesign.

Although this research contributed to the literature surrounding the need for improving the preparation of teachers to teach integrated STEM lessons, some limitations were identified. One limitation was the use of a small convenience sample consisting of minimally diverse participants. Although this research contributed to the gap in the literature surrounding the need for improving methodological coursework that best prepares teachers to teach integrated STEM lessons, some limitations were identified. One limitation was the use of a small convenience sample (N = 24) consisting of minimally diverse participants. All 24 participants who completed the questionnaires were female elementary preservice teachers (1 African American and 23 Caucasian). Also, the focus group participants were all Caucasian female students. Furthermore, the participants were from a single university, which may have limited the generalizability of the findings. The university in which the study was conducted prepares K-6 teachers to teach in both regular classrooms and special education classrooms, leading to dual certification in both areas. The time that the preservice teachers spend in the elementary classroom and the methods of instruction coursework that they complete is divided between regular education and special education. Other universities may have different types of teacher preparation programs, specifically those that focus only on the regular education classroom. Elementary preservice teachers completing programs at other universities would likely have different experiences within the elementary classroom field experience and university coursework.

Another limitation was the reliability of two of the components of the STEM Attitudes Questionnaire that was adapted from the SATS-36 (Schau, 2003a). This questionnaire relied heavily on negatively worded items. When completing the STEM Attitudes Questionnaire, participants may have missed the presence of a negative term or may have been confused resulting in difficulty with interpreting items. Furthermore, the use of two different procedures for the administration of the pre-, post-, and delayed post-questionnaires may have limited the study. The participants completed the pre- and post-questionnaires in a classroom on the university campus during a regularly scheduled class meeting. The participants completed the delayed post-questionnaire through an emailed link to both questionnaires.

Research has shown that the implementation of integrated STEM education at all levels prepares students for the global economy of the 21st-century (Epstein & Miller, 2011; PCAST, 2010). Integrated approaches pique student interests in and motivation for learning STEM subjects, which will hopefully lead to more students choosing STEM careers. Future teachers need to develop the necessary skills, attitudes, and confidence to incorporate integrated STEM learning experiences in their classrooms. Thus, adequate preparation for PST to teach integrated STEM content and implement practices of STEM fields as part of elementary TPP is imperative in developing 21st-century competencies in all K-12 students.

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