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

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ELEMENTARY PRESERVICE TEACHER PREPARATION TO TEACH
MATHEMATICS AND SCIENCE IN AN INTEGRATED STEM FRAMEWORK

by

Kelly Overby Byrd

A Dissertation
Submitted to the Graduate School,
the College of Arts and Sciences
and the School of Center for Science and Mathematics Education
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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ABSTRACT

This study investigated 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, and the extent to which their attitudes and confidence correlated with their proficiency in planning integrated STEM lessons. A mixed-methods, longitudinal research design, with a sequential, explanatory approach was used. Participants included twenty-four elementary preservice teachers enrolled in their final two semesters of a teacher preparation program at a four-year public university in the southeastern U.S. To address the research questions in this study, both quantitative and qualitative data were analyzed from questionnaires, a learning segment rubric, and semi-structured interviews. Descriptive and inferential statistics, including repeated measures MANOVAs and multiple regression analyses, were calculated to analyze the quantitative data. Multiple cycles of coding were used to analyze the qualitative data.

Quantitative results of this study indicated no statistically significant difference in the participants' attitudes toward or confidence in teaching integrated STEM lessons. However, qualitative data revealed heightened attitudes and increased confidence throughout the two semesters. While the data indicated an overall positive change in the participants' attitudes and confidence over the two semesters, there was a slight decrease in both at the completion of the internship semester. While the elementary preservice teachers reported fairly positive attitudes toward and fairly high levels of confidence in teaching integrated STEM lessons, responses to the open-ended questions revealed specific barriers to effective implementation of integrated STEM lessons in the

elementary classroom. Potential barriers identified by the participants included the difficulty of planning and implementing integrated STEM lessons, emphasis on high-stakes testing, and lack of resources. Further results of this study indicated that the attitudes and confidence of preservice teachers did not statistically significantly predict their proficiency in planning integrated STEM lessons. While no statistical significance was found in the repeated measures MANOVA or the multiple regression analyses, the findings from this study, particularly of the qualitative discussion, may have important implications for the numerous stakeholders of STEM education surrounding successful preparation of teachers to implement integrated STEM education in the K-6 classroom.

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DEDICATION

This dissertation is dedicated to my two angels in heaven looking down. To my dad, Marvin Brannon Overby, I miss you every single day, but I hope I have made you proud, Daddy – the first Dr. Overby in our family. To my dear friend, Dr. Nancy Gaillard, your sweet and loving spirit still surrounds us all, and I will always treasure our time together. You were always one of my biggest cheerleaders, and I miss your smile and friendship so much. I wish you both were here with me to celebrate.

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CHAPTER I – INTRODUCTION

Introduction

In order 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 across the nation. “The success of the United States in the 21st Century – its wealth and welfare – will depend on the ideas and skills of its population. These have always been the Nation’s most important assets. As the world becomes increasingly technological, the value of these national assets will be determined in no small measure by the effectiveness of science, technology, engineering, and mathematics (STEM) education in the United States” (President’s Council of Advisors on Science and Technology [PCAST], 2010, p. 1). The importance of the need for STEM education has been further highlighted by the decrease in the number of students interested in STEM disciplines, leading to a smaller number of students entering the STEM workforce upon graduation.

The recent 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 of mathematics and science concepts and an emphasis on mathematics and science practices in the K-12 classroom. This, along with the inclusion of engineering design in the NGSS, supports an integrated approach to learning in both the K-12 mathematics and science curricula through the integration of STEM content. Integrated learning experiences in mathematics and science allow students to use mathematics and apply scientific inquiry skills in authentic real-life

problem-solving contexts to develop more meaningful knowledge and understanding of the world around them (Al Orime & Ambusaidi, 2011; Stinson, Harkness, Meyer, & Stallworth, 2009).

Contemporary perspectives on STEM teaching and learning include a constructivist approach in which students are engaged in meaningful, active, inquiry-based learning of integrated content within complex, real-life, problem-solving contexts (Balka, 2011; Barcelona, 2014; Stohlmann, Moore, & Cramer, 2013). National standards and reform efforts suggest that integrated skills and knowledge in STEM disciplines are vital to the development of 21st-century skills in our children. Current research promotes integrated STEM curriculum in the elementary school, as young children's openness to and curiosity about mathematical and scientific concepts provide fertile ground for developing student interest in and understanding of STEM content and STEM careers (Becker & Park, 2011; Kermani & Aldemir, 2015; Nadelson et al., 2013; Sanders, 2009).

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; Berlin & White, 2010; Kurup, Brown, Powell, & Li, 2017). The number of U.S. elementary teachers who are proficient in integrating STEM practices into the curriculum is also deficient (National Research Council [NRC], 2010; PCAST, 2010). Lack of support from school administrators, elementary teachers' lack of content knowledge in the STEM disciplines, and elementary teachers' lack of pedagogical content knowledge (PCK) for teaching integrated STEM all contribute to this void (Becker & Park, 2011; Berlin & White, 2010; Nadelson et al., 2013).

Among all education degrees completed in 2016, elementary education and teaching generalist degrees were among the most earned (32%) (National Center for Education Statistics [NCES], 2017). However, many of these graduates are not adequately prepared to teach integrated mathematics and science in grades K-6. Although many preservice teachers value STEM integration, they are not exposed to STEM integration within their teacher preparation programs, leading them to feel less confident and less prepared to teach in a STEM-infused classroom (Berlin & White, 2010; Kurup, et al., 2017). This suggests a lack of opportunity for preservice teachers to engage in authentic mathematics and science practices that allow them to deepen the content knowledge of their future students in these disciplines (Adams, Miller, Saul, & Pegg, 2014; Jeffery, McCullough, & Moore, 2015).

The responsibility for developing preservice teachers' content knowledge and PCK for teaching integrated STEM content lies within elementary teacher education programs (Barcelona, 2014; Berlin & White, 2010; Kurup et al., 2017; Lewis, Dema, & Harshbarger, 2014; Murnane, 2016; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). Within teacher preparation programs, embedding explicit instructional strategies for mathematics and science integration situated in authentic learning experiences may increase preservice teachers' 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. Best practices for meaningfully teaching integrated mathematics and science lessons include hands-on learning, problem solving, cooperative group work, inquiry-based learning, appropriate use of technology, and

assessments aligned with instruction (Al Orime & Ambusaidi 2011; Frykolm & Glasson, 2005; Furner & Kumar, 2007; Stinson et al., 2009).

According to Kalchman and Kozoll (2012), methods of instruction courses highly impact preservice teachers' self-efficacy in teaching, and recommendations have been made for embedding integrated methods courses at the elementary level to better prepare preservice teachers to teach as generalists in the elementary classroom. Content specific courses, embedded in elementary teacher preparation programs, have also been identified as opportunities for preservice teachers to develop STEM content knowledge while recognizing the interconnectedness among the STEM disciplines (Jeffery et al., 2015; Moseley & Utley, 2006; Stohlmann et al., 2013). Furthermore, engaging preservice teachers in STEM learning allows them to make connections across STEM disciplines, increasing their own content competency. By experiencing authentic common teaching practices, preservice teachers can deepen their content knowledge and PCK and increase their self-efficacy and beliefs as related to STEM education (Barcelona, 2014; Berlin & White, 2010; Kurup et al., 2017; Murnane, 2016; Rinke et al., 2016).

Other factors that influence how and what teachers implement and continue to implement cannot be ignored. Research has shown that the attitudes teachers have toward a subject influence their own instructional practices, and the attitudes that teachers have towards STEM subjects can potentially decrease their students' interest in these subjects and in future STEM careers (Alexander, 2011). Preservice teachers' value of and perceived behavioral control for STEM teaching is significantly impacted by explicit instruction and experiences in STEM teaching and learning included in teacher preparation programs. Therefore, an important factor in STEM education is improving

preservice teachers' attitudes toward an integrated approach to teaching mathematics and science, which leads them to understanding and teaching integrated STEM with authentic real-life connections in their future classrooms (Corlu, Capraro, & Corlu, 2015; Lin & Williams, 2016).

According to Maher, Bailey, Etheridge, & Warby (2013), preservice teachers' attitudes and beliefs form before they enter a university teacher preparation program due to their K-12 experiences, and many recognize the influence that their attitudes and beliefs have on their future students. Preservice teachers, by examining their own attitudes, concerns, and beliefs toward STEM education, may develop positive perceptions of STEM education and an awareness of how their future students will be impacted by positive experiences as learners and participants in authentic STEM lessons (Alexander, 2011; Maher et al., 2013; Watters & Ginns, 2000). Throughout the elementary teacher preparation program, more exposure to authentic STEM teaching and learning, focusing on K-6 student learning in real-life experiences, may enhance the preservice teachers' STEM teaching in their future classrooms (Adams et al., 2014; Barcelona, 2014; Cady & Rearden, 2010; Kurup et al., 2017; Radloff & Guzey, 2017). Support from school administrators, community members, in-service teachers, and university faculty has the potential to further provide preservice teachers with the opportunity to identify and work through the challenges of teaching integrated STEM lessons in the classroom, thus enhancing the preservice teachers' perceived control for STEM teaching (Lin & Williams, 2016).

Theoretical Framework

The theoretical framework for this study included the combined elements of self-efficacy theory, the theory of planned behavior, the theory of social constructivism, and the construct of PCK. Efficacy beliefs have long been associated with the work of psychologist Albert Bandura (1978), who defined efficacy as intellectual activity by which one develops beliefs about his or her ability to achieve a certain level of accomplishment. As a social cognitive theory, self-efficacy conceives a set of beliefs about a teacher's capacity to have a positive influence on his or her students' learning. Research has consistently shown that teacher efficacy is related to a variety of desirable student outcomes (Knoblauch & Hoy, 2008; Putman, 2012; Tschannen-Moran & Hoy, 2001) and is considered a powerful influence on teachers' overall effectiveness with students (Pendergast, Garvis, & Keogh, 2011). At the same time, research supports the idea that teacher efficacy can be developed among preservice teachers (Charalambous, Philippou, & Kyriakides, 2008; Palmer, 2006). This current study explored the construct of teacher efficacy among preservice teachers regarding integrated STEM education.

In addition to self-efficacy, attitudes also influence a person's behavior. 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 this theory, attitudes are a function of behavioral beliefs, suggesting that positive attitudes toward a particular behavior stems from a belief that this behavior will lead to positive outcomes. Furthermore, subjective norms are a function of normative beliefs. Normative beliefs are imparted through encouragement, instigation, or pressure from society to accept a subjective norm. A

person who believes that others who are important to him or her believe that he or she should perform the behavior will feel pressure to do so. Thus, of importance is the opportunity for elementary preservice teachers to explore their perceived behavioral intentions to embrace and implement authentic integrated STEM education in the elementary classroom.

Vygotsky's social constructivism theory (1962, 1986) is based on his sociocultural theory in which social experience shapes the ways that individuals interpret the world. More knowledgeable peers and adults guide the learner to construct their own knowledge from what they presently know. Learning is the result of the individuals participating in a community of classroom discourse that encourages the learners to actively communicate their ideas and critique the reasoning of others (Fosnot & Perry, 1996). This study employed this theory as the methods of instruction faculty, while engaging elementary preservice teachers in a community of discourse, used modeling and scaffolding techniques to demonstrate and teach how integrated STEM lessons can be effectively designed and implemented in the elementary classroom.

The construct of PCK (Shulman, 1986) was developed to explain the necessary components to effectively teach particular content. Required components include implementation of appropriate pedagogical strategies, assessment of student needs, knowledge of the curriculum, and the ability to explain particular content-specific concepts in a way that leads to meaningful understanding. However, research (Becker & Park, 2011; Berlin & White, 2010; Nadelson et al., 2013) shows that elementary teachers lack PCK in STEM subjects. Thus, in order for elementary teachers to effectively teach STEM content, both their STEM content knowledge and teaching strategies for integrated

STEM lessons must be improved. One way to improve elementary teachers' PCK for teaching integrated STEM content is to provide preservice teachers opportunities to develop an understanding of particular strategies for effectively teaching integrated STEM content within teacher preparation programs (Epstein & Miller, 2011; PCAST, 2010).

This study was situated within the conceptual framework shown in Figure 1. The theoretical framework served as the foundation on which experiences were designed within the teacher preparation program to positively influence the preservice teachers' attitudes toward, confidence in, and proficiency in planning integrated mathematics and science lessons in a STEM framework.

Figure 1. Conceptual Framework

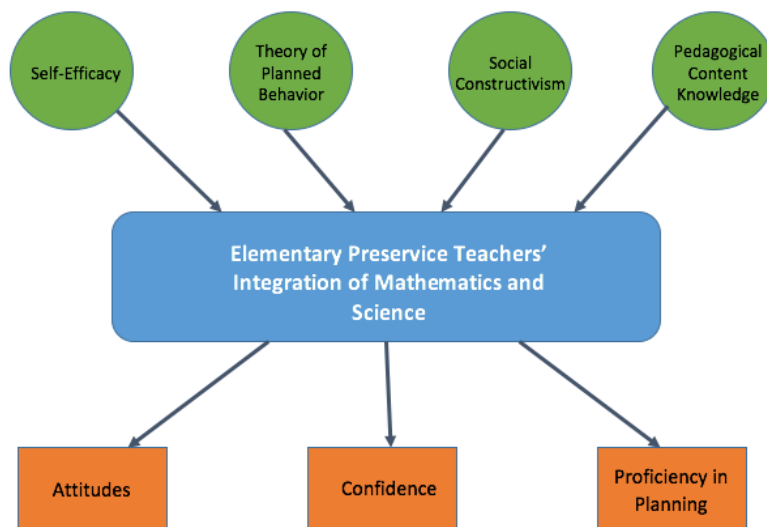


Figure 1. The circles represent the theoretical foundations of the study, and the rectangles represent the variables measured in the study.

Statement of the Problem

National standards and reform efforts indicate that integrated skills and knowledge in STEM disciplines are vital to the development of 21st-century skills in our children. Integrated approaches to STEM education, beginning at the elementary school level, may increase student achievement and better prepare students for the 21st-century global economy (Barcelona, 2014; Berlin & White, 2010; Kurup et al., 2017). According to DeJarnette (2012), elementary school students' interests in future STEM careers is fostered by providing them opportunities to develop critical thinking skills through early exposure to STEM content. However, U.S. students lack proficiency in mathematics and science with less than one-third of U.S. eighth graders scoring at the proficient level on the National Assessment of Education Progress (NCES, 2017). Furthermore, the deficiency of student interest in STEM content has resulted in fewer students graduating in STEM fields and pursuing STEM-related careers (PCAST, 2010).

Although the idea of STEM integration in the early grades is gaining support on the national scene, the facilitation of STEM education at the elementary school level remains a scarcity (Barcelona, 2014; Berlin & White, 2010; Kurup et al., 2017). STEM curricula cannot be advanced if teachers do not have adequate understandings of the definition of STEM education or the attitudes and confidence needed to implement effective STEM instruction. Research (Epstein & Miller, 2011; PCAST, 2010) has revealed a shortage of teacher expertise to successfully integrate STEM practices. Thus, an increased focus on preparing preservice and in-service teachers to integrate STEM content at the elementary level, putting theory into practice by immersing those teachers in STEM practices, is needed (Epstein & Miller, 2011; NRC, 2010; PCAST, 2010).

Along with STEM content knowledge and PCK, teacher attitudes and confidence regarding teaching integrated STEM lessons contribute to effective integrated STEM instruction. As teachers' negative attitudes can impact student learning, the need exists more opportunities for preservice teachers to increase their attitudes and confidence toward teaching throughout their teacher preparation programs (Riegle-Crumb et al., 2015). Moreover, an important factor in STEM education is improving preservice teachers' attitudes toward an integrated approach to teaching mathematics and science, which can lead them to understanding and teaching integrated STEM lessons with authentic real-life connections in their future classrooms (Corlu et al., 2015). Whereas, preservice teachers' attitudes toward and confidence in STEM subjects are impacted by positive experiences as learners and participants in integrated STEM lessons, providing them with opportunities to examine their own attitudes, concerns, and beliefs toward STEM education within a teacher preparation program could likely advance the goals of STEM education for their future students (Alexander, 2011; Maher et al., 2013; Watters & Ginns, 2000).

Unfortunately, few elementary teacher education programs in the U.S. exist that adequately prepare preservice teachers with sufficient content knowledge in more than one STEM subject or necessary PCK to teach integrated STEM lessons (Honey, Pearson, & Schweingruber, 2014). As of 2018, limited research on how to effectively prepare K-12 teachers to teach integrated STEM content in the classroom exists (Berlin & White, 2010; Murnane, 2016; Rinke et al., 2016). Thus, research is needed to determine how to most effectively prepare elementary preservice teachers to teach integrated STEM content with the aim of advancing the goals of STEM education for their future students.

The extent to which successful completion of integrated mathematics and science methods of instruction courses is related to either preservice elementary teachers' attitudes and confidence or to the implementation of integrated STEM lessons in the K-6 classroom is also unknown. Therefore, through this dissertation, the researcher aimed to move the field forward by implementing a co-teaching model within integrated elementary mathematics and science methods of instruction courses to examine elementary preservice teachers' attitudes toward, confidence in, and proficiency in planning integrated STEM lessons. This, in turn, may have better prepared them to successfully teach integrated STEM lessons in their future classrooms.

Purpose Statement, Research Questions, and Hypotheses

The purpose of this study was to investigate the extent to which successful completion of integrated mathematics and science methods of instruction courses relates to elementary preservice teachers' attitudes toward and confidence in teaching integrated STEM lessons, and the extent to which their attitudes and confidence correlate with their proficiency in planning integrated STEM lessons. In particular, the researcher proposed to provide a model for elementary integrated STEM teacher preparation. This mixed-methods study was guided by the following questions:

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

RQ1. ...to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?

H₁: Elementary preservice teachers' attitudes toward teaching integrated STEM lessons will be significantly higher after successful completion of integrated mathematics and science methods of instruction courses.

RQ2. ...to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

H₂: Elementary preservice teachers' confidence in teaching integrated STEM lessons will be significantly higher after successful completion of integrated mathematics and science methods of instruction courses.

RQ3. ...to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?

H₃: Elementary preservice teachers' attitudes and confidence with regard to teaching integrated STEM lessons will positively correlate with their proficiency in planning integrated STEM lessons after successful completion of integrated mathematics and science methods of instruction courses.

Definition of Terms

21st Century Skills: Necessary skills to be successful in the 21st-century that include, but are not limited to research, critical thinking, problem solving, and communication skills (NRC, 2013).

Attitude: A learned predisposition to respond to an object or behavior in a favorable or non-favorable way that is a function of the beliefs the person has about the object (Fishbein & Ajzen, 1975).

Confidence: A feeling of belief in oneself and one's ability to succeed. Within the context of this study, confidence was defined as opinions or convictions held by elementary preservice teachers toward teaching integrated STEM lessons.

Curriculum Integration: An educational approach among two or more content areas in which students simultaneously do and learn important concepts in the respective content areas while gaining a deeper understanding of the concepts because of the connections between the content areas (Schleigh, Bosse', & Lee, 2011).

Elementary Teacher Preparation Program: A program that prepares undergraduate students to teach in a K-6 classroom. The program includes methods of instruction courses that teach content-specific pedagogy and concludes with a full semester internship. Within the context of this study, the K-6 Teacher Education elementary teacher preparation program was a dual certification program in both K-6 Elementary Education and Collaborative Teaching (Special Education).

Elementary Preservice Teacher: A student enrolled in an elementary teacher preparation program at a college or university.

Integrated STEM: The integration of the four content areas of science, technology, engineering, and/or mathematics. Within the context of this study, integrated STEM instruction was limited to the integration of mathematics and science enhanced with technology to provide opportunities for students to apply 21st-century skills.

Internship: A one-semester experience where preservice teachers spend full days in an elementary classroom. They design and implement lessons in each content area throughout the semester, eventually assuming nearly all of the responsibilities of the assigned classroom teacher supervisor. Within the context of this study, the internship

semester included a minimum of a five-week regular education classroom experience and a minimum of five-week special education classroom experience.

Methods of Instruction Courses: Courses embedded in the teacher preparation program that focus on content-specific pedagogical content knowledge for teaching. These courses are completed prior to internship and include reading/language arts, social studies, mathematics, and science.

Pedagogical Content Knowledge (PCK): Teachers' interpretations and transformations of subject-matter knowledge in the context of facilitating student learning (Shulman, 1986). PCK is a unique combination of content and content-specific pedagogy focusing on the students, the subject matter, and the curriculum.

Self-Efficacy: Beliefs in one's level of competence he or she expects to exhibit in given circumstances (Bandura, 1978).

STEM: Acronym for science, technology, engineering and mathematics (Bybee, 2013).

Delimitations

The purpose of this study was not to determine the effectiveness of elementary preservice teachers implementing integrated STEM lessons in the classroom. Furthermore, the researcher did not seek to investigate the impact of integrated STEM lessons on elementary student learning of mathematics and science. The findings of this study were not generalizable beyond the elementary preservice teachers enrolled in the final two semesters of an elementary teacher preparation program at a university located in the southeastern region of the U.S. during the spring and fall 2018 semesters.

Assumptions

One assumption of this study was that the participants responded truthfully during each phase of data collection. The researcher also assumed that the participants would continue to design and implement integrated STEM lessons in their future classrooms. Furthermore, a third assumption was that future elementary teachers would benefit from a teacher preparation program that included integrated STEM content knowledge and PCK.

Significance of the Study

The *Common Core State Standards for Mathematics* (CCSSM; NGACPB, 2010) and the *Next Generation Science Standards* (NGSS; Achieve, 2012) both emphasize the necessity of making real-life connections among mathematics and science concepts in an integrated STEM framework in the K-12 classroom. According to Nadelson et al. (2013), the need for increasing elementary teachers' capacity to teach integrated STEM content is based on the potential positive effects of quality elementary STEM instruction on student learning as well as our nation's STEM performance. Thus, teacher preparation for STEM education serves as a foundation to ensure that our teachers are prepared to teach in the STEM classroom. Due to the importance placed on students graduating in STEM fields and pursuing STEM-related careers (PCAST, 2010), the findings from this study may have helped decrease the deficit of integrated STEM education in elementary school. This study, consequently, contributed to the gap in knowledge of how to adequately prepare elementary teachers to teach mathematics and science in an integrated STEM framework.

Exposure to integrated STEM teaching and learning throughout this study may have led to an increase in the participants' attitudes toward, confidence in, and

proficiency in planning integrated mathematics and science lessons, as well as their knowledge of content integration in the elementary school. Participants may have experienced an increase in their intention to teach integrated STEM lessons in their future classrooms as well. At the program level, results of this study may have also supported or informed best practices for how to implement an elementary STEM teacher preparation program. Results of this study may encourage more teacher educators to teach mathematics and science methods courses using an integrated STEM framework. This, in turn, could result in heightened attitudes towards, greater confidence in, and proficiency in planning integrated mathematics and science lessons of elementary preservice teachers, which in turn may increase K-6 students' knowledge of and interest in STEM content and future careers.

Additionally, findings of this study, coupled with current literature, may contribute to the design of district-level professional development aimed at enhancing effective implementation of STEM education. Potential benefits for elementary classroom teachers from this type of professional development include positive changes in practice and increased STEM content knowledge and PCK. Furthermore, the impact of this professional development on elementary classroom teachers could lead to an increase in STEM literacy and interest to pursue STEM careers among elementary school students. The students, while developing 21st-century skills, gain creativity in learning and the ability to make connections among STEM disciplines moving the country forward in the 21st-century global society.

CHAPTER II – REVIEW OF THE LITERATURE

Introduction

Compared to other nations, a perception of low student performance in the STEM disciplines has resulted in an emphasis on STEM teaching and learning in K-12 education throughout the U.S. This emphasis on the need for STEM education has been further highlighted by a decrease in students interested in STEM content, leading to a smaller number of students entering the STEM workforce upon graduation. Although elementary grades are formative years for laying a foundation for future success, most elementary teachers are trained as generalists (NCES, 2017) and do not possess the confidence in and knowledge of teaching STEM content in an integrated framework. Thus, teacher education programs have begun to focus on ways to integrate STEM education, preparing preservice teachers to be confident and knowledgeable in teaching integrated STEM content (Adams et al., 2014).

Furthermore, national standards and reform efforts in mathematics, science, and technology emphasize the need for collaboration and integration across the disciplines that provide rich, meaningful learning experiences for all students. In order for this integrated teaching and learning environment to be implemented in the classroom, teacher education programs need to offer authentic experiences for preservice teachers to participate in, plan, and implement integrated mathematics, science, and technology lessons (Berlin & White, 2010). Although STEM initiatives have been at the forefront of education for the past two decades, many schools continue to deliver coursework in mathematics and science in isolation, absent of an integrated approach and void of engineering integration (Hoachlander, 2015). Additionally, U.S. student achievement in

both mathematics and science remains at a discouragingly low level. According to the 2017 National Assessment of Educational Progress (NAEP) report for mathematics, only 40% of fourth-graders and 33% of eighth-graders scored at or above proficient in mathematics. Similarly, the 2015 results for mathematics showed that only 40% of fourth-graders, 33% of eighth-graders, and 25% of twelfth-graders scored at or above proficient in mathematics. The 2015 science results mirrored that of the mathematics as only 38% of fourth-graders, 34% of eighth-graders, and 22% of twelfth-graders scored at or above proficient in science (NCES, 2017). These results suggest the need for more effective initiatives.

Curriculum Integration

Curriculum integration is defined as a “curriculum design theory that is concerned with enhancing the possibilities for personal and social integration through the organization of curriculum around significant problems and issues, collaboratively identified by educators and young people, without regard for subject-area lines” (Beane, 1997, p. 19). Knowledge is accessed within more meaningful thematic contexts situated in real-life, problem-solving situations rather than individual content area silos. Learning is transformed into personally relevant, real-life experiences within which discipline-specific concepts, topics, skills, attitudes, standards, and habits of mind are shared. Integration occurs when commonalities emerge from within the disciplines providing genuine connections among the subjects, thus increasing levels of academic achievements (Barcelona, 2014; Beane, 1997; Fogarty & Pete, 2009; Schleigh et al., 2011).

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 science and mathematics 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). Although mathematics and science are closely related, these subjects are often taught in isolation with no relation to each other. However, integrating mathematics and science allows students to use their mathematical knowledge to understand the world around them, applying scientific principles and skills in authentic real-life problem solving. Integrated mathematics and science lessons can raise student interest in and motivation to learn mathematics and science in an exciting and relevant way. As outlined in the 5E model of teaching (Bybee et al., 2006) and the Mathematics Practice Standards (NCTM, 2014), effective teaching of both science and mathematics includes hands-on, inquiry-based learning centered around a conceptual theme in which natural real-world integration is evident in the curriculum. Thus, continued efforts to create and implement meaningful integrated curriculum may lead to the further development of student learning in mathematics and science (Al Orime & Ambusaidi, 2011; Kim & Cho, 2014; Schleigh et al., 2011).

To be successful with implementing an integrated approach, Stinson et al. (2009) suggested that teachers need deeper content knowledge in both mathematics and science. They must also have a solid understanding of what integration is and is not if they are

expected to integrate the subjects in the curriculum, providing confirmation that a clear definition of integration is necessary for teachers to authentically integrate the subjects for more meaningful learning. Thus, professional development that includes an operational definition of integration, as well as effective strategies for teaching and learning the mathematics and science content could lead to teachers implementing integrated practices that they understand and value. Such professional development embedded in teacher education programs may lead to more future teachers that are confident and prepared to teach mathematics and science lessons in an integrated STEM framework.

Additional research (Frykholm & Glasson, 2005; Furner & Kumar, 2007) suggested that engaging preservice teachers in authentic, active-learning experiences in mathematics and science can serve as a means of increasing content knowledge in both disciplines. 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).

Models of Mathematics and Science Integration

According to Stinson et al. (2009), there are several different models of integration based on what is being integrated, structures for integration, and levels of integration. Evolving over a period of 15 years, Berlin and White proposed an integrated model of mathematics and science in 1994. Included in this model are six aspects of how science and mathematics can be integrated: (a) ways of learning, (b) ways of knowing, (c) content knowledge, (d) process and thinking skills, (e) attitudes and perceptions, and (f) teaching strategies. This framework was designed to provide a conceptual foundation for generating operational definitions of mathematics and science integration. Furthermore, with all six aspects in constant interplay, the focus was on effective characteristics, skills, teaching methods, and aspects of measurement and assessment (Berlin & White, 1999).

Focusing more on the relationship between the mathematics and science content and the curricular goals for the disciplines, Lonning and DeFranco (1997) developed a continuum model of mathematics and science integration. This model was designed to be used for the creation of new integrated mathematics and science curricula or adaptation of existing commercial materials used to teach mathematics and science. Included in their continuum model are five categories: independent mathematics, mathematics focus, balanced mathematics and science, science focus, and independent science. At the two ends of the continuum are activities that develop mathematics and science concepts that are independent of each other. Discipline-specific content for a particular grade level in one of the subjects (mathematics or science) that includes content from the other subject area on a different grade level is characterized as “mathematics focus” or “science focus” on the continuum. Instruction that is described as “balanced” engages students in

meaningful activities that include both mathematics and science content on the same grade level.

Similar to the continuum model proposed by Lonning and DeFranco (1997), the Mathematics/Science Continuum framework (Huntley, 1998) was developed 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. This differs from the middle of the continuum presented by Lonning and DeFranco (1997) in which mathematics and science concepts are given equal treatment but are not necessarily supporting each other in student learning as they are in the Mathematics/Science Continuum (Huntley, 1998).

Designed to replace the continuum model, Kiray (2012) presented the balance model which manifests the balance in the process of mathematics and science integration.

Seven levels of integration are presented in the balance model: mathematics, mathematics-centered science-assisted integration, mathematics-intensive science-connected integration, total integration, science-intensive mathematics-connected integration, science-centered mathematics-assisted integration, and science. With the mathematics and science content central to the development of this model, the desired integrated curriculum is balanced by allotting equal time to both disciplines throughout the year. This model offers teachers a variety of levels of integration of mathematics and science while keeping the content and standards the same as outlined in the existing curricula.

STEM Education

Standards-Based Reform in STEM Education

Released in 1983, *A Nation at Risk* described the state of U.S. education as unpromising leading to serious consequences in our future economy (Gardner, 1983). Although some states already had accountability systems in place, many created or revised accountability policies and procedures over the next several years. Over the past several decades, considerable reform in each of the STEM education communities has occurred, leading to the creation and implementation of new standards that focus on real-world problem solving and preparing students for the 21st-century workforce. Each of these reform efforts has provided a foundation for the need of integrated STEM education in K-12 classrooms (Sanders, 2009).

Many of these state-led efforts in improving mathematics teaching and learning were driven by the National Council of Teachers of Mathematics' (NCTM) publication of *Curriculum and Evaluation Standards for School Mathematics* (1989) which provided

goals and objectives for school mathematics centered around NCTM's vision for K-12 mathematics education. The five goals for all K-12 students include: "(1) that they learn to value mathematics, (2) that they become confident in their ability to do mathematics, (3) that they become mathematical problem solvers, (4) that they learn to communicate mathematically, and (5) that they learn to reason mathematically" (NCTM, 1989, p. 5). As these goals permeate throughout the curriculum, students engage in rich, numerous, interconnected experiences with authentic mathematical problem solving, increasing their mathematical literacy. In subsequent publications, NCTM monitored and updated the existing standards, recognizing that "the need to understand and be able to use mathematics in everyday life and the workplace has never been greater and will continue to increase", resulting in the publication of *Principles and Standards for School Mathematics* (NCTM, 2000, p. 4). Set forth in this document are content and process standards providing learning progressions for essential mathematics content and key processes for learning mathematics with understanding. Teaching the mathematics content through the five processes of problem solving, communication, representation, reasoning and proof, and connections, students can engage in learning, applying, communicating, and reasoning with mathematics and developing mathematical proficiency.

In addition to the NCTM efforts to reform and advance mathematics education, the National Research Council (NRC) presented five strands of mathematical proficiency that emphasize teaching and learning through conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (NRC, 2011). These strands, along with the NCTM principles and standards, impacted the

development of the most recent standards for mathematics education. The content and practice standards set forth in the *Common Core State Standards for Mathematics* call for students to apply mathematics to solve real-world problems and to use mathematical practices that can connect to those of science and engineering, supporting efforts to make connections across the disciplines (CCSSM; NGACPB, 2010).

Recognizing the critical importance of bringing significant reform in mathematics, science, and technology, *Science for all Americans* offered recommendations for improving scientific literacy that includes mathematics and technology (American Association for the Advancement of Science [AAAS], 1989). As described in the publication, student learning goals are achieved through the connection of the mathematical, scientific, and technological concepts and practices that are intertwined and designed to not be taught in isolation from one another. More recently, the National Research Council (NRC, 2012) provided a framework for K-12 science education that highlights the importance of integrating scientific ideas and practices with those of mathematics, technology, and engineering. The committee shared a vision for science and engineering education that includes “that students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of each field’s disciplinary core ideas” (p. 2). Grounded in research, this framework provided a basis for the improvement of science teaching and learning, leading to the publication of the *Next Generation Science Standards* (NGSS; Achieve, 2012).

While many initial efforts to improve STEM education concentrated on improving mathematics and science education, more recent state and district-level

initiatives have included both technology and engineering education. Over the last two decades, technology education has become more prevalent in K-12 classrooms nationwide with the development and implementation of the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association [ITEA], 2000, 2002, 2007). The technology learning standards provide students the opportunity to apply and integrate content area knowledge from various disciplines, including mathematics and science, thereby making connections among the disciplines and learning more meaningful. Moreover, engineering education has increased significantly in K-12 classrooms facilitating integrated STEM education. Three principles that guide K-12 engineering education include engaging learners in the engineering design process, promoting engineering “habits of mind” aligned with 21st-century skills, and integrating mathematics, science, and technology content knowledge and skills. These reform efforts have led to the strengthening of both the technology and engineering components of STEM education in K-12 classrooms across the U.S. (NRC, 2009).

Reform efforts in each of the STEM disciplines have supported the need for addressing the STEM challenges faced by our nation. The number of students losing interest in mathematics and science at an early age has resulted in too few students entering STEM fields and the STEM workforce upon graduation. Due to a traditional approach being used to teaching STEM content, this loss in interest has been challenged by an integrative approach, as evidenced by a large percentage of students who have avoided the more rigorous mathematics and science coursework at the secondary level

and graduated with low ability in mathematics and science (PCAST, 2010; Sanders, 2009).

Definition of STEM Education

With the advancement of integrated STEM education, the use of the acronym has revealed significant disparities in the meaning of integrated STEM education. Thus, pertinent to this study was to define integrated STEM education. According to English (2016), different interpretations of integrated STEM education have been problematic for researchers and curriculum developers. Brown, Brown, Reardon, & Merrill (2011) investigated teachers' and administrators' perceptions of STEM education, including their definitions of integrated STEM education and the perceived importance within in their schools. Results showed that the definition of STEM education was not clear to the administrators or the teachers in STEM fields. Less than half of the administrators, which included principals, assistant principals, and assistant superintendents, were able to describe STEM education and/or demonstrate an understanding of the concept. The teachers in the STEM fields held different levels of understanding of STEM education, with less than half of the mathematics teachers providing an appropriate definition of STEM education. If teachers are to take up the charge to lead students in applying various facets and intricacies of STEM disciplines to their lives, then they themselves must first possess a clear understanding of STEM education (Bybee, 2013; Honey et al., 2014).

Grounded in social constructivist theory, STEM education provides opportunities for students to actively construct, contextualize, and connect science, technology, engineering, and/or mathematics concepts in a social environment that is both learner-centered and knowledge-centered. STEM education can thus be described as a form of

curriculum integration that includes teaching and learning between or among two or more STEM subjects. (Czerniak & Johnson, 2014; Sanders, 2009). Similarly, Moore and Smith (2014) defined integrated STEM education as the combination of some or all of the STEM disciplines into one class, unit, or lesson, purposefully connecting the subjects with real-life application. STEM integration has also been defined to include STEM practices built upon the science, engineering, and mathematics practices outlined in the NGSS (Achieve, 2012), CCSSM (NGACPB, 2010), and the Mathematics Practice Standards (NCTM, 2014). Bounded by STEM practices within a real-life context, integrated STEM learning has been evident as students identified, applied, and integrated concepts from science, technology, engineering, and mathematics to understand and solve complex problems using innovative strategies (Balka, 2011; Kelley & Knowles, 2016).

Characteristics of STEM Education

The ideas of real-world problem solving, collaborative learning, and active inquiry-based learning all provide the theoretical constructivist foundations for effective STEM teaching and learning. Historically, the constructivist views of learning of Dewey (1938), Piaget (1977), Vygotsky (1962, 1986), and Bruner (2009) have influenced practices and contributed to research in effective teaching in mathematics, science, and engineering classrooms. Dewey (1938) believed that students learn best from real-world experiences rather than rote memorization, and should be encouraged to think for themselves. According to Dewey, students would be engaged in problem solving, reasoning or thinking for themselves, in real-life settings, allowing them to make real-world connections in mathematics. Piaget (1977) also contributed to the constructivist

view with his notion of stages of learning and schema. He suggested that children are active learners that progress through four stages relative to their mental readiness. His theory was also based on schema that children bring with them to a new learning experience. This prior knowledge and experience, which also includes misconceptions and misunderstandings, serves as a foundation for the development of new ideas and knowledge.

In contrast to Piaget, Vygotsky (1962, 1986) focused on the social aspect of constructivism. He believed that cognitive development was dependent on experiences shared with others in which language and culture play a big role. Two major components of this social constructivist theory are the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO is someone who has a higher understanding or ability-level than the child within the same culture. The child actively learns concepts or skills with the assistance of the MKO. The ZPD refers to the target skills or concepts a child can do with the assistance of the MKO, but not alone. The child actively constructs new knowledge but with the guidance and assistance of someone else. Within the realm of education, the teacher serves as a facilitator of knowledge, enabling the student to engage in problem solving and inquiry-based learning that connects to his or her cultural and social surroundings. Within the ZPD, scaffolds are used by the MKO to guide student learning. As the students gain more knowledge and understanding, the scaffolds can be removed. The teacher must know and understand the students' prior understandings and misconceptions to determine their ZPD and create meaningful experiences that will facilitate learning.

Bruner (2009) shared the same social/cultural view of constructivist learning as Vygotsky. He believed that effective teaching occurs when the students are engaged in discovery learning facilitated by the teacher. As students are immersed in problem solving, they discover properties, rules, facts, and relationships for themselves. Working collaboratively in social settings, students bring their prior knowledge and experiences and share ideas and discoveries resulting in new knowledge and understanding. They work with manipulatives, perform experiments, make predictions, and use questioning to discover new ideas. Bruner also used the term ‘scaffolding’ to describe the support given to the child by the teacher or adult so they can achieve success. The idea of scaffolded learning is integral to building an effective foundation for the application of STEM concepts.

Building on the work of Dewey (1938), Piaget (1977), Vygotsky (1962, 1986), and Bruner (2009), many characteristics of STEM education have been identified. Among those are active and inquiry-based learning, cooperative learning, the 5E model of teaching (Bybee et al., 2006), and mathematics teaching practices. Through STEM education, students can engage in active educational experiences focused on real-world, problem-based learning connecting the STEM disciplines. Within the classroom, teachers act as facilitators of student-centered learning rather than dispersers of knowledge. Students actively participate in authentic, meaningful, problem-solving activities that are important to them and connected to their personal lives, cultures, and communities (Capps & Crawford, 2013; English, 2016; NCTM, 2000). Teachers encourage active learning by embedding inquiry-based instruction in the classroom. Situated in the constructivist theory, inquiry-based learning allows students to build on their prior

knowledge, developing a greater understanding of the content by asking questions and discovering learning for themselves. Engaging students in inquiry-based instructional activities develops critical thinking skills and leads to a deeper understanding of STEM content (Nadelson et al., 2013). Furthermore, inquiry-based learning provides students with opportunities to pose and refine questions, plan and design experiments, and use collected data as evidence to explain a phenomenon which are all components of STEM education (Capps & Crawford, 2013).

As emphasized by Vygotsky (1962, 1986), cooperative learning is also an important component of the social constructivist view of teaching. Within small groups, students engage in active learning by communicating ideas and discussing concepts so that learning is a shared experience. According to NCTM (2000), through the exploration and communication of ideas from different perspectives, students develop critical thinking skills and make connections among mathematical concepts. According to the Nation's Report Card (NCES, 2017), cooperative learning has had a significant impact on student achievement. Fourth-grade students who participated in collaborative learning groups once or twice a month to once or twice a week had higher average scores than their peers who did so less frequently. Similarly, the participation of eighth-grade students in collaborative learning groups every day or almost every day resulted in higher scores than their peers who did so less frequently.

Further supporting the constructivist view of learning is the 5E model for teaching through which the teacher facilitates student-centered learning (Bybee et al., 2006). The 5E model is a cycle of learning consisting of five stages that engages students in active, inquiry-based learning and self-reflection. In the *engage* phase, the teacher uses prior

student knowledge and experiences to pique student interest and motivate the lesson or activity. Prior knowledge is activated and student misconceptions are identified. The *explore* stage allows students the opportunity to begin constructing new ideas based on hands-on experiences such as working with manipulatives, building models, conducting experiments, making and testing predictions, and collecting data. After this stage, students then begin to *explain* what they discovered in the prior stage. Using evidence to support their claims, students use appropriate vocabulary to clarify concepts and ideas in a social learning setting as supported by Vygotsky (1962, 1986) and Bruner (2009). Acting as the MKO, the teacher has the opportunity to address and correct any misconceptions, introduce new terminology, and help students make connections to what they discovered in both the *engage* and the *explore* stages. In the *elaborate* stage, students apply, extend, or elaborate on concepts learned in new situations. They synthesize their knowledge which allows for a deeper understanding of the concepts learned. In the *evaluate* stage, students demonstrate their level of understanding of the concepts through formative and/or summative assessments. Because this model is intended to be cyclical, the results from the assessments are then used to guide future instructional decisions.

Building on the theory of constructivism, effective STEM education is further characterized by the research-based Mathematics Teaching Practices outlined in *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014). Learning goals are identified and situated in learning progressions transitioning students from prior knowledge to deeper understanding of the mathematical concepts. Students participate in meaningful, authentic, real-world tasks to enhance their reasoning and problem-solving

skills while engaging in productive discourse through communication with their peers and the teacher, posing and responding to purposeful questions. Various representations are also used to make connections among the mathematical concepts through different lenses while building procedural fluency from conceptual understanding leading to more sophisticated mathematical understanding. These practices provide a framework for enhancing the teaching and learning of mathematics, which also impacts the teaching and learning of integrated STEM education.

Aspirations of STEM Education

The advocates of STEM education believe that by preparing our students for advanced education or jobs in STEM fields, the U.S. would once again move to the forefront of scientific discovery and innovation (Brown et al., 2011; Cotabish, Dailey, Robinson, & Hughes, 2013). The quality of STEM education is driven by overarching goals that include increasing the number of students pursuing advanced degrees and careers in STEM fields, expanding participation in the STEM workforce, and increasing STEM literacy (NRC, 2011). More specifically, major goals for STEM education have been identified for students and as well as educators. The five goals for students include developing: (a) STEM literacy, (b) 21st-century skills, (c) STEM workforce readiness, (d) interest and engagement in STEM subjects, and (e) the ability to make connections among STEM disciplines (Honey et al., 2014).

STEM literacy is evidenced by an awareness of how STEM subjects form our material, cultural, and intellectual world. Specifically, STEM literacy encompasses a person's "knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions

about STEM related-issues; understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design; and willingness to engage in STEM-related issues and with the idea of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen” (Bybee, 2013, p. 101). STEM workforce readiness includes the development of 21st-century skills within our students. Key principles of 21st-century competencies include problem solving, critical thinking, creativity and innovation, communication and collaboration, accessing and analyzing information, and global awareness. Related to the key principles are four components that are evident in STEM education. The use of real-world issues provides the context for authentic problem solving while giving students the opportunity to develop information literacy and global awareness. Using active, inquiry- and problem-based learning develops critical thinking and problem-solving skills in students while providing opportunities for creativity and innovation. Additionally, the social skills of students are enhanced through communication and collaboration within a constructivist framework (Bybee, 2013).

In addition to student-focused goals of STEM education, major goals for educators have been outlined. As STEM education becomes more prevalent and necessary to our nation’s success, teachers will need to increase their own STEM content knowledge and STEM PCK, so they can purposefully engage students in integrative thinking. Teaching STEM content in a more connected manner, especially in the context of real-world issues, can increase student interest and engagement in STEM subjects by providing relevancy of the content to the students. Knowledge and skills within and across the STEM disciplines can be developed through integrated, meaningful

experiences provided by educators. Furthermore, the ability to make connections among the STEM disciplines results in more integrated knowledge and understanding than otherwise achieved within the separate disciplines. Through the development of teachers' STEM content knowledge and PCK, their future students will be able to collectively use science, technology, engineering, and mathematics concepts to design, make, and evaluate solutions to authentic real-world problems (Honey et al., 2014; NAE & NRC, 2014; Sanders, 2012).

Barriers to STEM Education

According to the literature (Frykolm & Glasson, 2005; Lehman, 1994), barriers to integrative approaches to teaching STEM content can be categorized into two domains, teacher-level characteristics and contextual characteristics of the teaching setting. Teacher-level characteristics have included personal barriers to integrated STEM teaching. Insufficient content knowledge in other STEM fields has been a concern for teachers, both preservice and in-service, as they do not feel as confident about teaching the content from each discipline. Teachers have also been concerned about the need for different pedagogical strategies that could assist them in making meaningful and appropriate connections between or among the subjects for the students (Becker & Park, 2011; Frykolm & Glasson, 2005; Lehman, 1994). As specific disciplines possess their own ways of knowing, making connections across disciplines becomes more complicated (Bybee, 2013; English, 2016). Developing disciplinary content knowledge while supporting students to make connections across the disciplines is further challenged by the different meanings of the science and engineering practices and the mathematics practices. The Standards for Mathematical Practice (NGACPB, 2010), the Mathematics

Practice Standards (NCTM, 2014), and the Scientific and Engineering Practices (Achieve, 2012) may use the same terms or phrases but such terms or phrases have different meanings depending on the discipline. Teachers will need to distinguish between, for example, what making viable arguments means in mathematics and in science and how this practice enhances student learning (NAE & NRC, 2014). 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. Most teachers, instructors, and administrators have seldom been a part of an integrative educational environment in their prior experiences when learning or teaching STEM content (Frykolm & Glasson, 2005; Lehman, 1994; Moore & Smith, 2014; Schleigh et al., 2011).

Other concerns identified relate to the contextual characteristics of the teaching setting. Interpretations of STEM education and integration varies among stakeholders, researchers, and curriculum developers (Bybee, 2013; English, 2016). Teachers may also perceive authentic integration as impractical as they feel the pressure of high-stakes testing. With an emphasis on mathematics and reading/language arts, students do not get adequate access to science, technology, or engineering until high school grade levels. Furthermore, high-stakes tests are designed with mathematics and science segregated, focusing on single content-specific knowledge, not practices or applications of knowledge (Moore & Smith, 2014; NAE & NRC, 2014; Schleigh et al., 2011). Other potential barriers include lack of support from school administrators (Becker & Park, 2011) and the scarcity of research-based integrated STEM curricula (Moore & Smith, 2014).

Berlin and White (2012) found a significant change in preservice teachers' attitudes related to the feasibility of integrating mathematics, science, and technology education while participating in an integrated STEM teacher preparation program at the graduate level. Collaboratively planning in small groups, the secondary mathematics and science preservice teachers developed integrated units while promoting their own specialized content. The preservice teachers remarked that the integration was an efficient but slow process and the execution was more difficult to plan, design, and implement than they had initially thought, yielding findings similar to Koirala and Bowman (2003). Findings suggested that teacher educators need to better prepare preservice teachers to handle possible barriers of complexity, insufficiency, and difficulty while exposing them to specific STEM-related concepts and skills which developed a deeper understanding of integrated STEM content. Additionally, attention to these components in teacher preparation programs may enhance preservice teachers' attitudes and confidence related to the feasibility of integrating STEM lessons in their future classrooms.

In the face of these challenges is a vision for establishing positive conditions for change. At the forefront of curriculum reform is creating a teaching and learning environment where experimentation and innovation are encouraged and rewarded, with a greater emphasis on long-term gains rather than on such immediate goals as raising test scores (AAAS, 1989). Embedding integrated teaching experiences in teacher preparation programs at all levels may also lead to the breakdown of the barriers, as preservice teachers who participate in an integrated approach to teaching will have experienced learning and teaching in an integrated STEM framework. This, in turn, may lead to their

understanding and teaching of integrated STEM content in their future classrooms (Bybee, 2013; Corlu et al., 2015).

Factors Influencing Teacher Behavior: The Affective Domain

Teacher Attitudes

Research has suggested that the attitudes towards teaching that a teacher possesses influence his or her behavior in the classroom (Koballa, 1988; Riegle-Crumb et al., 2015; van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Based on the assumption that humans are rational and consider ramifications of their actions before they actually take them, Fishbein and Ajzen (1975) introduced the theory of reasoned action. This theory asserts that a person's behavior is directly influenced by their intentions. The key component to this theory is that behavioral intentions are formed by two independent constructs including attitudes toward a behavior and subjective norms. Attitudes toward a behavior is a function of behavioral beliefs and is impacted by the outcome expectancy beliefs of performing the behavior. As a function of normative beliefs, subjective norms include the expectations of significant others as to if the behavior should or should not be performed. Subjective norms also include the evaluation of risks and benefits of the outcome as predictors of the person's intention to perform the behavior.

As an extension of the theory of reasoned action, Ajzen and Fishbein (1980) introduced the theory of planned behavior. In both theories, attitude is described as a "mental state of readiness, which was organized through experience" (p. 18). Perceived behavioral control was added to the original two constructs of attitude and subjective norms suggesting that perceived behavioral control directly influences behavior.

Perceived behavioral control is situational and refers to a person's perception of their ability to perform the behavior, which varies across situations and actions. As attitudes are closely related to behaviors, teachers' attitudes toward teaching the content is measured rather than their attitudes toward the content itself. Teachers' attitudes play a fundamental role in guiding classroom practices, in the way they understand the content, and in the acceptance of new approaches, techniques, and activities (Ball, 1990; Koballa, 1988; Riegle-Crumb et al., 2015; Thibaut, Knipprath, Dehaene, & Depaepe, 2018; van Aalderen-Smeets et al., 2012).

Teacher Confidence/Self-Efficacy

Also influencing teacher behavior in the classroom is a teacher's self-efficacy related to one's approaches to instruction, attitudes toward the discipline of teaching, and personal goals and aspirations of teaching (Tschannen-Moran, Hoy, & Hoy, 1998). According to Tschannen-Moran et al. (1998), teaching efficacy is a teacher's belief in his or her perceived ability (rather than actual ability) to successfully accomplish a specific teaching task in a particular context. Teaching efficacy is composed of two categories: general teaching efficacy and personal teaching efficacy. General teaching efficacy relates to the teaching task and its context. Factors such as the availability of required resources to facilitate learning and perceived difficulties or constraints of the teaching task and its context impact teachers' efficacy. Personal teaching efficacy relates to self-perceptions of teaching competence. This includes recognizing personal strengths and weaknesses of one's content knowledge and PCK, skills, and personality traits in a particular teaching context. Both general and personal teaching efficacy contribute to

teacher efficacy and to the effect on student learning that originate from efficacy beliefs (Tschannen-Moran et al., 1998).

Grounded in social constructivist theory, perceived self-efficacy is defined as one's beliefs about the level of competence he or she will display in a particular situation. Self-efficacy beliefs strongly influence thought patterns and emotions that play a major role in how people approach a given task. According to Bandura (1978), self-efficacy expectations are drawn from four principal sources of information: performance accomplishments, vicarious experiences, verbal persuasion, and physiological states. Based on personal mastery experiences directly related to one's capabilities, personal accomplishments are the most influential source of efficacy expectations. Mastery expectations are enhanced by successfully completing a challenging task with little or no assistance, or when a success is attributed to internal or controllable causes such as ability or effort. However, if an individual's success is attributed to luck or the intervention of others, or if he or she is unsuccessful when performing previous tasks, then self-efficacy may not be strengthened or may be lowered (Bandura, 1986; Tschannen-Moran et al., 1998).

The three other sources of efficacy expectations include vicarious experiences, verbal persuasion, and emotional arousal. Vicarious experiences occur when an individual witnesses the successful performance of others completing a task or modeling the desired behavior. The individual is then convinced that he or she should be able to successfully perform the task or model the behavior as well, leading to increased self-efficacy. The effect on the observer's self-efficacy is moderated by several factors including the degree to which the observer identifies with the person experiencing

success (the model), the perceived difficulty of the task, and the context by which the modeled achievements were carried out. Verbal or social persuasion may also influence one's self-efficacy. Through persuasive suggestion that one possesses the capabilities to master difficult situations, an individual may develop beliefs that lead to greater self-efficacy. The effect on the person's self-efficacy may be influenced by the persuader's perceived credibility, trustworthiness, and assuredness; the more believable the source of the information, the more likely efficacy expectations will change (Bandura, 1986). Emphasized in Bandura's social learning theory (1978), one's state of physiological arousal determines their levels of anxiety and stress and may also affect one's self-efficacy toward a task or behavior.

Tschannen-Moran et al. (1998), through examining the development of teacher efficacy beliefs, found that all four sources postulated by Bandura (1986) have been included in sources of teaching efficacy expectations. In accordance with Bandura (1986), the personal accomplishment achieved through mastery experiences was found to be the most powerful source of teaching efficacy. Through actual teaching experiences in the classroom, teachers can assess their ability to teach and can determine how their strengths and weaknesses affect their ability to manage, instruct, and evaluate students. Also, observing others teach, through vicarious experiences, provides insight into the nature of the teaching task, including decisions about who is responsible for student learning and to what extent the teacher can make a difference in that learning. Verbal persuasion from supervisors, other teachers, and even students may also influence teacher efficacy and provide information about the nature of teaching. This may include providing encouragement and/or strategies for meeting challenges and providing specific

feedback about how to develop the teacher's skills and strategies to effectively implement a specific teaching task. Lastly, one's self-perception of teaching ability may be impacted by the degree of emotional and physiological stimulation experienced in a particular teaching situation (Brand & Wilkins, 2007; Tschannen-Moran et al., 1998).

Elementary STEM Teacher Preparation

In order for the U.S. to compete in the 21st-century global workforce, elementary school teachers' ability to teach content and skills in the STEM disciplines needs improvement. 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 content knowledge and PCK in order to teach STEM lessons and make meaningful connections among STEM disciplines in their future classrooms (Berlin & White, 2012; Epstein & Miller, 2011; Kurup et al., 2017). "If teachers do not have a solid understanding of what constitutes effective STEM integration then it may be implemented poorly. For teachers new to integrated STEM education, content knowledge and teaching practices are the most important considerations" (Stohlmann et al., 2013, p. 13). Research (Alexander, 2011) has also suggested that the attitudes and beliefs that teachers have toward a subject influence their own instructional practices. Specifically, the attitudes that teachers have towards STEM subjects can potentially decrease their students' interests in these subjects and future STEM careers.

Elementary STEM Education

The foundation for future STEM learning is built in elementary school mathematics and science. Early exposure to STEM education provides the youngest students with opportunities to learn and understand basic STEM content. Through real-world experiences, these future professionals are provided an authentic view of STEM-related working environments created to nurture positive impressions of integrated STEM content. Furthermore, engaging elementary students in integrated STEM education gives students insight into STEM content areas and job opportunities at a younger age, informing important decisions concerning their future career paths (DeJarnette, 2012; Epstein & Miller, 2011; Murphy & Mancini-Samuels, 2012).

Kermani and Aldemir (2015) investigated the influence of content-specific, purposeful, and intentional integrated STEM activities including mathematics, science, and technology on pre-K student learning of mathematics and science skills and concepts. Participants included 58 pre-K students (24 females and 34 males) from a local school district that were randomly assigned to the treatment group that received the mathematics, science, and technology intervention. The mathematics and science scores of the participants in this study significantly increased as a result of the integrated approach to teaching mathematics and science with technology. These findings suggest that early education programs should include an integrated approach to teaching mathematics and science as preschoolers' "openness to math concepts and their innate scientific curiosity provide a perfect opportunity to nurture their growth in science, math, and technology areas" (p. 1504).

Similar to findings at the early childhood level, a review of the research (Barcelona, 2014; Becker & Park, 2011; Kermani & Aldemir, 2015; Sanders, 2009) revealed benefits of integrated STEM learning experiences at the elementary school level. Barcelona (2014) found that student achievement at the elementary level was higher when students were engaged in integrated STEM learning. Integrative approaches to STEM education improve student learning and student attitudes as they are engaged in real-life, problem-solving learning contexts. The constructivist learning approach also includes engaging students in higher-order thinking, which requires teachers to adjust their role in the classroom to be more of a facilitator of student-centered learning. Providing early access to an understanding of the foundations of STEM learning within the elementary curriculum offers unique opportunities for integrative approaches to STEM education that may increase interest in and preparation of students to enter STEM careers (Becker & Park, 2011; Kermani & Aldemir, 2015; Sanders, 2009).

However, research (Nadelson, et. al., 2013; NAE & NRC, 2014) suggests that many elementary teachers lack the content knowledge, confidence, and self-efficacy for teaching STEM content and guiding their students to greater success in STEM fields. The lack of content knowledge can negatively impact a teacher's efficacy, confidence, and comfort in teaching STEM lessons. Furthermore, with the emphasis on numeracy and literacy blocks, the amount of time teaching STEM-related disciplines has declined (Nadelson et. al., 2013; NAE & NRC, 2014). Nadelson et al. (2013) recognized the importance of STEM curriculum and instruction at the elementary school level as a means to increase student interest in STEM fields. Increasing student interest in, awareness of, and understanding of STEM careers requires teachers to possess adequate

knowledge of teaching STEM content and awareness of STEM careers. Thus, providing opportunities for elementary teachers to increase their STEM content knowledge and heighten their perceptions of STEM teaching and learning may influence their efficacy, confidence, and comfort with teaching integrated STEM content so they may effectively implement integrated STEM education into their classrooms.

Developing Preservice Teachers' STEM Content Knowledge

Content knowledge is defined as the amount and organization of knowledge that a teacher possesses. Extending beyond the rules or facts within the discipline, teachers must be able to justify concepts or propositions and explain why they are important. Teachers must be able to relate them to other concepts within and outside of the discipline in theory and in practice (Shulman, 1986). Specific to mathematics, mathematical knowledge for teaching includes a deep understanding of the content and using multiple representations that surpasses the ability to perform an algorithm. Using their own mathematical reasoning, teachers carry out instructional tasks in the classroom that include analyzing student misconceptions and misunderstandings to enable them to develop their own reasoning and deepen their understanding of the mathematical concepts. In an analysis of 700 teachers in grades 1-3 (and almost 3,000 students), findings indicated that the teachers' mathematical knowledge, both common and specialized content knowledge, was a significant predictor of gains in student achievement (Ball, 1990; Ball, Hill, & Bass, 2005).

Lewis et al. (2014) investigated the impact of an interdisciplinary model of teaching science on preservice teachers' ideas about teaching science. Participants were engaged in a 5-week summer elementary science methods course paired with a daily field

experience in an inner-city summer school program. The preservice teachers developed and implemented two lessons that followed the 5E model (Bybee et al., 2006) and used science notebooks throughout the course, learning how to effectively use them in the elementary classroom to develop scientific practices. Results from this study supported the researchers' hypothesis that an interdisciplinary approach to teaching science would positively impact the elementary preservice teachers' beliefs about teaching science and increase their understanding of science and knowledge of strategies for introducing new scientific concepts. They "identified how an inquiry-based instructional approach encouraged the development of critical thinking skills, science process skills, and a greater awareness and self-regulation of one's own learning" (Lewis et al., 2014, p. 160). They further recognized the importance and value of inquiry-based teaching and learning, science notebooks, addressing equity issues in the classroom, and integrated science instruction.

Participation in an intensive mathematics and science content professional development program has also shown to positively impact elementary and secondary preservice teachers' mathematics and science content knowledge (Jeffery et al., 2015). The preservice and in-service teachers within this study engaged in hands-on mathematics and science lessons and participated in workshops focusing on developing their understandings of mathematical and scientific concepts taught in grades 4-8. Throughout the development of STEM lessons and reflection on teaching practices, the collaboration between preservice teachers, in-service teachers, mathematics and science educators, and peers was an integral part of this program and could be an invaluable experience within other teacher preparation programs (Jeffery et al., 2015).

Yet with the focus on developing teachers' STEM content knowledge, few teacher preparation programs exist in the U.S. that are preparing teachers with appropriate content knowledge in more than one STEM discipline (NAE & NRC, 2014). Preservice teachers also bring their own ideas to teacher education programs about what content knowledge will be sufficient to teach STEM content. Stemming from how they learned mathematics and science in grades K-12, they believe the sufficient content knowledge for teaching includes the basic facts, rules, definitions, and procedures within the disciplines. Whereas knowledge of facts and procedures is important, this limited knowledge does not adequately prepare preservice teachers to engage their future students in developing conceptual understanding through inquiry-based learning, nor to identify and address student misunderstandings and misconceptions within mathematics and science (Ball, 1990; Fuentes, Bloom, & Peace, 2014).

Developing Preservice Teachers' STEM Pedagogical Content Knowledge

A deeper science and mathematics content knowledge is not the only factor in increasing preservice teachers' confidence and self-efficacy to teach integrated STEM lessons. Teachers' content knowledge is insufficient without knowledge of rich connected understandings within their content as well as the ability to teach with understanding. The interconnections between the mathematics and science content and common teaching strategies must also be emphasized to ensure more effective delivery of instruction. Within Shulman's (1986) construct of PCK, effective teachers should understand how to organize and present content in such a way that students' interests are stimulated. Teachers that have command of PCK utilize planning and lesson implementation in such a way that they move students beyond a basic understanding into

deeper conceptual understanding. In the case of STEM content, students begin to recognize the interconnectedness of the disciplines (Ball, 1990; Shulman, 1986). This deep understanding suggests that a teacher can communicate not only a particular concept but the rationale for the concept and the way in which it connects to other related concepts. This includes the ability to access and address foundational prior knowledge and extend beyond the concepts to develop students' higher-order understandings (Kelley & Knowles, 2016). Strong PCK also considers assessment as well as reflection on one's teaching practice (Ball, 1990; Shulman, 1986). Thus, professional organizations have suggested that teacher preparation programs must include opportunities for preservice teachers to engage in authentic mathematics and science practices (Achieve, 2012; NCTM, 2014; NGACBP, 2010), allowing them to deepen both their content knowledge and PCK in mathematics and science.

Enhancing Preservice Teacher Attitudes and Confidence/Self-Efficacy

In addition to content knowledge and PCK, preservice teachers enter teacher education programs with beliefs in their abilities and attitudes towards their skills in teaching STEM content effectively (Maher et al., 2013). Findings of Corlu et al. (2015) revealed that poor attitudes of preservice teachers toward mathematics and science may negatively affect their ability to learn and effectively teach the content in both subjects. The impact of the integrated approach offered by the university in the study was significant for preservice mathematics and science teachers' attitudes toward teaching integrated mathematics and science lessons. The preservice teachers in the integrated program experienced more balanced coursework of content and pedagogy within an integrated framework, which may have led to enhanced attitudes related to teaching

mathematics and science. Implications revealed that preservice teachers who participate in an integrated approach to teaching mathematics and science may understand and teach STEM content with strong real-life connections in their future classrooms. Additionally, research suggests that elementary preservice teachers exhibited more positive attitudes toward science and mathematics after participating in inquiry-based content and methods courses while also showing increased confidence to do so (Ball, 1990; Jong & Hodges, 2013; Riegler-Crumb et al., 2015).

Preservice teachers also recognize the influence that their own beliefs about STEM content and STEM teaching and learning have on their future students. Maher et al. (2013) found that preservice teachers' beliefs about teaching are formed during their K-12 educational years. According to belief theory (Bryan and Atwater, 2002), beliefs drive a person's actions based on their thinking about the particular constructs. Beliefs are defined as "opinions or convictions firmly held by preservice teachers, specifically toward teaching and learning in STEM fields" (p. 268). Thus, teacher preparation programs should provide opportunities for preservice teachers to examine their beliefs and attitudes toward STEM education in order to escalate the goals of STEM education for their future students.

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. Preservice teachers participating in the study identified important aspects that would positively impact their ability to effectively teach STEM content including resources and leadership, their own STEM content knowledge, and collaboration among teachers using an integrated framework. Identified concerns that

impact the implementation of integrated STEM education included lack of confidence in their ability to teach mathematics and science, to incorporate STEM content in the curriculum, and to facilitate a creative, integrated, active learning environment for their students. Analysis of the data suggested that future teachers need to develop skills within teacher preparation programs to incorporate science, technology, engineering, and mathematics in an integrated framework. Furthermore, future teachers need more exposure to better leadership, more professional development, and specialization in STEM practices and procedures including integrated teaching. Preservice teachers need to feel confident and well-prepared to teach the content, as well as the practices in STEM fields so that their students are equipped with 21st-century skills (Kurup et al., 2017).

According to Moseley & Utley (2006), reform in teacher education and science education called for a revision of science courses to include both content and pedagogy for teacher education students. Using Bandura's (1978) social learning theory of self-efficacy as the theoretical framework, the researchers in this study measured the impact of participation in a mathematics and science content-based course on elementary preservice teachers' efficacy, beliefs, personal teaching, and outcome expectancy of mathematics and science teaching. They suggested that participation in a content course emphasizing science and mathematics could impact preservice teachers' efficacy, especially in their beliefs about their influence on student outcomes. The researchers suggested that preservice teachers who begin their career as a teacher with a greater self-efficacy in mathematics and science will be more apt to enter the classroom better prepared and more likely to remain in the teaching field for a longer amount of time.

Rinke et al. (2016) investigated the impact of a redesigned science and mathematics methods course on elementary preservice teachers' efficacy and knowledge for planning and teaching integrated STEM lessons. Results indicated that each of the preservice teachers increased his or her mathematics and science teaching efficacy as well as PCK. The STEM block offered preservice teachers opportunities to increase their confidence in teaching STEM content through more concentrated learning and more opportunities to practice teaching strategies, leading to greater efficacy in teaching integrated STEM content. Implications included the revisions of the traditional methods of instruction courses may better prepare future elementary teachers to teach integrated STEM lessons.

Providing Meaningful Elementary School Classroom Experience

Preservice teachers not only lack exposure to STEM teaching in their university coursework but also in their elementary classroom field placements, leading them to feel unprepared to teach STEM lessons in their future classrooms (Kurup et al., 2017). Field placements also play a pivotal role in determining the extent to which integrated STEM lessons are planned and implemented. Preservice teachers rarely observe classrooms in which teachers implement an integrated approach to teaching mathematics and science. Rather, they experience lecture-based instruction with segregated mathematics and science curricula. Schleigh et al. (2011) suggested the need for change in preservice teachers' field experiences in the elementary classroom to include exposure to integrated instruction in order to support their future teaching using an integrated approach.

In an effort to advance integrated instruction, Adams et al. (2014) used place-based learning to provide 50 elementary education preservice teachers with authentic and

diverse experiences with elementary school students throughout two semesters of mathematics, science, and social studies methods of instruction coursework. The outdoor science classroom and the local reservation school provided the context for the preservice teachers to design and implement STEM lessons. Results indicated that engaging elementary preservice teachers in place-based learning led to a more meaningful understanding of place-based learning and its impact on teaching authentic STEM lessons relevant to the community and environment. Preservice teachers' attitudes toward teaching STEM content were heightened throughout this experience, as well as their intent to teach integrated STEM lessons using place-based experiences in their future classrooms. Exposing elementary preservice teachers to the abundant local resources that can be utilized to teach authentic STEM lessons may lead to heightened attitudes toward teaching integrated STEM content through the lens of place-based learning. These authentic and diverse experiences may also engage preservice teachers in creating and implementing student-centered, inquiry-based, hands-on lessons that lead to meaningful learning of STEM content in an integrated framework. It is suggested that teacher preparation programs need to include STEM education in their coursework and offer preservice teachers 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 in the STEM subjects and in which integrated STEM lessons are prevalent (Barcelona, 2014; Kurup et al., 2017; Radloff & Guzey, 2017).

Conclusion

With an emphasis on the need for 21st-century skills, some researchers claim that teacher preparation programs must be the starting point for future teachers to develop

those skills within their students. By providing a safe environment of teaching and learning where misconceptions can be addressed within teacher preparation programs, preservice teachers have the opportunity to gain confidence in their understandings of STEM content and pedagogy for the K-12 classroom. Embedded throughout a teacher preparation program, experiences ensuring that explicit connections are made among the STEM disciplines contribute to the preparation of preservice teachers to teach integrated STEM lessons (Corlu et al., 2015; Epstein & Miller, 2011; Kurup et al., 2017; Murnane, 2016; Riegle-Crumb et al., 2015; Thanheiser, Browning, Moss, Watanabe, & Garza-King, 2010; Watters & Ginns, 2000).

STEM integration can be successfully implemented and positively impact education while increasing student interest in STEM disciplines. Integrated STEM education encourages student learning and increases students' confidence in learning mathematics and science in a fun, innovative way using real-world problem solving across disciplinary boundaries (Wang, Moore, Roehrig, & Park, 2011). Overall the review of the literature supported the need for additional research into ways to improve methodological coursework approaches at the elementary preservice teacher level as both mastery of integrated STEM content and pedagogy remain a challenge within teacher preparation programs.

CHAPTER III - METHODOLOGY

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, and the extent to which their attitudes and confidence correlated with their proficiency in planning integrated STEM lessons. In particular, the researcher proposed to provide a model for elementary integrated STEM teacher preparation. This mixed-methods study was guided by the following questions:

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

RQ1. ...to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?

H₁: Elementary preservice teachers' attitudes toward teaching integrated STEM lessons will be significantly higher after successful completion of integrated mathematics and science methods of instruction courses.

RQ2. ... to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

H₂: Elementary preservice teachers' confidence in teaching integrated STEM lessons will be significantly higher after successful completion of integrated mathematics and science methods of instruction courses.

RQ3. ... to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?

H₃: Elementary preservice teachers' attitudes and confidence with regard to teaching integrated STEM lessons will positively correlate with their proficiency in planning integrated STEM lessons after successful completion of integrated mathematics and science methods of instruction courses.

Research Design

The primary research goal of this study was to explore changes in elementary preservice teachers' attitudes and confidence with regard to teaching integrated STEM lessons, and the correlation of those constructs with their proficiency in planning integrated STEM lessons. To do this, a mixed-methods, sequential, explanatory design was used (Creswell & Plano Clark, 2011). In a mixed-methods approach, the collection and analysis of both quantitative and qualitative data are necessary to gain a better understanding of the phenomena under investigation. In this mixed-methods, sequential, explanatory design, strong pre-existing quantitative data were analyzed in the first phase, followed by informative qualitative data collected and analyzed in the second phase. The strength of this design is that it is straightforward, with qualitative data used to support initial quantitative data, allowing the researcher to connect quantitative statistics with personal experiences (Creswell & Plano Clark, 2011; Johnson & Christensen, 2008). The rationale for this approach was that the results from the quantitative data would provide an overall measure of the impact of the preservice teachers' successful completion of integrated mathematics and science methods of instruction courses on their attitudes toward, confidence in, and proficiency in planning integrated STEM lessons. The qualitative data and subsequent analysis was used to provide an explanation of the

quantitative results by exploring the elementary preservice teachers' perceptions of planning and teaching integrated STEM lessons in more depth.

Secondarily, a longitudinal research design was also used to make comparisons across time (Johnson & Christensen, 2008). As illustrated in the research design (Figure 2), the researcher compared the changes in the preservice teachers' attitudes and confidence over their final two semesters in the K-6 Teacher Education Program, culminating in the internship semester. Quantitative data from O₁, and O₂, as well as data from the qualitative phase were collected during Spring 2018 as part of a systematic program review that included the newly designed and implemented integrated mathematics and science methods of instruction courses. The final quantitative data from O₃ were collected during Fall 2018. Data were analyzed and triangulated to establish corroboration of the quantitative and qualitative data (Bryman, 2006).

Figure 2. Design of the research study

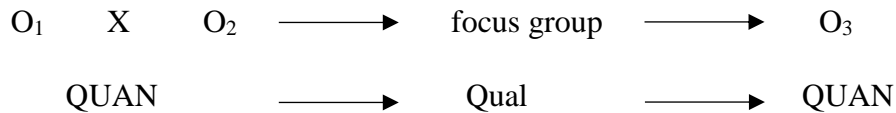


Figure 2. O₁ included the first (pre-) administration of both questionnaires, O₂ included the second (post-) administration of both questionnaires and the analysis of the learning segment, and O₃ included the final (delayed post-) administration of both questionnaires. The qualitative phase included responses to semi-structured interviews.

Participants

Participants in this study consisted of 24 elementary preservice teachers enrolled in their final two semesters of the K-6 Teacher Education Program at a four-year public university situated in an urban city in the southeastern U.S. As part of a program in which all K-6 Teacher Education candidates have an opportunity for attaining an initial teaching certificate in both K-6 Elementary Education and Collaborative K-6 Teacher Education (Special Education), the participants completed the final two semesters of the program

which included a Tier 3 methods of instruction block semester and a Tier 4 internship semester. Participant data were obtained and analyzed from data collected by the Tier 3 faculty during the Spring 2018 semester as part of a systematic program review.

Additional data were collected and analyzed from the participants during the Fall 2018 internship semester.

Quantitative Phase

The elementary preservice teachers enrolled in the Spring 2018 Tier 3 coursework were available and could easily be recruited for participation in the study. Furthermore, the researcher was the Tier 3 elementary mathematics methods of instruction course instructor, resulting in the use of a convenience sample for the quantitative phase (Johnson & Christensen, 2008). A power analysis was conducted in *G*Power* to determine the recommended sample size (Faul, Erdfelder, Buchner, & Lang, 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, Black, Babin, & Anderson, 2010). All 24 elementary preservice teachers were females ranging in ages 21-36, and were recruited and voluntarily agreed to participate in the study. No incentives were offered to the preservice teachers.

Qualitative Phase

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). The Tier 3 faculty agreed upon the participants selected for the sample based on their active

participation in class, course grades, and overall attitudes and effort they demonstrated toward becoming an effective teacher. Upon completion of the Tier 3 coursework, the researcher solicited 11 diverse participants to potentially participate in the focus group (typically 6 to 12 purposefully selected participants and a moderator). These 11 participants represented unique voices in the methods of instruction courses. Four of the 11 agreed to participate in the focus group and provided responses to open-ended questions used to provide useful information to complement and aid in the interpretation of the previously collected quantitative data (Johnson & Christensen, 2008; Merriam, 2002). According to Merriam (2002), the researcher is the primary instrument for data collection and analysis; thus, the researcher moderated the semi-structured interviews in the focus group. No incentives were offered to the preservice teachers, but light snacks were provided by the Tier 3 faculty.

Role of Researcher

The researcher had been the instructor of the elementary mathematics methods of instruction course for over 15 years, as well as a university supervisor for K-6 preservice teaching experiences in the elementary classroom. Using a constructivist, hands-on, inquiry-based approach, the researcher provided opportunities for elementary preservice teachers to develop the necessary mathematical PCK and identify effective strategies to teach mathematics in the K-6 classroom. Aligned with research (NAE & NRC, 2014), the researcher's observations in local elementary classrooms had revealed an emphasis on numeracy and literacy blocks, resulting in a decreased amount of time teaching STEM-related disciplines. The goal of the researcher was to determine how best to prepare elementary preservice teachers, through participation in an integrated approach to

mathematics and science methods of instruction courses, to teach integrated STEM lessons with authentic real-life connections in their future classrooms (Corlu et al., 2015).

Instrumentation

To address the research questions for this study, both quantitative and qualitative data were collected at different time points within the study. Because the researcher found no single instrument that would provide information to address all of the research questions in the study, questionnaires, a learning segment rubric, and semi-structured interviews were used to synthesize and triangulate the findings seeking corroboration of the quantitative and qualitative data (Bryman, 2006). Based on the results of the Fall 2017 pilot study, in which each of the instruments were pre-tested, necessary modifications to the instruments were completed. (Description of the pilot study can be found in Chapter IV.) During the initial and intermediate quantitative phases and the qualitative phase, data from the instruments were collected by the Tier 3 faculty as part of a systematic program review which included the newly designed and implemented integrated mathematics and science methods of instruction courses. The data were obtained by the researcher for use in the study (Appendix B). During the final quantitative phase, additional open-ended questions were added to both questionnaires to provide further explanation of the results from the data collected during Spring 2018.

Quantitative Phase

During the quantitative phase, data were collected at three time points. During the first week of the Spring 2018 semester, the participants completed two questionnaires, including demographics, which provided pre-treatment data (QUAN1). The questionnaires and the output data were generated using Qualtrics software, Copyright ©

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During the final week of the Spring 2018 semester, the participants completed the two questionnaires which provided post-treatment data, and their integrated STEM learning segment was scored using a rubric developed by the Tier 3 faculty (QUAN2). During the final quantitative phase, the participants completed the two questionnaires that included additional open-ended questions which provided delayed post-treatment data (QUAN3). Descriptions of each of the quantitative instruments are described in the following subsections.

STEM Attitudes Questionnaire

In order to accurately measure elementary preservice teachers' attitudes toward teaching mathematics and science in an integrated STEM framework, the researcher received permission to use and modify the *Survey of Attitudes Toward Statistics-36* (SATS-36) instrument developed by Schau (2003a) to measure post-secondary students' attitudes toward statistics (Appendix C). The SATS-36 instrument consists of items that assess six components of attitudes that include *Affect*, *Cognitive Competence*, *Value*, *Difficulty*, *Interest*, and *Effort*. Students respond to each item using a 7-point Likert-type response scale (Likert, 1967) ranging from 1 = *strongly disagree*, to 7 = *strongly agree*, with the middle represented by 4 = *neither agree nor disagree*. The composite and individual component scores are formed by reverse scoring the negatively worded items so that a higher numbered response corresponds to more positive attitudes. The composite score is determined by calculating the mean of all of the item responses. To determine each component score, the mean of the item responses within each component

are calculated. The survey was validated by an expert panel of instructors and statistics students determining significant positive correlation of the instrument with Wise's Attitudes Toward Statistics scale (Wise, 1985). Initial item analysis revealed a range of reliability coefficients depending on the sample using the original SATS©28 instrument which included the components of *Affect* (.81 to .85), *Cognitive Competence* (.77 to .83), *Value* (.80 to .85), and *Difficulty* (.64 to .77) (Schau, Stevens, Dauphinee, & Del Vecchio, 1995).

In order to address RQ1 and RQ3, the participants completed the STEM Attitudes Questionnaire (Appendix D), adapted from the SATS-36 instrument, at three different time points within the study. Modifications were made to the original items to reflect a focus on integrated STEM education rather than statistics. Items such as "I will have trouble understanding statistics because of how I think" were rewritten as "I will have trouble understanding how to integrate mathematics and science because of how I think." The structure, original scale and scoring method, and the general theme of the original instrument were maintained. The composite attitudes score was determined by calculating the mean of all of the item responses. Each component score was determined by calculating the mean of the item responses within each component. Table 1 describes each component and provides sample items from the STEM Attitudes Questionnaire. During the Fall 2017 pilot study, the researcher pre-tested the modified instrument for internal reliability and validity to determine if the revised instrument functioned as it should (Creswell & Plano Clark, 2011; Johnson & Christensen, 2008).

Table 1

STEM Attitudes Questionnaire: components, definitions, and sample items

Component	Definition	Sample Item
<i>Affect</i> (6 items)	elementary preservice teachers' "feelings concerning" teaching integrated STEM lessons	"I will like teaching mathematics and science in an integrated STEM framework."
<i>Cognitive Competence</i> (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."
<i>Value</i> (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."
<i>Difficulty</i> (7 items)	elementary preservice teachers' "attitudes about the difficulty" of teaching integrated STEM lessons	"Integrating mathematics and science in a STEM framework is complicated."
<i>Interest</i> (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."
<i>Effort</i> (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 Attitudes Questionnaire was administered as part of a systematic program review including the design and implementation of the integrated mathematics and science methods of instruction courses. The data that were obtained from the Tier 3 faculty were used and analyzed as part of the first two quantitative phases of the study (QUAN1, QUAN 2).

STEM Confidence Questionnaire

In order to accurately measure elementary preservice teachers' confidence to teach mathematics and science in an integrated STEM framework, the researcher and the elementary science professor received permission to use and modify the *Self-Efficacy to Teach Science in an Integrated STEM Framework* (SETIS) Instrument (Appendix E), developed to measure active K-12 science teachers' confidence in their abilities (self-efficacy) to teach science within an integrated STEM framework (Mobley, 2015). The SETIS instrument consists of 30 self-report response items using a 1-4 Likert-type response scale (Likert, 1967), 12 demographic items, and one open-ended response question. According to Bandura (1978), items measuring self-efficacy should be worded in terms of "can do", representing the perception of ability. Thus, the option for neutral responses when measuring what a person can do does not allow for the accurate assessment of their ability to do something at that moment. The four-choice format was chosen to intentionally omit the neutral response option with 1 representing "not confident at all" and 4 representing "very confident I can do this" (Mobley, 2015).

The SETIS instrument identifies three factors that contribute to science teachers' confidence (self-efficacy) to teach science in an integrated STEM framework. The *Social* factor includes a teacher's beliefs about how others may perceive or affect his or her

ability; the *Personal* factor, a teacher's individual beliefs about his or her ability; and the *Material* factor, the technology-based resources and other constructs outside of a teacher's control. The survey was validated by an expert panel of college professors and advanced graduate students with STEM backgrounds and teaching experience. Reliability for each of the three factors was established through an item analysis using Cronbach's alpha (1951). The *Social* factor includes ten items and had the highest reliability coefficient ($r = .918$). The *Personal* factor, comprised of five items, also had a high reliability coefficient ($r = .917$). The *Material* factor had the lowest reliability coefficient ($r = .878$) but was determined to have good reliability ($r > .70$) (Mobley, 2015).

In order to address RQ2 and RQ3, the participants completed the STEM Confidence Questionnaire (Appendix F) at three different time points within the study. Modifications were made to some of the SETIS items to reflect a more general focus on integrated STEM by rewriting items such as "develop new knowledge and skills necessary to teach science from within an integrated STEM framework" to be "develop new knowledge and skills to teach science and mathematics within an integrated STEM framework." Table 2 describes each of the three factors and provides sample items from the STEM Confidence Questionnaire (Appendix F). The structure, original scale and scoring method, and the general theme of the SETIS instrument were maintained. The overall confidence score was determined by calculating the mean of all of the item responses. Each factor score was determined by calculating the mean of the item responses within each factor.

Table 2

STEM Confidence Questionnaire: factors, definitions, and sample items

Factor	Definition	Sample Item
<i>Social</i> "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."
<i>Personal</i> "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."
<i>Material</i> "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.

During the Fall 2017 pilot study, the STEM Confidence Questionnaire was pre-tested for internal reliability and validity to determine if it functioned as intended

(Creswell & Plano Clark, 2011; Johnson & Christensen, 2008). During the Spring 2018 semester, the STEM Confidence Questionnaire was administered as part of a systematic program review including the design and implementation of the integrated mathematics and science methods of instruction courses. The data were obtained from the Tier 3 faculty and were used and analyzed as part of the first two quantitative phases of the study (QUAN1, QUAN 2).

Additionally, open-ended questions were added to the STEM Attitudes Questionnaire and the STEM Confidence Questionnaire that were administered in the final quantitative phase (QUAN3) (Appendix G). These questions were added to give the participants an opportunity to explain in greater depth how their attitudes toward and confidence in teaching integrated STEM lessons had changed over their final two semesters. Furthermore, these questions gave the participants the opportunity to share their experiences with planning and teaching integrated STEM lessons throughout the two semesters.

Integrated STEM Learning Segment

To address RQ3, the participants' individual integrated STEM learning segments were analyzed using the Integrated Science/Math Learning Segment Rubric (Appendix H) developed by the researcher and the elementary science professor who co-taught the integrated mathematics and science methods of instruction courses. The integrated STEM learning segment included three to five consecutive days of integrated mathematics and science lessons utilizing the 5E model (Bybee et al., 2006). The framework of the rubric was based on components of STEM teaching and learning including active, inquiry-based learning; authentic, real-world problem solving; integration of mathematics and science

concepts using a variety of mathematical and scientific practices; and appropriate use of technology (Brown et al., 2011; Bybee, 2013; English, 2016).

The Integrated Science/Math Learning Segment Rubric was pre-tested in the Fall 2017 pilot study. After the pilot study, the Integrated Science/Math Learning Segment Rubric was modified to make the integrated STEM lesson components more explicit and more efficiently measured with specific allotted points to each component. During the Spring 2018 semester, the Integrated Science/Math Learning Segment Rubric was used to determine each participant's proficiency in planning his or her integrated STEM learning segment by providing a score out of a possible 170 points. The scores that were obtained from the Tier 3 faculty were analyzed in the intermediate quantitative data phase of the study.

Qualitative Phase

As part of the systematic program review, semi-structured interviews were conducted within a focus group of four purposefully sampled preservice teachers. Traditionally, focus group research is “a way of collecting qualitative data, which essentially involves engaging a small number of people in an informal group discussion (or discussions), ‘focused’ around a particular topic or set of issues” (Wilkinson & Silverman, 2004, p. 177). The research-based questions in the interview protocol were developed by the Tier 3 faculty which included the researcher, the elementary science professor, and the special education professor who co-taught within the methods of instruction courses (Appendix I). The protocol and the transcribed interviews were obtained by the researcher and analyzed in the qualitative phase of the study.

Procedures

This study was approved by the Institutional Review Board (IRB) at both the university in which the researcher was enrolled as a graduate student and the university in which the study was conducted (Appendices A-B). In order to pre-assess each instrument, a pilot study was conducted during the Fall 2017 semester, and instruments were modified based on the resulting data analyses.

Quantitative Phase

During the quantitative phase, the participants were surveyed at three different time points throughout the Tier 3 and Tier 4 semesters. Procedures within each phase are described in the following subsections.

Initial Quantitative Phase

The participants were introduced to the study during the first class meeting of the Spring 2018 Tier 3 semester. A Tier 3 faculty member, other than the researcher, described the goals of the study and administered paper copies of the long consent forms, required by the institution in which the researcher was enrolled as a graduate student, to the elementary preservice teachers enrolled in the methods of instruction courses. The elementary preservice teachers were invited to ask questions and express concerns regarding the study; however, there were no questions or concerns expressed by the elementary preservice teachers. The consent forms were signed by those who agreed to participate. The informed consent for the institution where the study was being conducted was embedded in the STEM Attitudes Questionnaire and the STEM Confidence Questionnaire that the participants completed online. The study was explained by the

faculty member, and the participants agreed to participate by selecting "yes" to the first question regarding the agreement to participate.

Using the Qualtrics (Qualtrics, Provo, UT) platform, the participants voluntarily completed both questionnaires online using their own laptops, tablets, or smartphones within 30 minutes in a classroom on the university campus. The participants used a 4-digit identification code so the data could be organized and matched to address all research questions. The researcher printed the electronically signed consent forms and obtained the long consent forms from the Tier 3 faculty member and stored them in a locked cabinet for one year after the dissertation defense. Both data sets were stored on the researcher's external hard drive for a period of one year after the dissertation defense.

Treatment

The mathematics and science methods of instruction courses were grounded in constructivism, engaging elementary preservice teachers in active, inquiry-based learning. Historically, the mathematics and science methods of instruction courses in the K-6 Teacher Education Program focused on content-specific, standards-based curriculum and pedagogy without emphasis on integration of the two STEM disciplines. Prior to the Fall 2017 pilot study, the researcher and the elementary science professor revised each course to include integrated mathematics and science pedagogy using a variety of co-teaching strategies, as reflected in each course's syllabus and schedule (Appendices J-K). Whereas both methods of instruction courses continued to include many content-specific learning activities and experiences, authentic and intentional integrated mathematics and science learning activities were included to offer the elementary preservice teachers an opportunity to experience integrated STEM education as learners and teachers.

Throughout the integrated mathematics and science methods of instruction courses, the preservice teachers participated in Team-Based Learning, working collaboratively through real-life problem solving to develop conceptual understanding of mathematical concepts, mathematical reasoning, and scientific literacy. The Standards for Mathematical Practice (NGACPB, 2010), the Mathematics Teaching Practices (NCTM, 2014), and the Science and Engineering Practices (Achieve, 2012) guided student engagement and learning, as well as the co-teaching strategies modeled by the instructors. As the preservice teachers were enrolled in the K-6 collaborative teacher preparation program (regular and special education), all preservice teachers engaged in multiple integrated STEM lessons co-taught by the mathematics methods instructor, the science methods professor, and the special education professor. To deepen their experience, the preservice teachers were also required to collaboratively plan an integrated STEM lesson utilizing Team-Based Learning. Each team of preservice teachers was assigned different grade-level content standards for mathematics and science. Working with their teams, they used the 5E model of instruction (Bybee et al., 2006) to guide the planning of the integrated mathematics and science lesson. Implementation of active, inquiry-based learning using a hands-on approach for both the mathematics and science content was a required component of the lesson, as well as student engagement in real-world problem solving. The mathematics and science and engineering practices were required to be embedded throughout the instructional activities as well. Using the Mathematics/Science Continuum model (Huntley, 1998) as the theoretical framework, the teams developed a “mathematics and science” integrated lesson (p. 322). After the initial draft of the lesson plan was completed, each team met with and received individual feedback from the

mathematics methods instructor, the science methods professor, and the special education professor using the stations co-teaching model. In order to share strategies and ideas, the revised team lesson plans were presented to both the faculty and the preservice teachers enrolled in the class, which provided an opportunity for the preservice teachers to receive additional feedback and suggestions for further refining their integrated STEM lessons. This lesson plan was not required to be implemented in an elementary classroom. However, all team lesson plans were shared with each of the preservice teachers so they could be used as future resources.

Following the team lesson planning, each preservice teacher was required to individually design and implement a consecutive three- to five-day integrated STEM learning segment in his or her elementary classroom teaching experience. Following the requirements and guidelines of the team integrated STEM lesson, the preservice teachers used both mathematics and science content standards aligned with their grade level placements to design consecutive integrated STEM lessons. Using the same station model of co-teaching, the preservice teachers received individual feedback from each of the three Tier 3 faculty, with collaboration among the faculty to ensure the integration was authentic. The individual three- to five-day integrated STEM learning segment was submitted to be evaluated using the Integrated Science/Math Learning Segment Rubric. Upon implementation of the learning segment in an assigned elementary school placement, the preservice teachers submitted a written reflection. Each of the Spring 2018 Tier 3 preservice teachers completed all of the outlined course requirements and had multiple opportunities to engage in integrated STEM education as a learner and a teacher.

Intermediate Quantitative Phase

During the last week of the Spring 2018 semester, the participants submitted their integrated STEM learning segments to the special education professor to be coded to match the code used for the questionnaires (See Appendix L for sample STEM learning segment). The names of the participants were removed to avoid any bias held by the researcher. Each learning segment was scored out of a possible 170 points using the Integrated Science/Math Learning Segment Rubric which reflected his or her proficiency in planning integrated STEM lessons. Additionally, the preservice teachers completed the STEM Attitudes Questionnaire and the STEM Confidence Questionnaire online during the final class meeting in the special education course. The participants used the same 4-digit code for both questionnaires as they did initially. All of the quantitative data was obtained from the Tier 3 faculty and was stored on the researcher's external hard drive until one year after the dissertation defense.

Final Quantitative Phase

The final quantitative phase data was collected during the final three weeks of the participants' Fall 2018 Tier 4 internship semester. The participants were enrolled in a full semester student teaching internship in a local elementary school with a minimum of 5 weeks in both a regular education classroom and special education classroom. Unlike the Tier 3 semester, the participants were not required to plan and implement integrated STEM lessons during the Tier 4 internship semester. However, they were required to teach all subjects in a regular education classroom for a minimum of 10 consecutive days, with the opportunity to teach mathematics and science in an integrated STEM framework.

During the Fall 2018 orientation where attendance is required by all preservice teachers who are entering their internship semester, the researcher presented and explained the dissertation study. Consent forms were distributed to the elementary preservice teachers seeking voluntary participation, collected by the researcher, and kept in a locked cabinet until one year after completion of the dissertation defense. Former elementary preservice teachers who were unable to attend the orientation were contacted via email to explain the study and seek voluntary consent to participate (Appendix M). Completed consent forms were emailed and collected by the researcher and stored in the locked filing cabinet with the other completed consent forms. During the final three weeks of the internship, links to both the STEM Attitudes Questionnaire and the STEM Confidence Questionnaire were emailed to the participants. In addition to the items on the original questionnaires, open-ended questions were added based on the analysis of the data during the initial and intermediate quantitative phases and the qualitative phase of the study.

Qualitative Phase

Following the quantitative data analysis, a sample of eleven diverse preservice teachers was purposefully selected (Creswell & Plano Clark, 2011) to participate in the focus group and represented the unique voices of the methods of instruction courses. The preservice teachers for the qualitative data collection included those who responded to an email sent to the purposeful sample soliciting volunteers for semi-structured interviews following the completion of the Tier 3 coursework (Appendix N). The focus group session lasted approximately one hour and included four participants, the researcher, and the other two Tier 3 faculty members. Though research has shown six to twelve

participants for a well-designed focus group, only four of the eleven who were selected responded (Johnson & Christensen, 2008). This may have been due to ongoing final exams during the week in which the focus group was conducted. However, according to Krueger (1994), as the participants were able to contribute specialized knowledge and/or experiences to the group conversation, “mini-focus groups” of three to four participants are effective and desirable in addressing research questions (p. 17).

The semi-structured interviews involving the four participants were conducted by the researcher and the other two Tier 3 faculty members. The purpose of the semi-structured interviews was to elicit more in-depth explanations and insights into the concerning quantitative data. The semi-structured protocol elicited conversation among the participants that painted a picture of their combined perceptions of integrating mathematics and science in the classroom and how the successful completion of the integrated methods of instruction courses related to their attitudes toward and confidence in teaching integrated STEM lessons. The semi-structured interviews were audio recorded. No incentives were offered to the participants; however, light refreshments were offered during the focus group session. The audio recording was obtained and transcribed by the researcher. The transcriptions and the audio recording were stored on the researcher’s external hard drive for one year after the dissertation defense. Qualitative data collected in the focus group was followed by a second qualitative component including additional open-ended questions on the questionnaires during the final quantitative phase of the study.

Data Analysis

To address the research questions in this study, quantitative and qualitative data were analyzed from questionnaires, a learning segment rubric, and semi-structured interviews. The combination of the quantitative and qualitative data analyses was used to provide a more thorough answer to the research questions with the qualitative data used to explain the quantitative data collected in the three phases. The planning matrix of the study (Table 3) maps each of the research questions to the data sources and analysis procedures that were employed in the study.

Table 3

Planning Matrix of the Study

Research Question	Sources of Data	Collection Timelines	Analysis Procedures
1. Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?	STEM Attitudes Questionnaire	January 2018	Repeated Measures MANOVA
		April 2018	
	Semi-structured student interviews	October 2018	Coding
		May 2018	
2. Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?	STEM Confidence Questionnaire	January 2018	Repeated Measures MANOVA
		April 2018	
	Semi-structured student interviews	October 2018	Coding
		May 2018	
3. Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, how do their attitudes and confidence correlate to their proficiency in planning integrated STEM lessons?	STEM Attitudes Questionnaire and STEM Confidence Questionnaire	January 2018	Multiple Regression Analysis
		April 2018	
	Integrated Science/Math Learning Segment Rubric	April 2018	

Quantitative data from questionnaires were downloaded from Qualtrics (Qualtrics, Provo, UT) and analyzed using SPSS software (IBM Corp. Released 2013. IBM SPSS Statistics for Macintosh, Version 22.0. Armonk, NY: IBM Corp.). Initial analysis included exploratory data analysis to check for missing values or entry errors to ensure the data accurately represented what was actually measured (Meyers, Gamst, & Guarino, 2013). Descriptive statistics, including measures of central tendency, were used to initially describe, summarize, and interpret the data noting any possible trends.

In order to inform the qualitative data collected through the Spring 2018 focus group, paired-samples *t* tests for each quantitative data set were conducted to determine if there were any overall statistically significant differences from pre-test to post-test in the preservice teachers' attitudes toward and confidence in teaching integrated STEM lessons during the Spring 2018 semester. This analysis provided the researcher and the other Tier 3 faculty members with an opportunity to reflect upon the interview protocol and add probing and follow-up questions to the protocol. During the Spring 2018 semester, the integrated STEM learning segments were also analyzed using the Integrated Science/Math Learning Segment Rubric to inform the researcher of each preservice teacher's overall proficiency in planning an integrated STEM learning segment. The initial analysis of the quantitative data, coupled with the analysis of the qualitative data collected in the focus group, was used to create the open-ended questions that were added to the questionnaires in the final quantitative phase of the study. The formal data analysis procedures that began at the conclusion of the final quantitative phase of data collection

in Fall 2018 are described next, according to the research questions which guided the study.

Attitudes Toward Teaching Integrated STEM Lessons

The first research question asked, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?” To answer this question, both quantitative and qualitative data were analyzed in an effort to synthesize and triangulate the data.

Quantitative Data

To determine the impact of participation in the integrated mathematics and science methods of instruction courses on elementary preservice teachers’ improvement in attitudes toward teaching integrated STEM lessons, a multivariate analysis of variance (MANOVA) with repeated measures was employed. This omnibus test was chosen as previous research suggested a relationship between teacher attitudes and confidence (Berlin & White, 2010; Tschannen-Moran & Hoy, 2001). Based on the results of the MANOVA, a repeated measures analysis of variance (ANOVA) was conducted to determine if there was a statistically significant difference between pre-, post-, and delayed post-scores of elementary preservice teachers’ attitudes with regard to teaching integrated STEM lessons before and after their successful completion of the integrated mathematics and science methods of instruction courses and internship semester.

Qualitative Data

As suggested by Merriam (2002), multiple cycles of coding were used to analyze the qualitative data collected through the semi-structured interviews. Based on the results

of the Fall 2017 pilot study, *a priori* codes emerged which included confidence, STEM content knowledge, content integration, teaching strategies, challenges, support, and co-teaching. The first coding cycle employed open-coding procedures to allow the researcher to identify any additional patterns of response. As the researcher was immersed in the data, additional codes were added as necessary. During the second coding cycle, codes were organized and categorized to identify emerging themes and patterns within the data. The responses to the open-ended questions were also analyzed for possible emergent themes to provide clarity and explanation of the findings.

Confidence in Teaching Integrated STEM Lessons

The second research question asked, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?” To synthesize and triangulate the data, both quantitative and qualitative analyses were performed.

Quantitative Data

To determine the impact of participation in the integrated mathematics and science methods of instruction courses on elementary preservice teachers’ gains in confidence toward teaching integrated STEM lessons, a MANOVA with repeated measures was employed. This omnibus test was chosen as previous research suggested a relationship between teacher confidence and attitudes (Berlin & White, 2010; Tschannen-Moran & Hoy, 2001). Based on the results of the MANOVA, a repeated measures ANOVA was conducted to determine if there was a statistically significant difference between pre-, post-, and delayed post-scores of the preservice teachers’ confidence in

teaching integrated STEM lessons before and after their successful completion of the integrated mathematics and science methods of instruction courses and internship.

Qualitative Data

As the qualitative data gathered from the semi-structured interviews were used to address each research question, the transcription of the interviews was analyzed using multiple cycles of coding to identify emerging themes and patterns within the data. Further analysis of the responses to the open-ended questions, identifying emerging themes, was used to provide clarity and explanation of the findings.

Relationship Between Affective Domain and Proficiency in Planning Integrated STEM Lessons

The third research question asked, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?”

Quantitative Data

Two multiple regression analyses were conducted to examine how elementary preservice teachers’ attitudes and confidence (independent variables) related to their proficiency in planning integrated STEM lessons (dependent variable). The first multiple regression analysis included the pre-test composite attitudes scores and overall confidence scores as the independent variables and the Integrated Science/Math Rubric scores as the dependent variable. The second multiple regression analysis included the post-test composite attitudes scores and overall confidence scores as the independent variables and the Integrated Science/Math Rubric scores as the dependent variable. For

both analyses, the overall model was evaluated for its effectiveness using the results from the ANOVA. The significance of each of the independent variables (predictors) in the model was determined using *t* tests.

CHAPTER IV – DATA ANALYSIS AND RESULTS

This mixed-methods, longitudinal study sought to determine 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, and the extent to which their attitudes and confidence correlated with their proficiency in planning integrated STEM lessons. The primary focus of this chapter is to report answers to the following research questions using the results of analyses of both quantitative and qualitative data:

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

RQ1. ...to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?

RQ2. ...to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

RQ3. ...to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?

This chapter is organized into three sections. The first section describes the methodology, analysis, and results of the pilot study, which included pre-testing the instruments used in the study. The second section describes the participant demographics for both the quantitative and qualitative phases. The final section provides the data analysis and results for each research question.

Pilot Study

This dissertation research was informed by a pilot study that was conducted in the Fall 2017 semester with a different cohort of 20 elementary preservice teachers. The pilot study was designed to pre-test the modified and developed instruments and to provide an initial assessment of the newly designed and implemented integrated mathematics and science methods of instruction courses. Before the pilot study was conducted, content validity was established for each of the three quantitative instruments by an expert panel of university teacher education professors with STEM backgrounds who conduct research on STEM integration. Upon review of the items for each of the two questionnaires and suggestions from the panel, minor changes were made to the wording of certain items that were unclear or confusing. The Integrated Science/Math Learning Segment Rubric was also adjusted by making the integrated STEM lesson components more explicit and more efficiently measured with specific allotted points to each component. During the pilot study, both questionnaires were pre-tested and internal reliability was established through the use of Cronbach's alpha (1951). After the qualitative data were analyzed and coded, additional questions were added to the original protocol and some wording was altered to provide more clear and concise question prompts. A revised application was submitted to the IRB to include the revised questionnaires, rubric, and interview protocol, as well as the inclusion of new participants who would be part of the study.

The STEM Attitudes Questionnaire was administered during the Fall 2017 pilot study to 20 elementary preservice teachers enrolled in Tier 3 coursework at the same institution. Content validity was established through an expert panel of university 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 items that were unclear or confusing. Internal consistency and reliability of the modified instrument was established using an item analysis to determine Cronbach's alpha (1951) for each of the six attitudes components: *Affect* ($r = .83$), *Cognitive Competence* ($r = .64$), *Value* ($r = .80$), *Difficulty* ($r = .62$), *Interest* ($r = .86$), and *Effort* ($r = .78$). The reliability analysis supported the prior analyses performed on the original SATS-36 components with single administration (Nolan, Beran, & Hecker, 2012).

During the Fall 2017 pilot study, the STEM Confidence Questionnaire was pre-tested for internal reliability and validity to determine if it functioned as intended (Creswell & Plano Clark, 2011; Johnson & Christensen, 2008). The STEM Confidence Questionnaire was administered to 20 elementary preservice teachers enrolled in Tier 3 coursework at the same institution. Content validity was established with an expert panel of university 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 items that were unclear or confusing. Internal consistency reliability for each of the three factors was established through an item analysis using Cronbach's alpha (1951). Factor 1, *Social*, defined by ten items had a reliability index of .93; Factor 2, *Personal*, comprised of five items had a reliability index of .93; and Factor 3, *Material*, composed of the remaining four items had a reliability index of .93. For all 19 items, the reliability index was .97. The reliability analysis supported the prior analyses of the factors in the development of the original SETIS instrument (Mobley, 2015).

To establish the validity of the rubric, an expert panel of university teacher education professors with STEM backgrounds reviewed the rubric to determine if it served as a viable means of accurately assessing elementary preservice teachers' proficiency in planning authentic integrated STEM lessons within a three- to five-day learning segment. After the pilot study, the Integrated Science/Math Learning Segment Rubric was modified to make the integrated STEM lesson components more explicit and more efficiently measured with specific allotted points to each component.

A random number generator was used to select 5 of the 34 preservice teachers' integrated STEM learning segments to evaluate using the Integrated Science/Math Learning Segment Rubric designed by the researcher and the science education professor. For each preservice teacher, the individual total score was recorded. After scoring the documents separately, the researcher and the science education professor discussed the scores and clarified the criteria on which the learning segments were to be assessed. For example, a maximum of six points was awarded based on the preservice teachers' description of the extent to which the K-6 students were engaged in active STEM learning and inquiry throughout the learning segment. Upon agreement of the criteria, the researcher evaluated each preservice teacher's learning segment using the Integrated Science/Math Learning Segment Rubric reflecting his or her proficiency in planning integrated STEM lessons.

The focus group interview protocol was reviewed by experts in the field to establish validity and provide suggestions for alternate wording to ensure the questions were clear and concise. After pilot testing the protocol during the Fall 2017 semester, additional questions were added to the protocol and the questions were re-ordered to

provide the opportunity for a more coherent discussion. Furthermore, upon the Tier 3 faculty's initial analysis of the quantitative data collected in Spring 2018, probes and follow-up questions were added to the final interview protocol to encourage more in-depth explanations. Based on the results of the Fall 2017 pilot study, *a priori* codes emerged which included confidence, STEM content knowledge, content integration, teaching strategies, challenges, support, and co-teaching.

Participant Demographics

Data were collected from 34 elementary preservice teachers enrolled in their final two semesters of the K-6 Teacher Education program at a large university in the southeast region of the U.S. at which the researcher was employed. As a result of data cleaning, which will be discussed in the following section, usable data were analyzed from 24 participants which included 24 female elementary preservice teachers (1 African American and 23 Caucasian) with ages ranging from 21 to 36 ($M = 23.88$, $SD = 4.397$). Non-traditional students who were older than 24 years of age (Kenner & Weinermann, 2011), represented 25% of the sample within this study. Similarly, of the four Caucasian female participants in the focus group, one (25%) was a non-traditional student.

Data Analysis and Results

Data Screening and Cleaning

Using SPSS statistical software, initial analyses included exploratory data analysis to check for missing values or entry errors to ensure the data accurately represented what was actually measured (Meyers et al., 2013). Throughout the three phases of the study, data were collected from 34 elementary preservice teachers. Of the 34, 94% ($N = 32$) participated in the pre-test, 94% ($N = 32$) participated in the post-test, and 83% ($N = 30$)

participated in the delayed post-test. All 34 successfully completed the integrated mathematics and science methods of instruction courses and completed the Integrated STEM Learning Segment. Incomplete data in the delayed post-test 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 pre-test were different from the two who did not participate in the post-test, 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 despite the fact that both positively-worded and negatively-worded items were included. Thus, data provided by a total of 24 participants were used in this study.

Reliability for both questionnaires at each of the three time points was established through item analysis using Cronbach's alpha (1951). The STEM Attitudes Questionnaire included both positively-worded and negatively-worded items within the four components of *Affect*, *Cognitive Competence*, *Value*, and *Difficulty*. Thus, prior to data analysis, the negatively-worded items indicated with an asterisk* (Appendix D) were reverse-coded using SPSS. The initial reliability analysis for the attitudes factors revealed $r < 0.60$ for both Effort in the pre-test and Difficulty in the post-test. One Difficulty item was removed resulting in reliability coefficients that more closely compared to those reported by Schau (2003a). This item "Teaching integrated STEM is a method of instruction quickly learned by most people" focused more on the rate at which the participants could learn how to teach integrated STEM content rather than the difficulty

of teaching integrated STEM lessons. Upon removal of this item, the reliability for Effort still remained low, thus results associated with this factor should be interpreted with caution.

Table 4

Reliability Analysis for the STEM Attitudes Questionnaire (r)

Component	Time 1	Time 2	Time 3
Affect	.87	.84	.87
Cognitive Competence	.78	.81	.72
Value	.84	.70	.79
Difficulty	.69	.52^a	.71
Interest	.89	.92	.91
Effort	.48	.79	.74

Note: Reliability coefficients < .70 are in boldface.

^aBefore removal of the difficulty item, $r = .46$ for this component.

The reliability coefficients for the three factors within the STEM Confidence Questionnaire (Social, Personal, and Material) were all above .80 for the pre-, post-, and delayed post-tests.

Preliminary Quantitative Analysis

In order to inform the qualitative data collected in the Spring 2018 focus group, paired-samples t tests using both pre- and post-questionnaire data sets were conducted to determine if there were any overall statistically significant differences from pre-test to post-test in the participants' attitudes toward and confidence in teaching integrated STEM lessons during the Spring 2018 semester. The paired samples t tests were conducted using a two-tailed 95% confidence interval. Data analysis comparing the participants' attitudes towards teaching integrated STEM lessons before ($M = 5.07$) and after ($M = 5.28$) the

completion of the integrated mathematics and science methods of instruction courses approached significance, $p = .076$. Shown in Table 5, the findings also revealed a statistically significant difference ($p = .001$) in the participants' confidence in teaching integrated STEM lessons from the beginning ($M = 3.00$) to the end ($M = 3.37$) of the Tier 3 semester.

Table 5

Growth in attitudes toward and confidence in teaching integrated STEM content (N=24)

	Pre-test	Post-test	<i>t</i>	df	Sig.	Effect size
	<i>M (SD)</i>	<i>M (SD)</i>				
Attitudes	5.07 (0.66)	5.28 (0.64)	-1.855	23	$p = .076$	$r = .36$
Confidence	3.00 (0.57)	3.37 (0.41)	-3.655	23	$p = .001$	$r = .37$

This initial quantitative analysis provided the researcher with an opportunity to reflect upon the interview protocol and add probing and follow-up questions to the protocol to be used in the semi-structured focus group interviews. This quantitative analysis, coupled with the qualitative data analysis from the focus group interviews, further guided the creation of additional open-ended questions that were added to the delayed post-questionnaires. Results of the formal data analysis for the study are described for each research question according to the quantitative and qualitative data analysis.

Research Question 1

To answer research question 1, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their attitudes toward teaching integrated STEM

lessons?”, both quantitative and qualitative analyses were performed to synthesize and triangulate the data. Qualitative data collected in the focus group was followed by a second qualitative component including responses to additional open-ended questions added to the questionnaires during the final quantitative phase of the study. The qualitative findings were used to support and explain the quantitative findings.

Quantitative Analysis

Descriptive statistics, including measures of central tendency, were used to initially describe, summarize, and interpret the data through which trends in the changes of the participants’ attitudes toward teaching integrated STEM lessons over the two semesters were noted (Appendix O). Participants were asked to rate their level of agreement using a 7-point Likert-type response scale (Likert, 1967) (1 = *strongly disagree*, 2 = *disagree*, 3 = *somewhat disagree*, 4 = *neither agree nor disagree*, 5 = *somewhat agree*, 6 = *agree*, and 7 = *strongly agree*). Higher mean scores reflected more positive attitudes, and lower mean scores indicated less positive attitudes. The results of the analysis are provided in Table 6 according to the components of attitudes toward teaching integrated STEM lessons including *Affect* (feelings), *Cognitive Competence* (intellectual knowledge and skills), *Value* (usefulness, relevance, and worth in their personal and professional life), *Difficulty* (difficulty planning and teaching), *Interest* (individual interest), and *Effort* (amount of work expended), as well as the composite attitudes scores.

Table 6

STEM Attitudes Questionnaire Component Mean Analysis (N=24).

Component	Time 1	Time 2	Time 3
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
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)

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

Findings revealed positive changes in the participants' attitudes in each of the components except *Effort* over the two semesters. Preliminary data analysis comparing the participants' attitudes toward teaching integrated STEM lessons before ($M = 5.07$) and after ($M = 5.28$) the completion of the integrated mathematics and science methods of instruction courses approached significance, $p = .08$. However, while the data showed an overall positive change in the participants' attitudes over the two semesters, the scores from post- to delayed post-test decreased throughout the Tier 4 internship semester. The growth in the participants' attitudes toward teaching integrated STEM lessons over the two semesters is shown in Figure 3.

Figure 3. Composite Attitudes Growth

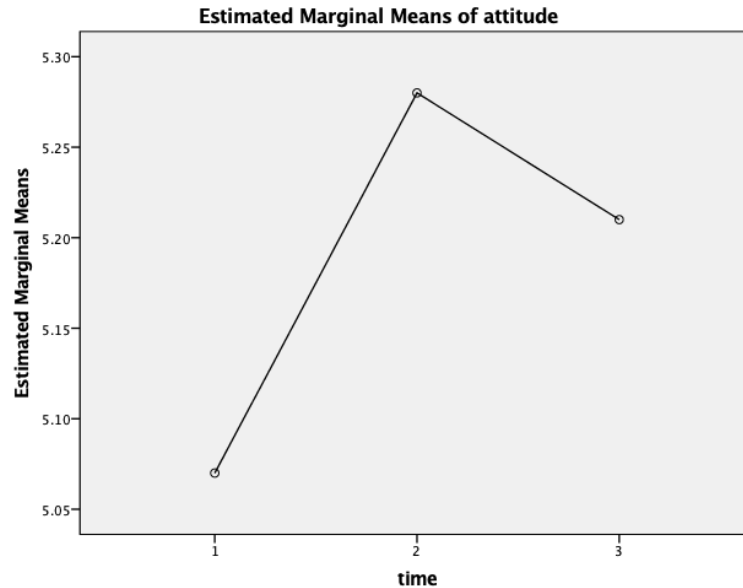


Figure 3. The three time points represent the composite attitudes pre-, post-, and delayed post-scores

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-test) for the scales associated with attitudes and confidence related to teaching integrated STEM lessons. The composite attitudes scores and overall confidence scores at each time point were used as the dependent variables and the time was the independent variable. Using Wilks' statistic, there was no statistically significant effect of time on elementary preservice teachers' attitudes towards or confidence in teaching integrated STEM lessons, $\Lambda = 0.68$, $F(4, 17) = 2.02$, $p = .14$. Thus, there was no statistically significant change in the participants' attitudes toward teaching integrated STEM lessons over the two semesters.

Qualitative Analysis

The constant comparative method (Glasser & Strauss, 1967) was implemented to analyze data obtained from the focus group interviews and the open-ended question responses. The constant comparative method utilizes multiple sources of evidence to code and categorize data, identifying patterns and emerging themes used to answer the research question. The audio file from the focus group interviews was transcribed by the researcher, and multiple cycles of coding were employed to identify emerging themes. Written responses to the open-ended question, “How has your attitude toward teaching integrated STEM lessons changed over the Tier 3 and 4 semesters?” were collected during the final quantitative phase. Adhering to the constant comparative method, the transcribed data and the written responses were analyzed using the qualitative software Quirkos (Turner, 2016). Analysis of the qualitative data from both sources contextualized and clarified the quantitative results.

A number of responses toward integrating STEM lessons reflected positive attitudes. Some responses spoke to the influence on student learning, such as, “My attitude towards STEM has improved greatly after witnessing the way it changes student learning.” Others reflected on how integration of STEM concepts seems work intensive, though worthwhile, with statements such as, “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!” A sense of excitement in actualizing STEM integration was also conveyed thematically 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.”

Information gathered from the focus group and open-ended question responses revealed that while the participants’ attitudes were heightened (38%), they were generally concerned about lack of resources, misalignment among mathematics and science content standards, lack of support and autonomy from the cooperating teacher, and an emphasis on preparation for and administration of statewide high-stakes tests. The participants were also concerned about the time demands of implementing and incorporating STEM instruction given the work load associated with other content areas. Sentiments such as, “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,” and “Not much has changed. There hasn’t been much opportunity to teach STEM lessons,” and that a few, “sometimes found it difficult to match the math and science together with the curriculum we had to teach that week,” were indicative of the concerns expressed.

Research Question 2

To answer research question 2, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?”, both quantitative and qualitative analyses were performed to synthesize and triangulate the data. Qualitative data collected in the focus group was followed by a second qualitative component asking additional open-ended questions on the

questionnaires during the final quantitative phase of the study. The qualitative findings from both sources were used to support and explain the quantitative findings.

Quantitative Analysis

Descriptive statistics, including measures of central tendency, were used to initially describe, summarize, and interpret the data through which possible trends were noted (Appendix O). Using a 1-4 Likert-type response scale (Likert, 1967), each participant was asked to rate his or her level of confidence in his or her abilities related to teaching integrated STEM lessons (1 = *cannot do at all*, 2 = *would have difficulty doing this*, 3 = *mostly confident that I can do this*, and 4 = *very confident that I can do this*). The results of this analysis are shown in Table 7 by the factors of confidence in teaching integrated STEM lessons including Social (beliefs of how others perceive or affect his or her ability), Personal (one’s own beliefs about his or her ability), and Material (constructs outside of one’s control).

Table 7

STEM Confidence Questionnaire Factor Mean Analysis (N=24)

Factor	Time 1	Time 2	Time 3
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
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)

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.

Findings revealed positive changes in the participants’ confidence in only the Social

factor over the two semesters. As reported in the preliminary analysis, findings revealed a statistically significant difference ($p = .001$) in the participants' confidence in teaching integrated STEM lessons from the beginning ($M = 3.00$) to the end ($M = 3.37$) of the integrated mathematics and science methods of instruction course. While the data showed a positive change in the participants' confidence over the two semesters, the overall confidence scores from post- to delayed post-test decreased throughout the Tier 4 internship semester. The growth in the participants' confidence in teaching integrated STEM lessons over the two semesters is shown in Figure 4. This was similar to the findings for overall attitudes scores.

Figure 4. Overall Confidence Growth

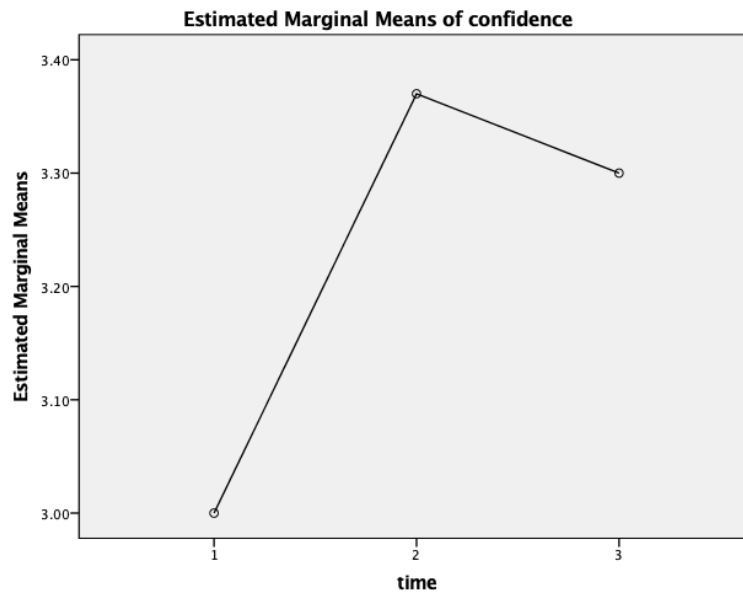


Figure 4. The three time points represent the overall confidence pre-, post-, and delayed post-scores.

A MANOVA with repeated measures was used to identify statistically significant main and interaction effects of time (pre-, post-, delayed post-test) for the scales associated with attitudes and confidence related to teaching integrated STEM lessons. The overall scores for attitudes and confidence at each time point were used as the dependent variables and time was the independent variable. Using Wilks' statistic, no statistically significant effect of time on elementary preservice teachers' attitudes towards or confidence in teaching integrated STEM lessons was found, $\Lambda = 0.68$, $F(4, 17) = 2.02$, $p = .14$. Thus, there was no statistically significant change in the participants' confidence in teaching integrated STEM lessons over the two semesters.

Qualitative Analysis

The constant comparative method (Glasser & Strauss, 1967) was implemented to analyze data obtained from the focus group interviews and the open-ended question responses. Rather than using just one source, the constant comparative method utilizes multiple sources of evidence to code and categorize data, identifying patterns and emerging themes in order to answer the research question. The audio recording of the focus group interviews was transcribed by the researcher and emerging themes were identified after multiple cycles of coding. Written responses to the open-ended question, "How has your confidence in teaching integrated STEM lessons changed over the Tier 3 and 4 semesters?" were collected during the final quantitative phase. In accord with the constant comparative method, the transcriptions and the written responses were analyzed using the qualitative software Quirkos (Turner, 2016). Analysis of the qualitative data from both sources complemented and explained the quantitative results.

Qualitative analysis of participant responses supported the quantitative results in that 83% reported increases in overall confidence to teach integrated STEM lessons throughout the Tier 3 and 4 semesters. 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 because I have observed and taught more STEM lessons”, and “Tier 3 offered great teaching tips and information regarding STEM but I didn’t feel as confident because we had minimal time in the classroom/field experience. Tier 4 has given me so many more opportunities to apply what I learned in Tier 3 and gain experience teaching and applying STEM.” Overall, participants’ increase in their confidence to teach integrated STEM lessons 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.”

Responses for confidence in teaching integrated STEM lessons were similar to those regarding attitudes toward teaching integrated STEM lessons. While 83% responded that their confidence increased over the two semesters, there were still participants who had concerns. One such concern that was prevalent focused on lack of resources. This concern included lack of supplies, technology, and class time to teach integrated lessons given the demands of state high-stakes testing. 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 elementary preservice teachers face in teaching integrated STEM lessons. Other responses such as, “I haven’t seen a lot of science being taught because it is put on the

back burner”, and “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 attitudes that existed among many elementary classroom teachers hindering the sustainability of preservice teachers implementing integrated STEM lessons in their future classrooms.

Research Question 3

To answer the third research question, “Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?”, two multiple regression analyses were conducted. This analysis was used to determine if the participants’ attitudes and confidence statistically significantly predicted their proficiency in planning integrated STEM lessons as measured by their rubric scores. The Integrated Science/Math Learning Segment Rubric was used to score each participants’ integrated STEM lesson plans which yielded a total score out of a possible 170 points ($M = 148.29$, $SD = 20.15$).

Using the data from the initial quantitative phase (pre-test), the results of the multiple regression analysis indicated that the participants’ attitudes and confidence prior to successful completion of the integrated mathematics and science methods of instruction courses did not statistically significantly predict their proficiency in planning integrated STEM lessons, $R^2 = 0.077$, $F(2, 21) = 0.88$, $p = .43$. Using the data from the intermediate quantitative phase (post-test), the results of the participants’ attitudes and confidence as predictors of proficiency in planning integrated STEM lessons approached

significance ($p = .08$). Thus, the participants' attitudes and confidence after successful completion of the integrated methods of instruction courses explained 21.4% of the variability in the lesson plan scores, $R^2 = 0.214$, $F(2, 21) = 2.862$, $p = .08$.

Summary

This chapter provided the quantitative and qualitative data analysis and results for this mixed-methods, longitudinal research study designed to investigate elementary preservice teachers' attitudes toward and confidence in teaching mathematics and science lessons in an integrated STEM framework. Further, this study examined the relationship between their attitudes and confidence and their proficiency in planning integrated STEM lessons. Data were collected from elementary preservice teachers enrolled in an elementary teacher education program at a large university in the southeast U.S. at three different time points throughout their final two semesters of the program.

Throughout the study, quantitative data pertaining to attitudes toward teaching integrated STEM lessons suggested no statistically significant change. Qualitative responses suggested improvement of attitudes over time. Still, some participants seemed increasingly discouraged due to barriers in teaching integrated STEM lessons. Change in confidence in teaching integrated STEM lessons revealed no statistical significance over the two semesters. However, through qualitative analysis most participants indicated increased confidence toward teaching integrated STEM lessons. Further, the attitudes and confidence of preservice teachers were not statistically significant predictors of their scores on the integrated STEM lessons. While no statistical significance was found in the repeated measures MANOVA or the multiple regression analyses, implications,

particularly of the qualitative discussion, as well as limitations and directions for future research are presented in Chapter 5.

CHAPTER V – DISCUSSION

The primary research goal of this study was to explore changes in elementary preservice teachers' attitudes and confidence with regard to teaching integrated STEM lessons, and the correlation of those constructs with their proficiency in planning integrated STEM lessons. This mixed-methods, sequential, explanatory design used qualitative data and subsequent analysis to provide an explanation of the pre-existing quantitative data analysis by exploring the elementary preservice teachers' perceptions of planning and teaching integrated STEM lessons in more depth.

The purpose of this mixed-methods 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, and the extent to which their attitudes and confidence correlated with their proficiency in planning integrated STEM lessons. This study was guided by the following research questions:

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

RQ1. ...to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?

RQ2. ...to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

RQ3. ...to what extent do their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?

Quantitative and qualitative data were collected from twenty-four elementary preservice teachers over the final two semesters of their K-6 Collaborative Teacher Education Program. Data were collected at three time points and included quantitative data from pre-, post-, and delayed post-questionnaires and the participants' scores on the learning segment rubric, and qualitative data from the focus group interviews and open-ended responses on the delayed post-questionnaires. Using IBM SPSS 23, descriptive and inferential statistics were calculated to answer the research questions. To answer both research questions 1 and 2, a repeated measures MANOVA was conducted using the dependent variables of composite attitudes scores and overall confidence scores and the independent variable of treatment with participation in the integrated mathematics and science methods of instruction courses. To answer research question 3, multiple regression analyses were conducted using independent variables of composite attitudes scores and overall confidence scores and the dependent variable of the Integrated Science /Math Learning Segment Rubric scores. Qualitative data from the focus group and responses to the open-ended questions were used to support, explain, and extend the quantitative results.

This final chapter is organized into four major sections. The first section discusses the key findings as they relate to each research question. The second section presents the implications for practice regarding teacher preparation and support of integrated STEM education. The third section defines the limitations of the study that may affect the interpretation of the results. Last, the fourth section provides recommendations for future research.

Key Findings and Discussion

Attitudes Toward Teaching Integrated STEM Lessons

Research Question #1: Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their attitudes toward teaching integrated STEM lessons?

The results from the repeated measures MANOVA indicated no statistically significant changes in the elementary preservice teachers' attitudes toward teaching integrated STEM lessons over the final two semesters of the teacher preparation program. The results of this study were consistent with those revealing no significant changes in preservice teacher attitudes toward integrated STEM education (Al Salami, Makela, & de Miranda, 2017; Berlin and White, 2010; Evans, 2015). Similar results were revealed by Tal, Dori, and Keiny (2001), who stated that one year is not enough time for a significant change in teacher attitudes.

Preliminary data analysis comparing the participants' attitudes toward teaching integrated STEM lessons from pre- ($M = 5.07$) to post-scores ($M = 5.28$) approached significance, $p = .08$. These results were consistent with previous findings that suggested that preservice teachers' attitudes toward STEM education were enhanced through engaging in authentic integrated STEM teaching experiences (Nadelson et al., 2013; Thibaut et al., 2018). The preliminary results were also supported by research that has shown elementary preservice teachers exhibited more positive attitudes toward mathematics and science after participating in inquiry-based methods of instruction courses (Ball, 1990; Jong & Hodges, 2013; Riegle-Crumb et al., 2015). The composite attitudes scores consisted of the subscales of *Affect*, *Cognitive Competence*, *Value*,

Difficulty, *Interest*, and *Effort*. There was an increase in each of the subscales except for *Effort*, which decreased by 1.11%.

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 ($M = 5.21$). Within the subscales of *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, $\Lambda = 0.67$, $F(4, 17) = 5.37$, $p = .01$. 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.

Potential barriers to the implementation of integrated STEM education in the elementary classroom were revealed including the difficulty (*Difficulty* subscale) of planning and implementing integrated STEM lessons. As revealed in related studies, the participants noted how they saw the positive impact on student learning (*Value* subscale), but also recognized the immense discipline and work (*Effort* subscale), it takes to plan and implement effective integrated mathematics and science lessons (Berlin & White, 2012; Koirala & Bowman, 2003). Challenges noted also included lack of resources, both monetary and time, lack of support from teachers and administrators, and lack of a coherent and rigorous curriculum essential for successful STEM education. A few participants experienced difficulty in planning integrated lessons as the mathematics and science content standards did not align based on the local school district's pacing guides.

Moore and Smith (2014) realized a scarcity of research-based integrated STEM curricula. Thus, supporting the need for the mathematics and science curriculum to be aligned and coherent to ensure STEM education is implemented in the classroom (NRC, 2011).

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.

Confidence in Teaching Integrated STEM Lessons

Research Question #2: Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do their experiences relate to their confidence in teaching integrated STEM lessons?

The results from the repeated measures MANOVA indicated no statistically significant changes in the elementary preservice teachers' confidence in teaching integrated STEM lessons over the final two semesters of the teacher preparation program. However, the preliminary analysis of overall pre- ($M = 3.00$) and overall post-scores ($M = 3.37$) on the STEM Confidence Questionnaire indicate a statistically significant change

in confidence in teaching integrated STEM lessons ($p = .001$). Throughout the integrated mathematics and science methods of instruction courses, the preservice teachers were afforded multiple opportunities to engage in STEM lessons, as well as plan and implement integrated STEM lessons, leading to increased self-efficacy and confidence in teaching integrated lessons. These results were supported by previous findings that suggested that embedding integrated mathematics and science teaching in the methods of instruction courses may lead to an increase in preservice teachers' self-efficacy in teaching meaningful STEM lessons in the classroom (Ball, 1990; Frykholm & Glasson, 2005; Furner & Kumar, 2007; Jong & Hodges, 2013; Riegle-Crumb et al., 2015; Rinke et al., 2016).

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.

However, while the data indicated an overall positive change in the participants' confidence over the two semesters, overall confidence decreased slightly at the completion of the internship semester ($M = 3.30$). While the elementary preservice teachers reported fairly 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 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). Furthermore, due to state high-stakes testing, the participants were not encouraged to teach integrated lessons as the tests were designed with mathematics and science segregated into content-specific knowledge (Moore & Smith, 2014; NAE & NRC, 2014; Schleigh et al., 2011). To face the challenges of integrated STEM education, Berlin and White (2012) suggested that attention and awareness of these components within teacher preparation programs may enhance the preservice teachers' attitudes and confidence related to the practicality of implementing integrated STEM lessons in their future classrooms.

Relationship Between Affective Domain and Proficiency in Planning Integrated STEM Lessons

Research Question #3: Among elementary preservice teachers participating in integrated mathematics and science methods of instruction courses, to what extent do

their attitudes and confidence with regard to teaching integrated STEM lessons correlate with their proficiency in planning integrated STEM lessons?

In order to answer research question three, two multiple regression analyses were conducted to examine how elementary preservice teachers' attitudes and confidence (independent variables) related to their proficiency in planning integrated STEM lessons (dependent variable). The first multiple regression analysis included the pre-test composite attitudes scores and overall confidence scores as the independent variables and the Integrated Science/Math Rubric scores as the dependent variable. The results of the multiple regression analysis indicated that the participants' attitudes and confidence prior to successful completion of the integrated mathematics and science methods of instruction courses did not statistically significantly predict their proficiency in planning integrated STEM lessons.

The second multiple regression analysis included the post-test composite attitudes scores and overall confidence scores as the independent variables and the Integrated Science/Math Rubric scores as the dependent variable. The results of this multiple regression indicated that the participants' attitudes and confidence as predictors of their proficiency in planning integrated STEM lessons approached significance ($p = .08$).

Although the findings from the multiple regression analyses were not statistically significant, responses to the open-ended questions provided an explanation of the quantitative findings. Furthermore, using standard power ($\beta = 0.80$), alpha level of 0.05, and a medium effect size ($f^2 = .15$), a power analysis for a multiple regression analysis with two predictor variables yields a recommended sample size of 68 (Faul, Erdfelder, Buchner, & Lang, 2013). As the number of participants in this study was 24, the study

lacked statistical power. Increasing the number of participants who would likely provide similar data may have resulted in statistically significant results.

According to Maher et al. (2013), preservice teachers' attitudes and beliefs form before entering a teacher preparation program based on prior K-12 experiences. Research has also shown that participation in inquiry-based content and methods of instruction coursework leads to more positive attitudes toward mathematics and science and an increase in confidence to teach integrated mathematics and science lessons (Corlu et al., 2015; Jong & Hodges, 2013; Riegler-Crumb et al., 2015). As noted by several participants, experience in their elementary field placement classroom gave them greater confidence in their skills of planning and teaching integrated STEM lessons. Having the opportunity to observe and co-teach multiple integrated STEM lessons led to greater confidence as well. One participant responded, "Tier 3 offered great teaching tips and information regarding STEM, but I didn't feel as confident because we had minimal time in the classroom for field experience. Tier 4 has given me so many more opportunities to apply what I learned in Tier 3 and gain experience of pros and cons of my teaching and applying STEM."

These findings supported research that suggested a need for teacher preparation programs to include STEM education in their coursework and to also provide elementary school field placements with teachers who are dedicated to integrated STEM education. In such classrooms where integrated STEM lessons are prevalent, preservice teachers 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 (Barcelona, 2014; Kurup et al., 2017; Radloff & Guzey, 2017).

Implications for Practice

Based on the findings of this study, several implications for practice have been identified. Several key issues have been highlighted that warrant serious consideration by the numerous stakeholders of STEM education including elementary preservice teachers, elementary teacher preparation program faculty, elementary in-service teachers, and district leaders surrounding successful preparation of teachers as implementers of integrated STEM education in the K-6 classroom. Recommendations for elementary teacher preparation programs, as well as those for elementary schools and district-level programs, which could enhance the intentional preparation and support of elementary teachers implementing integrated STEM education are presented. If these recommendations were to be followed, STEM educational goals in the U.S. may be advanced.

Elementary Teacher Preparation Programs

The results of this study may have important implications for improving teacher preparation programs to better prepare future teachers to teach integrated STEM lessons with regard to developing preservice teachers' STEM pedagogical content knowledge, increasing preservice teachers' STEM content knowledge, and providing preservice teachers with meaningful field experiences. According to Kurup et al. (2017), future teachers need more exposure to specialization in STEM practices and procedures including integrated teaching. Reorganizing teacher preparation programs to include integrated STEM education could provide preservice teachers with opportunities to improve both their STEM content knowledge and STEM pedagogical content knowledge

This also includes offering preservice teachers' opportunities to observe good STEM practices in their field placements (Kurt & Pehlivan, 2013; Kurup et al., 2017).

Developing Preservice Teachers' STEM Pedagogical Content Knowledge

The results of this study indicated that providing preservice teachers with meaningful experiences with participating in, planning, and implementing integrated mathematics and science lessons can positively influence preservice teachers' attitudes toward and confidence in implementing STEM education in the elementary classroom. Thus, the researcher recommends that an integrated STEM methods of instruction course be taught in addition to elementary mathematics and science methods of instruction courses already in place. This recommendation is supported by Rinke et al. (2016) who suggested that the traditional methods of instruction courses be revised to include explicit STEM preparation with integrated STEM methods.

The integrated mathematics and science methods of instruction courses described in this study modeled how to collaborate as teachers and how to make connections between content areas in order to engage students in integrated STEM learning. Experiencing the co-teaching model in the integrated methods of instruction courses allowed elementary preservice teachers to see the value in co-planning and collaborating with colleagues. As found in a similar study (Zhou, Kim, & Kerekes, 2011), this faculty collaboration motivates future teachers to implement collaborative teaching in the elementary schools. This collaboration provided a holistic view of knowledge and eliminated the disconnection between mathematics and science. Consistently modeling integrated mathematics and science lessons played an integral part of the preservice teachers' knowledge of planning integrated STEM lessons. As noted by several

participants, even when there was not a specific lesson being modeled, the faculty continuously suggested ways that the other discipline (mathematics or science) could be integrated, providing the preservice teachers with multiple examples of what authentic integration looks like in the elementary classroom.

The researcher also recommends that elementary preservice teachers have multiple opportunities to plan integrated mathematics and science lessons while receiving feedback from peers and faculty. Since preservice teachers typically have no experience planning integrated mathematics and science lessons prior to the methods of instruction courses, the researcher suggests that they first have the opportunity to plan an integrated STEM lesson in teams. This would allow preservice teachers time to research the mathematics and science content standards together and discover how to meaningfully combine the standards into an authentic learning experience for the students. Guided by the mathematical practices and the science and engineering practices, the participants collaboratively developed an integrated lesson using peer review and faculty feedback and presented their lessons to their peers and shared their ideas. This team lesson experience proved to be very meaningful and helpful as the preservice teachers began developing their individual lessons, as evidenced by comments such as “the team lesson plan helped me out tremendously when doing my individual,” and, “my strengths came out, but then I could also see what my teammates were doing. I could see how they were thinking which helped with my individual plan.”

Furthermore, preservice teachers should individually plan and implement integrated STEM lessons in their elementary school field placements. Similar to the requirements for the team lesson plan, the preservice teachers researched the mathematics

and science content standards and planned authentic learning experiences for their K-6 students that was guided by the mathematical practices and the science and engineering practices. Feedback provided by peers and the faculty members led to increased knowledge of and confidence in planning integrated STEM lessons as reflected in comments such as, “I just learned so much, like y’all consistently giving us feedback.” The co-teaching model of the integrated mathematics and science methods of instruction courses provided the structure necessary for collaborative planning and consistent feedback from the methods of instruction faculty.

Findings from this study also revealed barriers and challenges of planning and teaching integrated STEM lessons in the classroom. Thus the researcher further recommends explicitly addressing these difficulties and barriers within the methods of instruction courses, as also suggested by Berlin and White (2012). The participants in this study experienced frustration with time restraints, material resources, and lack of support from their cooperating teachers and school administration. Addressing these issues while planning lessons may increase their confidence in teaching the integrated lessons as ways to overcome these obstacles are realized. Moreover, these barriers and challenges to K-6 content integration across all disciplines should be explicitly outlined in all methods of instruction courses, not just mathematics and science.

Increasing Preservice Teachers’ STEM Content Knowledge

Results from this study supported existing research (Kurt & Pehlivan, 2013; Kurup et al., 2017) related to providing preservice teachers with a solid foundation of content in the STEM disciplines. Implications of the study include a recommendation to increase the quantity and quality of the STEM content coursework required in elementary

teacher preparation programs. For the participants in this study, program requirements for STEM content coursework included 12 hours of mathematics coursework and 12 hours of science coursework. Although there were two K-6 mathematics content courses offered at the university, only Mathematics for Elementary Teachers I was required. This course did not address the K-6 domains of Measurement and Data and Geometry (Alabama State Department of Education, 2016). Furthermore, there were no K-6 science content courses offered at the university in which the study was conducted. The science content coursework requirements included 12 hours of any of the “hard” sciences, with limited opportunity to engage in the scientific and engineering practices. Thus, the researcher recommends increasing the number of K-6 mathematics and science content courses, including two K-6 content courses in each discipline, with explicit connections between the subjects being made within the courses. This will lead to better prepared preservice teachers who are able to understand and interpret the content and practice standards, increasing their ability to integrate the mathematics and science standards and create authentic learning experiences for their future students.

Moseley & Utley (2006) suggested that preservice teachers who enter their teaching careers with strong self-efficacy in mathematics and science will be more apt to enter the classroom better prepared and more likely to remain in the teaching field for a longer amount of time. However, a deeper science and mathematics content knowledge is not the only factor in increasing preservice teachers’ confidence and self-efficacy. Thus, content courses should enhance the preservice teachers’ pedagogical content knowledge in mathematics and science as well. Park and Oliver (2008) found that student misconceptions and misunderstandings are more easily identified when the teacher has a

deeper understanding of the content being taught. Thus, preservice teachers need opportunities to analyze student work through which possible understandings, misunderstandings, misconceptions, and prior knowledge and skills needed to master the content in both mathematics and science may be revealed. Both content and pedagogy coursework included in teacher preparation programs should provide opportunities for preservice teachers to develop a deeper understanding of the mathematics and science content standards and the interconnections between the subjects to effectively implement STEM education in their future classrooms.

The researcher also recommends building strong relationships between education and STEM faculty to develop STEM faculty mentors. Maher et al. (2013) concluded that by using STEM faculty as mentors, preservice teachers' knowledge and understanding of teaching STEM subjects for conceptual understanding can be further developed. STEM faculty mentors also positively impacted preservice teachers' confidence in teaching STEM lessons (Maher et al., 2013). STEM faculty members could serve as mentors to preservice teachers to help build their knowledge of STEM content which could subsequently impact their effectiveness in planning STEM lessons. Through a meaningful collaboration between education and STEM faculty, implementing effective STEM education in the elementary school and aligning content standards and practices necessary to plan authentic integrated STEM lessons could be discussed on a regular basis. The education faculty could also collaborate with STEM faculty to improve elementary mathematics and science content courses through increased rigor, focusing on mathematical and scientific reasoning and understanding.

Providing Preservice Teachers' Meaningful Field Experiences

Implications from this study directly relate to the preservice teachers' elementary school field placements. Placements with teachers that modeled integrated STEM lessons and collaboratively planned STEM lessons with the preservice teachers led to enhanced attitudes toward and greater confidence in teaching STEM lessons indicated by responses such as, "the cooperating teachers I was fortunate to be with were wonderful resources for me to learn from," and "as I learn and gain more experience, I become more excited and eager to apply my knowledge to create (integrated mathematics and science) lessons for my students." Field placements played a big role in determining the extent to which integrated STEM lessons were planned and implemented. Thus, a strong partnership with schools, placing preservice teachers in classrooms where integrated STEM lessons are prevalent, is vital to the development of elementary preservice teachers' positive attitudes toward and confidence in implementing STEM education.

Assigning preservice teachers to classrooms with cooperating teachers who provide support, instructional strategies, and resources (both time and material) is necessary in order to assist preservice teachers in making integrated instruction time more efficient and less difficult to manage (Barcelona, 2014; Kurup et al., 2017; Radloff & Guzey, 2017; Schleigh et al., 2011). The value of STEM education was recognized by the participants through responses such as, "Doing it integrated, they (the elementary students) see how it makes the real life connection and purpose. It changes their attitudes completely," and "Deeper conceptual understanding. Like legitimately, that is what happens." However, the lack of resources and support from cooperating teachers were obstacles and barriers noted by the participants with comments such as, "Time is a big

issue with implementing STEM lessons,” and “No access to supplies.” Thus, preservice teachers need explicit educational experiences within their elementary field placements to enhance their attitudes toward STEM education and to provide insights concerning management and acquisition of resources needed for implementing STEM teaching. Hence, on-going collaboration between elementary preservice teachers, cooperating teachers, education faculty, STEM faculty, and peers, when developing STEM lessons and reflecting on teaching practices should be an integral component of teacher preparation programs.

Elementary Schools and District-Level Programs

The results of this study also have important implications at the school and district levels in terms of how to better prepare and support future elementary teachers to teach integrated STEM lessons including the provision of integrated STEM education professional development for teachers and the use of research-based integrated STEM curricula in the elementary school. According to Kurup et al. (2017), future teachers need more exposure to better leadership and more professional development that includes STEM practices and procedures for integrated instruction.

Engaging Teachers in Integrated STEM Education Professional Development

Findings from this study indicated a need for continued professional development that may potentially influence preservice teachers’ attitudes towards and confidence in teaching integrated STEM lessons. This continued professional development could potentially promote further STEM education in the elementary classroom. As noted by several participants, additional time and research for planning integrated STEM lessons would increase their confidence and proficiency in planning integrated STEM lessons.

This is supported by research (Nadelson et al., 2013) that suggested that engaging teachers in professional development at various levels of their teaching careers could have a positive impact on teacher practice. As the lack of content knowledge can negatively impact a teacher's efficacy, confidence, and comfort in teaching STEM content, the focus of STEM professional development should be on increasing STEM content knowledge and teacher perceptions of STEM teaching and learning, which could subsequently influence their efficacy, confidence, and comfort with teaching STEM content. Also supporting research (Nadelson et al., 2013), the findings of this study further suggested that this on-going professional development may also need to provide teachers with opportunities to explore how they may effectively implement STEM teaching into their classrooms.

The professional development should also include developing a clear definition of integration which is necessary for teachers to authentically integrate STEM content for more meaningful learning. According to the literature, in order for teachers to successfully implement STEM education and provide meaningful real-life learning experiences for their students, they themselves must first possess a clear understanding of STEM education (Bybee, 2013; Honey et al., 2014). Thus, professional development that includes an operational definition of integration, as well as effective strategies for teaching and learning mathematics and science content will lead to teachers implementing integrated practices that they understand and value. This professional development must also be embedded in teacher education programs so that future teachers are confident and prepared to teach mathematics and science integrated lessons in a STEM framework.

Implementing Research-Based Integrated STEM Curricula

The findings from this study also have important implications for district-level curriculum specialists surrounding ways to design rigorous STEM curricula that align mathematics and science content standards in a meaningful way to allow for more authentic integration. As the participants of this study were planning and implementing their integrated STEM lessons, barriers were identified through comments such as, “Standards did not align for both mathematics and science to produce a STEM lesson.” With no integrated STEM curriculum in place, as well as alignment issues between mathematics and science standards, the participants expressed concerns that K-6 students were not learning the content from either discipline. For example, they worried that the K-6 students may not understand the science concepts if the mathematics was “holding them back,” and “(the students) missing a whole lot more than they would have had I taught it separately.” As there are limited sources of good curricular examples of STEM integration that teachers can follow (Roehrig, Moore, Wang, & Park, 2012), the researcher recommends that curriculum specialists work to align the mathematics and science content standards in meaningful ways to provide the foundation on which STEM lessons can be developed.

Limitations of the Study

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.

Recommendations for Future Research

The purpose of this study was to add to the research in preparing teachers to teach STEM lessons in the elementary classroom. The current study examined the impact of participation in integrated mathematics and science methods of instruction courses on elementary preservice teachers' attitudes toward, confidence in, and proficiency in planning integrated STEM lessons. Because of the scarcity of research surrounding teacher preparation in STEM education, further studies are warranted to add to the existing body of research.

Although not investigated in this study, research should be conducted that explores the relationship between the attitudes towards STEM education of the preservice teachers and those of the cooperating teachers with whom they are placed. Results of this research could lead to more meaningful field experience placements for the elementary preservice teachers. Field placements in classrooms with experienced teachers that value and implement integrated STEM lessons may provide preservice teachers more opportunities to plan and implement effective STEM integrated lessons. The mentoring and support of such cooperating teachers may lead to heightened attitudes toward STEM education of the preservice teachers, which may increase their intention to teach integrated STEM lessons in their future classrooms.

Additionally, research on what the actual content of a STEM methods of instruction course should be is needed. Through this research appropriate textbooks could be identified, as well as other STEM resources that should be included in such methods of instruction courses. Results of this research could be used by teacher preparation programs to assist them with program course additions and possible redesign.

Summary

Research (Epstein & Miller, 2011; PCAST, 2010) has shown that the implementation of integrated STEM education at all levels prepares student for the global economy of the 21st-century. Integrated approaches pique student interests in and motivation for learning STEM subjects, which will hopefully lead to more students choosing STEM careers. “The lesson for us as educators is to realize that school subjects need to connect and not be taught in isolation from each other. Students must be able to transfer all learning across curricular areas and make connections that can increase levels of academic achievements” (Barcelona, 2014, p. 865).

These connections need to also be made at the preservice level in order to better prepare future teachers to teach integrated STEM lessons. Participation in integrated mathematics and science methods of instruction courses may afford preservice teachers the opportunities to experience, plan, and implement authentic integrated STEM lessons, building their confidence and enhancing their attitudes toward STEM education. Field placements for preservice teachers should also include classrooms where teachers are committed to curriculum integration in the STEM subjects. Future teachers need to develop the necessary skills, attitudes, and confidence to incorporate mathematics and science in an integrated STEM framework. Thus, adequate preparation for preservice teachers to teach integrated STEM content and implement practices of STEM fields as part of elementary teacher preparation programs is imperative, so that their future students are equipped with 21st-century skills.

APPENDIX A – IRB Approval Letter



INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: CH2-17072507
PROJECT TITLE: The Impact of Integrated Mathematics and Science Methods Course on Elementary Preservice Teachers' Attitudes and Confidence in Integrating Mathematics and Science in a STEM Framework
PROJECT TYPE: Change #2 to a Previously Approved Project
RESEARCHER(S): Kelly Byrd
COLLEGE/DIVISION: College of Arts and Sciences
DEPARTMENT: Center for Science and Mathematics Education
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Exempt Review Approval
PERIOD OF APPROVAL: 08/07/2018 to 08/06/2019
Edward L. Goshorn, Ph.D.
Institutional Review Board

INSTITUTIONAL REVIEW BOARD
LONG FORM CONSENT

LONG FORM CONSENT PROCEDURES	
<p>This completed document must be signed by each consenting research participant.</p> <ul style="list-style-type: none"> The Project Information and Research Description sections of this form should be completed by the Principal Investigator before submitting this form for IRB approval. Signed copies of the long form consent should be provided to all participants. 	
<small>Last Edited August 28th, 2014</small>	

Today's date: 1.08.17		
PROJECT INFORMATION		
Project Title: The Impact of Integrated Mathematics and Science Methods Courses on Elementary Preservice Teachers' Attitudes and Confidence in Integrating Mathematics and Science in a STEM Framework		
Principal Investigator: Kelly O. Byrd	Phone: 251-753-2440	Email: kelly.byrd@usm.edu
College:	Department: Science and Math Education	
RESEARCH DESCRIPTION		
<p>1. Purpose:</p> <p>The main purpose of this research study is to provide data for faculty to further refine and implement newly developed integrated mathematics and science methods courses to better prepare preservice teachers to teach STEM lessons. The results of this research study will provide insight on the pre-service teachers' ability to plan and implement effective integrated mathematics and science lessons, attitudes towards mathematics and science integration, and confidence in planning and implementing mathematics and science integrated lessons. The results may also be used as rationale for future grants that may be used to redesign a university classroom as a STEM lab.</p> <p>The goals of this project are 1) to engage elementary pre-service teachers in the planning, implementation, and assessment of effective integrated STEM lessons addressing the mathematics and science pedagogical content knowledge, 2) prepare preservice teachers by addressing pedagogical content knowledge in an integrated format, and 3) positively impact elementary pre-service teachers' attitudes towards and confidence in teaching STEM lessons.</p>		
<p>2. Description of Study:</p> <p>The participants in this study are 34 Senior-level elementary preservice teachers enrolled in mathematics and science methods courses in a K-6 Teacher Education program prior to internship. All students will be invited to participate in two on-line pre- and post- surveys. At the conclusion of the course, participants will be notified by email, as well as in-class announcement, of the opportunity to participate in a focus group. In a classroom on campus, the focus group participants will meet with the researcher. Video recordings will be used to record each participant's verbal responses and body language. Recordings will be transcribed and analyzed for important themes relating to knowledge of and perceived attitudes toward and confidence in teaching integrated mathematics and science.</p>		
<p>3. Benefits:</p> <p>While participants will not receive direct benefits, it is hoped that this research will contribute to the literature and practice of preparing elementary teachers to teach mathematics and science in an integrated STEM</p>		

framework.

4. Risks:

none

5. Confidentiality:

Videos of interviews will only be reviewed by the researcher in order to transcribe and analyze for the research. Data will be stored for three years, then videos will be deleted and physical data shredded.

6. Alternative Procedures:

N/A

7. Participant's Assurance:

This project has been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations.

Any questions or concerns about rights as a research participant should be directed to the Chair of the IRB at 601-266-5997. Participation in this project is completely voluntary, and participants may withdraw from this study at any time without penalty, prejudice, or loss of benefits.

Any questions about the research should be directed to the Principal Investigator using the contact information provided in Project Information Section above.

CONSENT TO PARTICIPATE IN RESEARCH

Participant's Name: _____

Consent is hereby given to participate in this research project. All procedures and/or investigations to be followed and their purpose, including any experimental procedures, were explained to me. Information was given about all benefits, risks, inconveniences, or discomforts that might be expected.

The opportunity to ask questions regarding the research and procedures was given. Participation in the project is completely voluntary, and participants may withdraw at any time without penalty, prejudice, or loss of benefits. All personal information is strictly confidential, and no names will be disclosed. Any new information that develops during the project will be provided if that information may affect the willingness to continue participation in the project.

Questions concerning the research, at any time during or after the project, should be directed to the Principal Investigator with the contact information provided above. This project and this consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-5997.

Include the following information only if applicable. Otherwise delete this entire paragraph before submitting for IRB approval: The University of Southern Mississippi has no mechanism to provide compensation for participants who may incur injuries as a result of participation in research projects. However, efforts will be made to make available the facilities and professional skills at the University. Participants may incur charges as a result of treatment related to research injuries. Information regarding treatment or the absence of treatment has been given above.

_____ Research Participant	_____ Person Explaining the Study
_____ Date	_____ Date

APPENDIX B – IRB Approvals for Pilot Study

irb@southalabama.edu



TELEPHONE: (251) 460-6308
CSAB 138 · MOBILE, AL. 36688-0002

INSTITUTIONAL REVIEW BOARD
April 13, 2017

Principal Investigator: Elizabeth Allison
IRB # and Title: IRB PROTOCOL: 16-435
[972713-2] Scholarship of Teaching and Learning: STEM and Co-Teaching in
Elementary Science and Mathematics Methods Courses
Status: APPROVED Review Type: Expedited Review
Approval Date: March 10, 2017 Submission Type: New Project
Initial Approval: March 10, 2017 Expiration Date: March 9, 2018
Review Category: Category: 45 CFR 46.110 (6):
Collection of data from voice, video, digital, or image recordings made for
research purposes.

This panel, operating under the authority of the DHHS Office for Human Research and Protection, assurance number FWA 00001602, and IRB Database #00000286, has reviewed the submitted materials for the following:

1. *Protection of the rights and the welfare of human subjects involved.*
2. *The methods used to secure and the appropriateness of informed consent.*
3. *The risk and potential benefits to the subject.*

The regulations require that the investigator not initiate any changes in the research without prior IRB approval, except where necessary to eliminate immediate hazards to the human subjects, and that **all problems involving risks and adverse events be reported to the IRB immediately!**

Subsequent supporting documents that have been approved will be stamped with an IRB approval and expiration date (if applicable) on every page. Copies of the supporting documents must be utilized with the current IRB approval stamp unless consent has been waived.

Notes:



INSTITUTIONAL REVIEW BOARD

April 20, 2018

Principal Investigator: Elizabeth Allison
IRB # and Title: IRB PROTOCOL: 16-435
[972713-3] Scholarship of Teaching and Learning: STEM and Co-Teaching in
Elementary Science and Mathematics Methods Courses
Status: APPROVED Review Type: Expedited Review
Approval Date: April 18, 2018 Submission Type: Continuing Review
Initial Approval: March 10, 2017 Expiration Date: April 17, 2019
Review Category: Category: 45 CFR 46.110 (6):
Collection of data from voice, video, digital, or image recordings made for
research purposes.

This panel, operating under the authority of the DHHS Office for Human Research and Protection, assurance number FWA 00001602, and IRB Database #00000286, has reviewed the submitted materials for the following:

1. *Protection of the rights and the welfare of human subjects involved.*
2. *The methods used to secure and the appropriateness of informed consent.*
3. *The risk and potential benefits to the subject.*

The regulations require that the investigator not initiate any changes in the research without prior IRB approval, except where necessary to eliminate immediate hazards to the human subjects, and that **all problems involving risks and adverse events be reported to the IRB immediately!**

Subsequent supporting documents that have been approved will be stamped with an IRB approval and expiration date (if applicable) on every page. Copies of the supporting documents must be utilized with the current IRB approval stamp unless consent has been waived.

Notes:

Expedited review and approval for the continuation of research granted for one additional year where the research remains ongoing and open to additional enrollment; amendment submitted to include an additional questionnaire and lesson plan rubric



INSTITUTIONAL REVIEW BOARD

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Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

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- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: CH17072507

PROJECT TITLE: The Impact of Integrated Mathematics and Science Methods Course on Elementary Preservice Teachers' Attitudes and Confidence in Integrating Mathematics and Science in a STEM Framework

PROJECT TYPE: Change to a Previously Approved Project

RESEARCHER(S): Kelly Byrd

COLLEGE/DIVISION: College of Science and Technology

DEPARTMENT: Center for Science and Mathematics Education

FUNDING AGENCY/SPONSOR: N/A

IRB COMMITTEE ACTION: Exempt Review Approval

PERIOD OF APPROVAL: 08/07/2017 to 08/06/2018

Lawrence A. Hosman, Ph.D.

Institutional Review Board

APPENDIX C – Permission to Modify SATS-36 Instrument

From: Candace cschau@comcast.net
Subject: RE: Register
Date: August 13, 2017 at 2:01 PM
To: Kelly Byrd kbyrd@southalabama.edu

Hi, Kelly,

Yes, you can use it. I look forward to hearing about your results.

Candace

Candace Schau, PhD
CS Consultants, LLC
505-301-1310
www.evaluationandstatistics.com

-----Original Message-----

From: Kelly Byrd [mailto:kbyrd@southalabama.edu]
Sent: Saturday, August 12, 2017 4:11 PM
To: Candace
Subject: Re: Register

Candace,


I do not have funding, as I am a graduate student, but would appreciate using the survey for one year. I plan to collect data this fall and spring semester. I have made revisions to the SAT survey to measure attitude toward teaching mathematics and science in an integrated STEM framework. I did eliminate question one on the SAT-36. This is a course requirement, and we could not get the question to make sense or fit. I am attaching the revised survey in hopes that you will still allow me to use it. I am looking forward to the results, and will send you copies of all research published or presented on the results.

Thank you again so very much,
Kelly Byrd

Candace

RE: Register

To: kbyrd@southalabama.edu

 New contact info found in this email: Candace cschau@comcast.net

Dear Kelly,

Thanks for your interest in using my SATS. If you have funding, I charge a small licensing fee for use of the SATS. If you don't have funding, I always hope that you can find some money within your institution to help with our research. If not, then you can use the SATS free for one year. At the end of your year, contact me again if you would like to continue to use my measure. I do require that you send/e-mail me a copy of anything you write that includes information about your use of the SATS. Also, when you use the SATS or write about it, you need to indicate that I hold the copyright.

Please send me a copy of the revised SATS for my files when you finish with it.

I encourage to use all of the items that comprise each attitude component on the SATS (and I encourage you to use the other items too). If you want to omit or change any of those items, you will need to contact me again. Scores from the SATS attitude components using all of the items have been carefully validated on postsecondary students with a wide variety of characteristics taking statistics in a large number of institutions both within and outside of the US. That validation work does not apply to altered items, individual items or to incomplete components. Also, it is not appropriate to use a "total" attitude score. You are welcome to change the demographic and academic items to fit your circumstances.

You can find references and scoring information on my web site. I have attached the pretest and posttest versions of the SATS.

I wish you the best of luck with your work.

Candace

PS - Your study sounds really interesting. I will be interested in your results. I would encourage you to consider using the SATS-36 items since the two added components are important. I've attached both versions of the SATS.

Candace Schau, PhD
CS Consultants, LLC
505-301-1310
www.evaluationandstatistics.com

-----Original Message-----

From: Trellix Mailer [<mailto:webmaster@yourhostingaccount.com>]

Sent: Friday, July 14, 2017 6:59 AM

To: cschau@comcast.net

Subject: Register

firstname: Kelly

lastname: Byrd

company: University of South Alabama

address1: 3100 UCOM

city: Mobile

state: Alabama

zip: 36688

email: kbyrd@southalabama.edu

Information: I would like to request permission to use/adapt this survey to measure elementary preservice teachers' attitudes towards teaching mathematics and science in an integrated STEM framework. My colleagues and I have recently implemented a co-teaching model for teaching mathematics and science methods courses to prepare K-6 teachers to integrate STEM teaching in the classroom. This survey really focuses on the four components of attitude in which we are interested.

Thank you for your consideration.



SAT 28 items &
scoring...08.doc



CS final web
SATS p...10.doc



CS final web
SATS p...10.doc

APPENDIX D – STEM Attitudes Questionnaire

Directions: The questions below are designed to identify your attitudes about statistics. The item scale has 7 possible responses, ranging from 1 (strongly disagree) through 4 (neither disagree nor agree) to 7 (strongly agree). Please read each question. From the 7-point scale, carefully mark the one response that most clearly represents your agreement with that statement. Use the entire 7-point scale to indicate your degree of agreement or disagreement with our items. Try not to think too deeply about each response. Record your answer and move quickly to the next item.

1. I plan to teach all of my integrated mathematics and science methods lesson plan requirements.
2. I plan to persevere in planning and teaching integrated mathematics and science lessons.
3. I will like teaching mathematics and science in an integrated STEM framework.
4. *I will feel insecure when I have to teach mathematics and science in an integrated STEM framework.
5. *I will have trouble understanding how to integrate mathematics and science because of how I think.
6. Integrated mathematics and science lessons are easy to plan and teach.
7. *Teaching mathematics and science in an integrated STEM framework is not as beneficial as teaching mathematics and science independent of each other.
8. *Integrating mathematics and science in a STEM framework is complicated.
9. Teaching mathematics and science lessons in an integrated STEM framework should be a required part of my professional teacher preparation.
10. *I will struggle when trying to plan and teach lessons that integrate mathematics and science.
11. I am interested in being able to plan and teach lessons that integrate mathematics and science.
12. *Learning mathematics and science in an integrated STEM framework is not useful to the typical professional.
13. I plan to work hard planning and teaching mathematics and science in an integrated STEM framework.
14. *I will get frustrated planning and teaching mathematics and science in an integrated STEM framework.
15. *Integrating mathematics and science in a STEM framework is not applicable in my life outside of teaching
16. I use integrated mathematics and science in my everyday life.
17. *Planning and teaching mathematics and science in an integrated STEM framework will be stressful for me
18. I will enjoy teaching mathematics and science in an integrated STEM framework.
19. I am interested in teaching mathematics and science in an integrated STEM framework.
20. *Integrated STEM is rarely presented in everyday life.

21. I am interested in understanding how to plan and teach mathematics and science in an integrated STEM framework.
22. *Planning and teaching mathematics and science in an integrated STEM framework requires a great deal of discipline.
23. *I will have no need for teaching mathematics and science in an integrated STEM framework when I become a teacher.
24. *I will make a lot of math and science errors in planning and teaching integrated STEM lessons.
25. I plan to attend every mathematics and science methods class sessions.
26. *I am scared to teach mathematics and science in an integrated STEM framework.
27. I am interested in learning how to plan and teach mathematics and science lessons in an integrated STEM framework.
28. *Planning and teaching mathematics and science in an integrated STEM framework involves immense work.
29. I am capable of learning how to teach mathematics and science in an integrated STEM framework.
30. I will understand how to teach mathematics and science in an integrated STEM framework.
31. *Teaching mathematics and science in an integrated STEM framework is irrelevant in my life as a teacher.
32. *Teaching mathematics and science in an integrated STEM framework is highly procedural.
33. *I will find it difficult to understand how to teach mathematics and science in an integrated STEM framework.
34. *Most people have to learn a new way of thinking to teach mathematics and science in an integrated STEM framework.

None at all - A Moderate Amount - A Great Deal

35. What is your previous experience with learning mathematics and science in an integrated STEM framework?
36. What is your previous experience with observing the teaching of mathematics and science in an integrated STEM framework?
37. What is your previous experience with teaching mathematics and science in an integrated STEM framework?

DEMOGRAPHICS

- Your sex:
 The last four digits of your USA Jag Number:
 Your age (in years):
 Your Tier 2 placement (School Name):
 Your Tier 2 placement (Grade Level):
 Your Tier 3 placement (School Name):
 Your Tier 3 Placement (Grade Level):
 Your Tier 4 Placement (School Name):
 Your Tier 4 Placement (Grade Level):

APPENDIX E – Permission to Modify SETIS Instrument

On Mon, Aug 1, 2016 at 2:09 PM, Monica Mobley <mclutch@gmail.com> wrote:
Good afternoon, Dr. Allison.

I received your request to use the SETIS instrument. You are certainly welcome to do so. I hope it proves useful for your research. If you have any questions, please feel free to contact me.

If possible, I would love to see the final version you develop should you choose to use the instrument. Also, I would love to read your research paper when you complete your work. An informal, electronic version is fine.

Best wishes in your endeavors!

Monica Mobley

On Thu, Jul 28, 2016 at 10:35 AM, Elizabeth Allison <erallison@southalabama.edu> wrote:
Good morning,

A colleague and I are beginning a research project with our science and math methods courses...We are going to co-teach together part of the semester to incorporate a more STEM-focused approach. I would like to formally ask for permission to use the SETIS instrument. We would likely need to adjust some of the questions to meet our specific needs, but we would certainly cite your work in any research proposals or publications if we decided to use the SETIS instrument.

Elizabeth Allison, Ph.D., NBCT

Assistant Professor

Department of Leadership and Teacher Education

erallison@southalabama.edu

P: (251) 380-2650

F: (251) 380-2758

APPENDIX F – STEM Confidence Questionnaire

Informed Consent

Dear Potential Participant:

You are invited to participate in a research study conducted by Dr. Elizabeth Allison, from the The University of South Alabama, Department of Leadership and Teacher Education. I hope to learn how your participation in the elementary science and mathematics methods courses affects what you think about planning and teaching mathematics and science in an integrated STEM framework, co-teaching, and inclusion classrooms. You were selected as a possible participant in this study because you are currently (or were previously) a student in the elementary science and mathematics courses.

If you decide to participate, you will complete a survey online where you will indicate how you feel about planning and teaching integrated STEM in elementary classrooms and how you feel about participating in co-taught STEM classes.

There are no known risks or discomforts associated with your participation in this study. Your grade in EDU 337 and EDU 335 will in no way be affected by completing this survey or participating a focus group. Likewise, I cannot guarantee that you personally will receive any benefits from this research.

Subject identities will be kept confidential by completing the surveys anonymously. Survey data will be kept on a password protected computer for up to five years.

Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with The University of South Alabama. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions, please feel free to contact Dr. Elizabeth Allison at 251-380-2650. You will be offered a copy of this form to keep.

For questions about your rights as a research participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Institutional Review Board at 251-460-6308 or email irb@southalabama.edu

You have read, or have had read to you, and understand the purpose and procedures of this research. You have had an opportunity to ask questions which have been answered to your satisfaction. You voluntarily agree to participate in this research as described.

Completing and submitting the questionnaire/survey constitutes your consent to participate and certifies that you are 19 years of age or older. If you choose not to participate in the survey you can close this browser at any time.

Do you agree to participate in this survey?

Directions: Choose your level of confidence for each statement. (STEM = Science, Technology, Engineering, and Math)

(1) Cannot do this at all - (2) Would have difficulty doing this - (3) Mostly confident I can do this - (4) Very confident I can do this

1. Connect science concepts to those of engineering, mathematics, and technology.
2. Promote students grade-level appropriate acquisition of core engineering knowledge.
3. Develop summative assessments to measure students' integrated knowledge of STEM at the end of an instructional unit.
4. Develop formative assessments to measure student learning of discipline-specific content while teaching integrated STEM.
5. Earn acceptable teacher-evaluation/performance scores while teaching science and mathematics in an integrated STEM framework.
6. Access resources necessary to teach science and math within an integrated STEM framework.
7. Obtain the materials necessary to teach science and mathematics through STEM in an integrated way.
8. Get students to experience excitement, interest, and motivation to learn about phenomena in the natural world.
9. Use currently available resources to provide my students with technology to engage in learning within an integrated STEM framework.
10. Meet evaluation requirements while teaching integrated STEM.
11. Use my teaching experience to teach science and mathematics effectively from within an integrated STEM framework.
12. Teach my content within an integrated STEM framework.
13. Use current knowledge and skills to teach science and mathematics within an integrated STEM framework.
14. Use my understanding of integrated STEM in a way that allows me to teach science and mathematics effectively.
15. Develop new knowledge and skills necessary to teach science and mathematics within an integrated STEM framework.
16. Learn new technologies that will enable me to teach from within an integrated STEM framework.
17. Adapt to new teaching situations such as those necessary to teach science and mathematics from within an integrated STEM framework.

18. Use currently available resources to provided my students with technology to engage in learning within an integrated STEM framework.
 19. Access technology to teach science and mathematics from within an integrated STEM framework.
-

Short Answer

20. Is there anything else you would like to say about how you feel about teaching STEM?
-

DEMOGRAPHICS

- Your sex:
- The last four digits of your USA Jag Number
- Your age (in years):
- Your Tier 2 placement (School Name)
- Your Tier 2 placement (Grade Level)
- Your Tier 3 placement (School Name)
- Your Tier 3 Placement (Grade Level)
- Your Tier 4 Placement (School Name)
- Your Tier 4 Placement (Grade Level)
- Would you like to submit your responses?

APPENDIX G –Open-Ended Questions Added to Questionnaires

1. Describe your opportunities and/or experiences teaching integrated STEM lessons during your Tier 4 internship.
2. Describe any obstacles/barriers you have encountered implementing integrated STEM lessons during your Tier 4 internship.
3. How has your confidence in teaching integrated STEM lessons changed over the Tier 3 and Tier 4 semesters?
4. How have your attitudes toward teaching integrated STEM lessons changed over the Tier 3 and Tier 4 semesters?

APPENDIX H – Integrated Science/Math Learning Segment Rubric

Integrated Science/Math Learning Segment Rubric

Item/Criteria	Points Possible	Points Earned	Comments
<p>Vital Information/Justification for Goals and Objectives</p> <ul style="list-style-type: none"> • Central focus is appropriate and describes the broad focus of the unit (1 pt) • Content standards for science and math are listed, including the ACOS number and standard text. (4 pts) • Science and Engineering Practices and Crosscutting Concepts are listed and evident in lesson (4 pts) • Standards for Mathematical Practice are listed and evident in lesson (4 pts) • Objectives are included for math and science, and are observable and measurable. (4 pts) • Prior knowledge describes what students already know about the topic(s) for math and science. (4 pts) • Common errors are listed and strategies for addressing them are described for math and science. (4 pts) 	25		
<p>Day 1 Lesson Plan</p> <ul style="list-style-type: none"> • ENGAGE gains students’ attention in an interesting way, activates prior knowledge, and states the objective for the lesson. (4 pts) • EXPLORE AND EXPLAIN (18 pts) The lesson: <ul style="list-style-type: none"> ○ Is very organized (a very well-constructed and complete lesson) that adequately addresses multiple learning styles (4 pts) ○ Is appropriately aligned with the standards, practices, and objectives for math and science (4 pts) ○ addresses an essential question that is relevant and has real-life connections (4 pts) ○ uses appropriate instructional strategies (hands-on, discovery, inquiry-based, toward conceptual understanding in math and science) (6 pts) • Closure wraps up lesson by giving students an opportunity to connect and reflect to determine if the students are meeting the objectives. (3 pts) 	25		
<p>Day 2 Lesson Plan</p> <ul style="list-style-type: none"> • ENGAGE gains students’ attention in an interesting way, activates prior knowledge, and states the objective for the lesson. (4 pts) • EXPLORE AND EXPLAIN (18 pts) The lesson: <ul style="list-style-type: none"> ○ Is very organized (a very well-constructed and complete lesson) that adequately addresses multiple learning styles (4 pts) ○ Is appropriately aligned with the standards, practices, and objectives for math and science (4 pts) ○ addresses an essential question that is relevant and has real-life connections (4 pts) 	25		

<ul style="list-style-type: none"> ○ uses appropriate instructional strategies (hands-on, discovery, inquiry-based, toward conceptual understanding in math and science) (6 pts) • Closure wraps up lesson by giving students an opportunity to connect and reflect to determine if the students are meeting the objectives. (3 pts) 			
<p>Day 3 Lesson Plan</p> <ul style="list-style-type: none"> • ENGAGE gains students' attention in an interesting way, activates prior knowledge, and states the objective for the lesson. (4 pts) • EXPLORE AND EXPLAIN (18 pts) The lesson: <ul style="list-style-type: none"> ○ Is very organized (a very well-constructed and complete lesson) that adequately addresses multiple learning styles (4 pts) ○ is appropriately aligned with the standards, practices, and objectives for math and science (4 pts) ○ addresses an essential question that is relevant and has real-life connections (4 pts) ○ uses appropriate instructional strategies (hands-on, discovery, inquiry-based, toward conceptual understanding in math and science) (6 pts) • Closure wraps up lesson by giving students an opportunity to connect and reflect to determine if the students are meeting the objectives. (3 pts) 	25		
<p>Day 4 Lesson Plan (optional)</p> <ul style="list-style-type: none"> • ENGAGE gains students' attention in an interesting way, activates prior knowledge, and states the objective for the lesson. (4 pts) • EXPLORE AND EXPLAIN (18 pts) The lesson: <ul style="list-style-type: none"> ○ Is very organized (a very well-constructed and complete lesson) that adequately addresses multiple learning styles (4 pts) ○ is appropriately aligned with the standards, practices, and objectives for math and science (4 pts) ○ addresses an essential question that is relevant and has real-life connections (4 pts) ○ uses appropriate instructional strategies (hands-on, discovery, inquiry-based, toward conceptual understanding in math and science) (6 pts) • Closure wraps up lesson by giving students an opportunity to connect and reflect to determine if the students are meeting the objectives. (3 pts) 	25		
<p>Day 5 Lesson Plan (optional)</p> <ul style="list-style-type: none"> • ENGAGE gains students' attention in an interesting way, activates prior knowledge, and states the objective for the lesson. (4 pts) • EXPLORE AND EXPLAIN (18 pts) The lesson: <ul style="list-style-type: none"> ○ Is very organized (a very well-constructed and complete lesson) that adequately addresses multiple learning styles (4 pts) ○ is appropriately aligned with the standards, practices, and objectives for math and science (4 pts) ○ addresses an essential question that is relevant and has real-life connections (4 pts) 	25		

<ul style="list-style-type: none"> ○ uses appropriate instructional strategies (hands-on, discovery, inquiry-based, toward conceptual understanding in math and science) (6 pts) • Closure wraps up lesson by giving students an opportunity to connect and reflect to determine if the students are meeting the objectives. (3 pts) 			
Elaboration <ul style="list-style-type: none"> • Extends student learning in a new way for integrating math and science in a real-world context 	6		
Summative Evaluation <ul style="list-style-type: none"> • A description and copy of the assessment tools/procedures is provided and evident for math and science. (4 pts) • Assesses conceptual understanding AND procedural fluency or mathematical reasoning (6 pts) • Assessment is aligned with objectives. (2 pts) • The evaluation criteria are provided. (6 pts) <ul style="list-style-type: none"> ○ Addresses all objectives ○ Describes how judgement will be made about whether student learning objectives were met ○ Are appropriate for the assessment. 	18		
Other Lesson Plan Requirements <ul style="list-style-type: none"> • Higher order questions are listed and appropriate for the lessons- at least 12 math and 12 science questions (12 pts) • What Ifs are listed for both math and science with appropriate strategies for addressing them (4 pts) • All Materials and Resources are listed for each day (6 pts) 	22		
STEM <ul style="list-style-type: none"> • STEM Integration and application of STEM-Based Knowledge: Unit demonstrates that the candidate can design STEM instruction based on knowledge of students, STEM learning pedagogy, STEM subject matter, curricular goals, and community, using authentic integration of math and science content standards as appropriate to address real-world connections (6 pts) • Active Engagement in STEM and Inquiry: Candidate fosters active engagement in learning, student self-motivation, and positive social interactions, and creates a supportive learning environment. He/she consistently and authentically provides inquiry-based and hands-on opportunities using a variety of mathematical, science, and engineering practices. (6 pts) • Candidate provides opportunities for students to develop or use a systematic approach to investigate and develop solutions or answers to real-world problems using appropriate technology. (6 pts) 	18		
Neatness & Organization <ul style="list-style-type: none"> • Unit reflects a professional product. (2 pts.) • Unit reflects professional writing and is free of grammatical and mechanical errors. (4 pts) 	6		
Total 3 Days _____/170 4 Days _____/190 5 Days _____/210			

APPENDIX I – Focus Group Interview Protocol

1. Describe what you know and understand about integrated mathematics and science. Be as specific as you can be.

Probe: What does it mean to you?

2. What are some advantages of integrating mathematics and science in the elementary classroom?
3. What are some disadvantages of integrating mathematics and science in the elementary classroom?
4. Describe any teaching and/or learning experiences you have had throughout your educational career where mathematics and science have been integrated.

Probe: How have these experiences/training prepared you for teaching integrated STEM lessons? Specifically, in the integrated math and science methods courses.

5. Describe any challenges you encountered (this semester) when planning and teaching integrated STEM lessons.
6. (Now I would like to discuss your confidence in teaching integrated mathematics and science lessons). Describe for me how confident you are in planning and teaching integrated mathematics and science lessons in the K-6 classroom.)
 - a) Throughout your experiences this semester, how has your attitude toward planning and teaching integrated STEM lessons changed?
 - b) Confidence?

Probe: How has participation in the integrated math and science methods courses impacted these changes?

7. As a future teacher, how might you use integrated STEM in your instruction?

8. What are possible challenges you will encounter as a classroom teacher when planning and teaching integrated math and science lessons?
9. Based on your experiences this semester, describe how an elementary student would use or relate to integrated STEM?
10. What approaches or teaching strategies do you think are most effective when teaching mathematics? Science? Why do you think these are most effective instructional approaches for math? Science?
11. Please share anything else you would like to add that we have not discussed.

Follow-up questions:

1. (To Question 1) What does integrated mathematics and science mean to you?
2. (To Question 4) How have these experiences/training prepared you for teaching integrated STEM lessons, specifically, in the integrated mathematics and science methods courses?
3. (To Question 6) How has participation in the integrated mathematics and science methods courses impacted these changes?
4. What could be improved in the integrated mathematics and science methods courses that would
 - a. ...better prepare you to plan and implement STEM lessons in your future classroom?
 - b. ...heighten your attitudes toward teaching integrated STEM lessons?
 - c. ...increase your confidence in teaching integrated STEM lessons?
5. What resources or support do you feel is necessary to effectively teaching integrated STEM lessons in the elementary classroom.

APPENDIX J – Elementary Mathematics Methods Course Syllabus

Spring 2018 Syllabus

University of South Alabama
College of Education and Professional Studies
Department of Leadership and Teacher Education

EDU 335 Trends in Teaching Mathematics

3 credit hours (W)

Catalog Description: This is a course that deals with effective methods of teaching mathematics to elementary school students. Emphasis will be on developing an understanding of numbers, teaching basic operations, and using various teaching aids and materials to meet the different needs of elementary age students.

Instructor: Ms. Kelly Byrd
Office Hours: MW 8 – 9:15 am, 12:15 – 1:45 pm;
T 6:00 – 6:30 pm
& by appointment
Office: 3122 UCOM
Phone: 380-2673



Required Texts/Supplies:

- Alabama College and Career Ready Standards for Mathematics 2016 PDF. Print pages 10-18 as well as your grade level Overview and Standards. Place in your binder to have in class every day.
<https://www.alsde.edu/sec/sct/COS/2016%20Revised%20Alabama%20Course%20of%20Study%20Mathematics.pdf>
- Math Journal - 3-prong folder with loose leaf

College of Education's Conceptual Framework

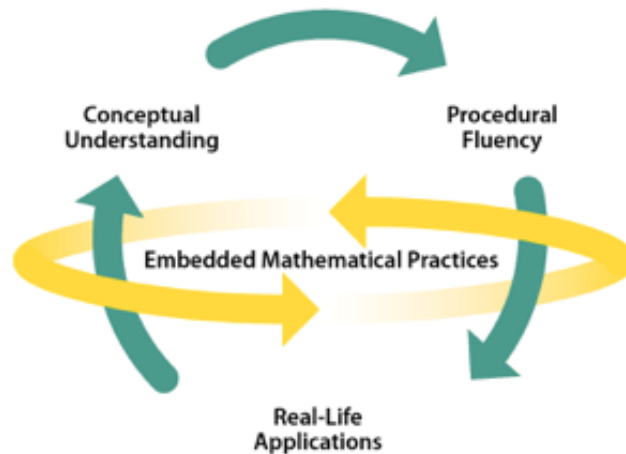
A purpose of this course will be to prepare professional educators through teaching, research, and service, to become committed to life-long learning and to facilitate the process of building better communities.

Program Statement

The K-6 education program applies a decision-making model for preparing teacher educators. Through a combination of classroom and intensive field experiences, prospective teachers master the technical skills needed to provide systematic, individualized instruction to all students, promote student welfare, and serve as effective professional team members across diverse educational settings.

Course Topics/Contents Include (but not limited to):

- NCTM Principles and Standards
- Common Core Standards for Mathematics
- Standards for Mathematical Practice
- Constructivism
- Conceptual Understanding, Procedural Knowledge & Mathematical Reasoning
- AMSTI
- Differentiation in Mathematics
- Lesson Planning
- Inquiry-Based Learning
- Mathematical Literacy
- Assessment and Evaluation
- Mathematic Knowledge for Teaching
- STEM Integration
- Manipulatives
- Problem-Solving
- Performance-Based Tasks
- Error Analysis



**Continuous Improvement in Educator Preparation (CIEP)
Rule 290-3-3-.03 Alabama Core Teaching Standards (ACTS)
Class B**

Standard	Activities and Resources
Standard 1: Learner Development	
(b) The candidate creates developmentally appropriate instruction that takes into account individual learners' strengths, interests, and needs and that enables each learner to advance and accelerate his/her learning.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(h) The candidate respects learners' differing strengths and needs and is committed to using this information to further each learner's development.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(i) The candidate is committed to using learners' strengths as a basis for growth and their misconceptions as opportunities for learning.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(j) The candidate takes responsibility for promoting learners' growth and development.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
Standard 2: Learning Differences	
(a) The candidate designs, adapts, and delivers instruction to address each student's diverse learning strengths and needs and creates opportunities for students to demonstrate their learning in different ways.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Informal Evaluations
(b) The candidate makes appropriate and timely provisions (e.g., pacing for individual rates of growth, task demands, communication, assessment, and response modes) for individual students with particular learning differences or needs.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Accommodations within the instruction as well as the assessments
(c) The candidate designs instruction to build on learners' prior knowledge and experiences, allowing learners to accelerate as they demonstrate their understandings.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Identification of prior knowledge and possible misconceptions
Standard 3: Learning Environments	
(i) The candidate understands the relationship between motivation and engagement and knows how to design learning experiences using strategies that build learner self-direction and ownership of learning.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Engage
(j) The candidate knows how to help learners work productively and cooperatively with each other to achieve learning goals.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Explore

Standard 4: Content Knowledge	
(h) The candidate creates opportunities for students to learn, practice, and master academic language in their content.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(j) The candidate understands major concepts, assumptions, debates, processes of inquiry, and ways of knowing that are central to the discipline(s) she/he teaches.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(k) The candidate understands common misconceptions in learning the discipline and how to guide learners to accurate conceptual understanding.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Identification of prior knowledge and possible misconceptions
(l) The candidate knows and uses the academic language of the discipline and knows how to make it accessible to learners.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Academic language embedded in higher order questions for each content area
(m) The candidate knows how to integrate culturally relevant content to build on learners' background knowledge.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Commentary and Lesson Evaluations
(n) The candidate has a deep knowledge of student content standards and learning progressions in the discipline(s) she or he teaches.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(o) The candidate has deep knowledge of current and emerging state initiatives and programs including, but not limited to, the Alabama Reading Initiative (ARI); the Alabama Math, Science, and Technology Initiative (AMSTI); Alabama Learning Exchange (ALEX); Alabama Connecting Classrooms, Educators and Students Statewide (ACCESS); and RTI (Response to Instruction) and their relationship to student achievement.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
Standard 5: Application of Content	
(a) The candidate develops and implements projects that guide learners in analyzing the complexities of an issue or question using perspectives from varied disciplines and cross-disciplinary skills (e.g., a water quality study that draws upon biology and chemistry to look at factual information and social studies to examine policy implications).	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Evidence of Authentic STEM Integration
(b) The candidate engages learners in applying content knowledge to real world problems through the lens of interdisciplinary themes (e.g., financial literacy, environmental literacy).	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Evidence of Authentic STEM Integration

(c) The candidate facilitates learners' use of current tools and resources to maximize content learning in varied contexts.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Appropriate use of manipulatives and technology
(e) The candidate develops learners' communication skills in disciplinary and interdisciplinary contexts by creating meaningful opportunities to employ a variety of forms of communication that address varied audiences and purposes.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Evidence of Authentic STEM Integration
(i) The candidate understands the ways of knowing in his/her discipline, how it relates to other disciplinary approaches to inquiry, and the strengths and limitations of each approach in addressing problems, issues, and concerns.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Evidence of Authentic STEM Integration
Standard 7: Planning for Instruction	
(b) The candidate plans how to achieve each student's learning goals, choosing appropriate strategies and accommodations, resources, and materials to differentiate instruction for individuals and groups of learners.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Accommodations within the instruction as well as the assessments
(c) The candidate develops appropriate sequencing of learning experiences and provides multiple ways to demonstrate knowledge and skill.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Commentary and Lesson Evaluations
(g) The candidate integrates Alabama-wide programs and initiatives into the curriculum and instructional processes.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Commentary and Lesson Evaluations
(i) The candidate understands content and content standards and how these are organized in the curriculum.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment
(j) The candidate understands how integrating cross-disciplinary skills in instruction engages learners purposefully in applying content knowledge.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment: Evidence of Authentic STEM Integration
Standard 8: Instructional Strategies	
(l) The candidate knows when and how to use appropriate strategies to differentiate instruction and engage all learners in complex thinking and meaningful tasks.	Three-Day Integrated Mathematics and Science (STEM) Learning Segment

Please note that in one semester we cannot cover all issues in teaching elementary school mathematics; consequently, this course syllabus is not intended to be totally comprehensive. Instead, the purpose is to raise the most relevant issues and questions about mathematical learning and teaching. This course will be guided by the following goals and objectives. Specifically the student will be given opportunities...

- to explore, understand, and be prepared to implement the Alabama Course of Study Content and Practice Standards for Elementary Mathematics, NCTM Principles and Process Standards, Alabama Mathematics Science Technology Initiative, and STEM Integration;
- to explore, develop conceptual and procedural understanding, and problem solving ability the major strands of the mathematics curriculum – number sense and operations, geometry, measurement, data analysis, and algebra – to in the various areas of mathematics;
- to study current trends and problems encountered in teaching mathematics and how to cope with them, including meeting the needs of exceptional students, being sensitive to the cultural backgrounds of students, and building positive attitudes;
- to increase theoretical knowledge and practical experience in the planning, teaching, and assessment of mathematics lessons and STEM lessons;
- to broaden one’s repertoire of practical teaching strategies and activities, including the use of manipulatives and technology in the classroom, and the integration of mathematics and science in and integrated STEM framework;
- and to effectively communicate mathematics both in written and oral form.

<p>Habits of Mind Of a Productive Mathematical Thinker</p> <p>MP.1 Make sense of problems and persevere in solving them.</p> <p>MP.6 Attend to Precision</p>	<p>Reasoning and Explaining</p> <p>MP.2 Reason abstractly and quantitatively</p> <p>MP.3 Construct viable arguments and critique the reasoning of others.</p>
	<p>Modeling Using Tools</p> <p>MP.4 Model with mathematics</p> <p>MP.5 Use appropriate tools strategically</p>
	<p>Seeing Structure and Generalizing</p> <p>MP.7 Look for and make sense of structure.</p> <p>MP.8 Look for and express regularity in repeated reasoning.</p>

Course Requirements:

o **Class Participation/Attendance/Activities/Mathematical Disposition: Points TBD**

You are expected to attend each of the scheduled class sessions and participate actively and collaboratively in class discussions, activities, and individual reflections. Everyone will teach and learn from each other in an environment that encourages creativity, the free flow of ideas, and a great deal of learning and interaction. Preparation for class involves completion of assigned readings and tasks. If you have to miss a class, you are responsible for the material from the missed class. Points will be earned from a variety of in- and out-of-class activities, online Units, group projects, online course evaluation, etc. Details for these assignments will be given in class and posted on USA Online. It is your responsibility to complete the outside readings and Units before coming to class. Our time in class will be spent primarily engaged in activities that correspond to each Unit.

Mathematical Disposition:

Learning mathematics extends beyond learning concepts, procedures, and their applications. It also includes developing a disposition toward mathematics and seeing mathematics as a powerful way for looking at situations. Disposition refers not simply to attitudes but to a tendency to think and to act in positive ways" (NCTM Curriculum and Evaluation Standards for School Mathematics, p. 233).

As preservice teachers, I am challenging you, and expecting you, to evaluate Your mathematical dispositions. I will be assessing these using the same standard: set forth by NCTM regarding our students:

The assessment of students' mathematical disposition should seek information about their--

- 1. confidence in using mathematics to solve problems, to communicate ideas, and to reason;*
- 2. flexibility in exploring mathematical ideas and trying alternative methods in solving problems;*
- 3. willingness to persevere in mathematical tasks;*
- 4. interest, curiosity, and inventiveness in doing mathematics;*
- 5. inclination to monitor and reflect on their own thinking and performance;*
- 6. value of the application of mathematics to situations arising in other disciplines and every day experiences;*
- 7. appreciation of the role of mathematics in our culture and its value as a tool and as a language.*

o **Mathematics Journal: 25 points**

Using a three-prong folder with loose leaf, you will keep a mathematics journal throughout this semester. The first page will be a *Table of Contents* where each entry will be recorded with the date and title. You must bring this to class with you every meeting. It will be collected and graded periodically throughout the semester, as well as at the end. This is in-class work, and considered to be class participation. If you are absent, the journal entry may not be made up or copied. You will be allowed one missing entry due to unexpected circumstances that come with life.

- **Midterm: 25 points**
You will complete a course midterm online that will reflect the core concepts of teaching and learning mathematics.

- **Mathematics Lesson Plan, Commentary, and Informal Evaluation (50 points):**
Plan and implement one lesson on your grade level that must include the use of commercial or teacher-made manipulatives (virtual or concrete), and either the integration of art or children's literature. This lesson plan will be graded and returned to you BEFORE you teach it. Follow the format posted on USA Online. In the lesson plan, you must include at least 5 higher order questions that you would ask throughout the lesson. Your cooperating teacher or university supervisor will complete an informal lesson evaluation.

After implementation of the lesson plan, you will complete and submit a professional commentary, along with the cooperating teacher/supervisor's evaluation, and revised lesson plan (if necessary). Follow the guidelines posted on USA Online.

- **Three-Day Integrated Mathematics and Science (STEM) Learning Segment: 170 points**
Plan and implement at least three consecutive integrated math/science lessons using the 5E instructional model. Objectives must be clearly stated and evaluated in the lesson and must reflect "hands-on/minds-on" learning. Follow the format posted on USA Online. Your cooperating teacher and/or university supervisor will evaluate this learning segment **each of the three days** using three different informal evaluation forms.

Each of the following **MUST** be integrated into your planning for the mathematics standards: 1) the use of virtual and/or commercial or teacher-made manipulatives to teach or introduce a mathematical concept, and 2) the use of interactive technology.

- **Three-Day STEM Learning Segment Commentary and Evaluations (50 Points):**
After implementation of the learning segment, you will complete and submit a professional commentary. All **three** cooperating teacher/supervisor evaluations will be submitted along with the commentary. Follow the guidelines posted on USA Online.

- **Integrated Mathematics and Science Team Lesson Plan (50 Points):**
Given both a science and a mathematics content standard, you will work with your team to create an integrated lesson plan. Then, you will present your lesson plan to a group of your peers to allow for feedback and reflection.

Since all classes do not progress at the same rate, the instructor may wish to modify the above requirements or their timing as circumstances dictate. For example, the instructor may wish to change the number and frequency of exams, or the number and sequence of assignments. However, the students must be given adequate notification. Moreover, there may be non-typical classes for which these requirements are not strictly applicable in each instance and may need modification. If such modification is needed, it must be in writing and conform to the spirit of this policy statement.

The <u>tentative</u> grading scale will be as follows:	
93 - 100%	A
85 - 92%	B
75 - 84%	C
70 - 74%	D
0 - 69%	F

Please note that the instructor has the right to raise or lower grades due to subjective matters. Lack of professionalism will result in the loss of points based on the instructor's discretion.

- **Assignments and Responsibility:**
 - All assignments (unless otherwise indicated) are to be typed double-spaced using 12 point Times New Roman font and 1 inch margins with your full name and section number in the header of each page using Microsoft Word. Assignments will be submitted to the instructor in hard copy and/or through USA Online as indicated in the assignment requirements.
 - All out-of-class assignments are due in USA Online **at 8 a.m.** on the assigned date, unless otherwise noted. If it is an assignment that cannot be submitted through USA Online, it will be due at the beginning of class on the date specified. If an assignment is turned in anytime during the 24 hours after the due date and time, one-half of the total point value of the assignment will be deducted before it is graded. Assignments will not be accepted after this 24-hour period. If you are tardy, you forfeit the right to begin a journal entry/activity, turn in an assignment for full credit, or begin your presentation.
 - All assignment responses are to be professionally written in complete sentences. All assignment responses will be evaluated on content and writing mechanics (up to 10% deduction for grammatical mistakes).
 - Each group assignment is to be completed collaboratively and jointly by each group member, not "individually" by splitting the assignment into component parts. All names are to be included in the assignment header in alphabetical order.
 - It is the candidate's responsibility to read, comprehend and ask questions about all assigned course readings and unit assignments. Class time will be used primarily for demonstration lessons and engaging in research-based activities appropriate for K-6 classroom use, as well as follow-up discussions.

Additional Course Policies:

PLEASE VIEW THE FOLLOWING DOCUMENTS WHICH ARE POSTED ON USA Online

- Student Academic Disruption Policy

- Student Academic Conduct Policy
 - Alabama Educator Code of Ethics
 - Professional Dispositions
 - Student Disability Statement
- **Attendance Policy:**
 - According to the *University of South Alabama Bulletin*: "An individual student is responsible for attending the classes in which the student is officially enrolled. The quality of work will ordinarily suffer from excessive absences..." Therefore, attendance and promptness are required. Furthermore, "For excessive absences (two or three consecutive class meetings) due to illness, death in family, or family emergency, the Dean of Students' office should be advised."
 - The Tier III Faculty firmly supports the philosophy that attendance is directly related to the level of learning that takes place in the classroom. The entire process of education requires regular instruction and classroom participation in order to reach maximum educational benefits. Regular contact with other students and participation in well-planned instructional activities are vital to this purpose. We strongly believe it is detrimental to student learning to have excessive absences from classroom instruction. Therefore, any student who misses 4 class sessions in any one Tier III course (2 sessions for the Baldwin County Campus) will be required to have a face-to-face meeting with Tier III faculty so that a recommendation can be made as to whether the student should continue the course or withdraw. If the recommendation is for the student to withdraw, and the student does not, then the student may receive an "F" for the course.



Please visit the COE's [LiveText](http://www.southalabama.edu/colleges/coe/livetext.html) web page for information regarding purchasing instructions and technology support: <http://www.southalabama.edu/colleges/coe/livetext.html>

Professionalism/Teacher Education Dispositions:

All teacher education candidates completing field experiences are expected to demonstrate appropriate professional dispositions. These dispositions are explained in detail in the USA College of Education Teacher Education Dispositions documents. Each candidate completing a field experience is required to sign a Teacher Educator Dispositions document each semester. This document outlines the behaviors that contribute to the development of appropriate professional standards. A copy will also

be distributed to each cooperating teacher. If at any time during the candidates' field experience it becomes necessary to discuss any behavior that conflicts with desired professional outcomes, the cooperating teacher will contact the field supervisor. The supervisor will then follow procedures outlined in the Teacher Education Dispositions document.

As challenges arise in field experiences, the clinical supervisor will work with the candidate and cooperating teacher(s) in effort to resolve the problem. If the problem cannot be resolved, the Director of Field Services will meet with the supervisor and teacher education candidate. Candidates who are asked to leave a school, violate the Alabama Educator Code of Ethics, demonstrate instructional incompetence and/or exhibit unprofessional behavior (see Teacher Education Dispositions document) may be dismissed from the field placement, the course, or the Teacher Education Program. These actions may result in the lowering of the candidate's course grade or a failing grade in the course. The clinical supervisor, program faculty, and appropriate administration will determine further course of action.

Teacher Education Dispositions

Role of Dispositions

Dispositions are built around a set of beliefs or a value system. Dispositions should lead to actions and patterns of professional conduct displayed by teachers in and out of the classroom.

Teachers should be role models and model positive behaviors for their students. Teachers with positive professional dispositions tend to act in ways that elevate the profession of teaching in the eyes of others.

Teacher education programs have a responsibility to convey, model, and promote positive standards of professional conduct. Procedures for promoting and assessing dispositions must be in place along with a referral system for candidates who exhibit unacceptable behaviors. This process helps ensure that only candidates with acceptable dispositions complete the program.

At the University of South Alabama, the College of Education has identified nine dispositions for teacher candidates. A set of procedures has been established to promote and assess teacher education candidates' dispositions and respond to candidates displaying negative dispositions and unprofessional conduct. Authority for enforcing the dispositions procedures resides in the College of Education.

Process for Assessing Dispositions

Because teaching dispositions encompass both beliefs and actions, the University of South Alabama College of Education has developed a multi-step system for evaluating dispositions. Dispositions must be demonstrated by candidates in courses and during field experiences in

schools. In keeping with established assessment principles and practices, the assessments are varied, multiple, and spread throughout the teacher education programs.

Promoting and Assessing Positive Dispositions

The following procedures have been established for assessing the professional dispositions and conduct of teacher education candidates:

- Candidates complete the *Dispositions Rubric* as a self-assessment prior to admission to teacher candidacy.
- The *Dispositions Rubric* is completed as an observational assessment at three points throughout the program—prior to candidacy, prior to internship, and during internship—by both cooperating teachers and/or university faculty serving as course instructors or field supervisors.
- Available *Disposition Rubric* results (self-assessment and observational) guide a discussion of the individual's strengths and needed improvements in the area of professional dispositions.

Responding to Negative Dispositions

If unacceptable behaviors are recognized in a teacher candidate, the following steps will be taken:

- Unacceptable response(s) on the *Dispositions Rubric* (either self-assessment or observational data) may result in denied admission to teacher education programs.
- First Referral – Unacceptable dispositions identified by a course instructor, field experience supervisor and/or cooperating teacher will be documented on the disposition referral form (see attached) and a conference will be held between the referring professional(s) and teacher candidate. An individualized plan for remediation will be presented.
- Subsequent Referrals – Subsequent unacceptable dispositions will follow the same documentation procedures as a first referral. The referral will be followed by a conference between the Department Chair and/or Director of Field Services, referring professional(s), and the teacher candidate. An individualized plan for remediation will be presented. Further instances of unacceptable dispositions will be directed to the appropriate Academic Misconduct Committee for disciplinary action, and may include removal from the program.

Appeals

Any appeal to this disposition assessment process follows the University of South Alabama procedures as outlined in the current edition of the Student Handbook (*The Lowdown*).

Bibliography

Appelbaum, Peter & Allen, David Scott (2008) *Embracing Mathematics: On Becoming a Teacher and Changing with Mathematics*. Routledge. ISBN 978-0-415-96385-5

Ashlock, Robert B. (2002) *Error Patterns in Computation*. Merrill/Prentice Hall. ISBN 0-13-027093-8

Burns, Marilyn & Silbey, Robyn (2000) *So You Have to Teach Math?* Math Solutions Publications. ISBN 978-0-941355-29-2

Dacey, Linder & Salemi, Rebeka Eston (2007) *Math for All: Differentiating Instruction, Grades K – 2*. Math Solutions Publications. ISBN 978-0-941355-77-3

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Gurganus, Susan Perry (2007) *Math Instruction for Students with Learning Problems*. Pearson Education, Inc. ISBN 0-205-46089-5

Leonard, Jacqueline (2008) *Culturally Specific Pedagogy in the Mathematics Classroom*. Routledge. ISBN 0-8058-6105-X

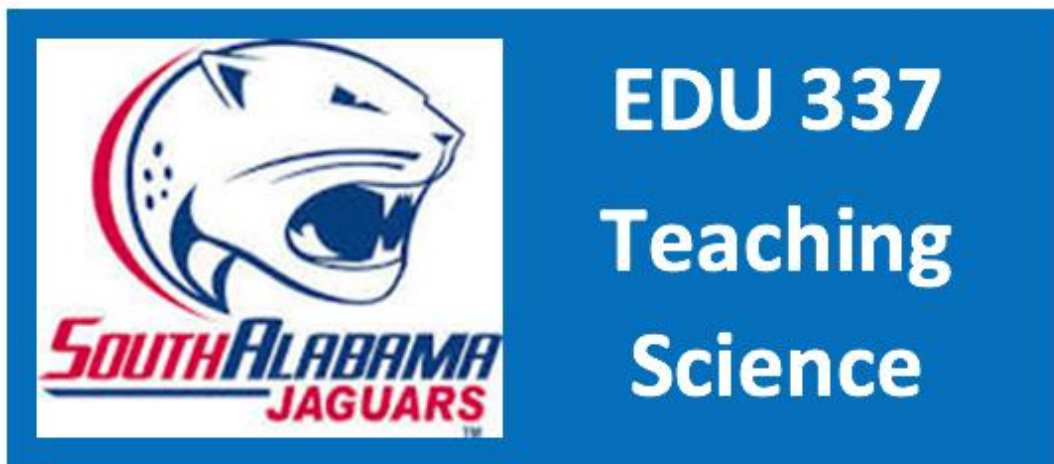
Ma, Liping (1999) *Knowing and Teaching Elementary Mathematics*. Lawrence Erlbaum Associates. ISBN 0-8058-2909-1

Sullivan, Peter & Lilburn, Pat (2002) *Good Questions for Math Teaching*. Math Solutions Publications. ISBN 094135551-9

Mathematics Dictionary and Handbook by Eugene Nichols and Sharon Schwartz. ISBN 1-882269-07-1

DATE	TOPICS COVERED	ASSIGNMENTS DUE
M 1/8	Syllabus and schedule Daily Data	Bring Math Journal
W 1/10	Constructivism & Inquiry-Based Learning Conceptual Understanding, Procedural Knowledge, Mathematical Reasoning	
M 1/15	MLK Holiday	Unit 1
W 1/17	Unpacking the CCSSM	
M 1/22	CCSSM Standards for Mathematical Practice	Unit 2
W 1/24	Planning to Teach Mathematics: Central Focus, Objectives, Integrating Children's Literature; Lesson: Arranging Chairs	
M* 1/29	Co-Teaching Workshop: Math and Science Standards and Learning Progressions; Prior Knowledge and Misconceptions	
W 1/31	Planning to Teach Mathematics with Manipulatives and Technology - Online Assignment	Unit 3
M 2/5	Assessment and Evaluation Conceptual Understanding/Procedural Knowledge	Unit 4
W 2/7	Questioning/Lesson plan work	
M 2/12	Math Lesson Planning Workshop	
W 2/14	Developing conceptual understanding of place value and operations on whole numbers	
M 2/19	Teaching Integrated Math and Science (STEM)	Unit 5
W* 2/21	Co-Teaching Workshop: Modeling Integrated STEM Lesson	Math Lesson Plan
M* 2/26	Co-Teaching Workshop: Modeling Integrated STEM Lesson	
W 2/28	Developing Conceptual Understanding of Fractions - Fraction Models	Unit 6
3/5-3/9	Field Week 1 – No Class	
M 3/12	Conceptual Understanding of Operations on Fractions	Revised Math Lesson Plan, Commentary & Evaluations
W 3/14	Conceptual Understanding of Operations on Fractions	
M* 3/19	Co-Teaching Workshop: Team Integrated STEM Lesson Planning Stations	Team Lesson Plan

DATE	TOPICS COVERED	ASSIGNMENTS DUE
W* 3/21	Co-Teaching Workshop: Team Integrated STEM Lesson Presentations	Revised Team Lesson Plan and Presentation
3/26- 3/30	Spring Break – No Class	
M 4/2	Error Analysis and Re-engagement	
W 4/4	Mathematics Assessment Task	In-class activity
M 4/9	Developing Conceptual Understanding of Geometry and Measurement Concepts	
W 4/11	3-Day Integrated STEM Learning Segment: In-class Workshop	3-Day Learning Segment Math Journals
4/16 – 4/20	Field Week 2 – No Class	
4/23 – 4/27	Field Week 3 – No Class	
4/30	EXAM WEEK	3-Day Commentary & Evaluations



INSTRUCTOR INFORMATION	
Name	Dr. Elizabeth Allison
Phone	251-380-2650
Email	erallison@southalabama.edu
Office Hours	MW 9:00-9:30; 12:00-1:30 T 3:00-5:00 Please make an appointment
Office	UCOM 3110

**COLLEGE OF EDUCATION'S
CONCEPTUAL FRAMEWORK**

A purpose of this course will be to prepare professional educators through teaching, research, and service, to become committed to life-long learning and to facilitate the process of building better

COURSE DESCRIPTION

A sequence course using discovery, inquiry, and problem-solving approaches as a means of teaching science. Relationship of science to entire early childhood and elementary curriculum is discussed.

REQUIREMENTS

Composition book (7 ½ x 9 ¾)

Please view the following "Additional Course Policies" on Sakai:

- Student Disability Services
- Academic Disruption
- Changes in Course Requirements
- Student Academic Conduct



Attendance Policy

According to the *University of South Alabama Bulletin*: "An individual student is responsible for attending the classes in which the student is officially enrolled. The quality of work will ordinarily suffer from excessive absences..." Therefore, attendance and promptness are required. Furthermore, "For excessive absences (two or three consecutive class meetings) due to illness, death in family, or family emergency, the Dean of Students' office should be advised."

The Tier III Faculty firmly supports the philosophy that attendance is directly related to the level of learning that takes place in the classroom. The entire process of education requires regular instruction and classroom participation in order to reach maximum educational benefits. Regular contact with other students and participation in well-planned instructional activities are vital to this purpose. We strongly believe it is detrimental to student learning to have excessive absences from classroom instruction. Therefore, any student who misses 2 class sessions in any one Tier III course will be required to have a face-to-face meeting with Tier III faculty so that a recommendation can be made as to whether the student should continue the course or withdraw. If the recommendation is for the student to withdraw, and the student does not, then the student may receive an "F" for the course.

Professionalism/Teacher Education Dispositions:

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As challenges arise in field experiences, the clinical supervisor will work with the candidate and cooperating teacher(s) in effort to resolve the problem. If the problem cannot be resolved, the Director of Field Services will meet with the supervisor and teacher education candidate. Candidates who are asked to leave a school, violate the Alabama Educator Code of Ethics, demonstrate instructional incompetence and/or exhibit unprofessional behavior (see Teacher Education Dispositions document) may be dismissed from the field placement, the course or the Teacher Education Program. These actions may result in the lowering of the candidate's course grade or a failing grade in the course. The clinical supervisor, program faculty, and appropriate administration will determine further course of action.

COURSE REQUIREMENTS

Not all classes progress at the same rate, thus course requirements might have to be modified as circumstances dictate. You will be given written notice if the course requirements need to be changed.

Class Participation/Attendance/Activities/Labs/Sakai Units (Points TBA): Your active participation in each class session is vital to your learning as well as to the learning of your peers. You are expected to attend each of the scheduled class sessions and participate actively and collaboratively in class discussions, activities, and individual reflections. Everyone will teach and learn from each other in an environment that encourages creativity, the free flow of ideas, and a great deal of learning and interaction. Preparation for class involves completion of assigned readings and tasks. If you have to miss a class, you are responsible for the material from the missed class period. Points will be earned from a variety of in- and out-of-class activities, writing assignments, forums, group projects, on-line course evaluation, etc. Details for these assignments will be given in class and posted on SAKAI. It is your responsibility to read for understanding each assigned reading before coming to class. Our time in class will be spent primarily engaged in activities that correspond to your readings.

Midterm: The course midterm will be administered online through Sakai and will cover a multitude of topics covered through Sakai Units, in-class activities/lectures, and other materials.

Interdisciplinary Unit (150 Points):

Plan and teach three to five consecutive integrated math/science lessons using the 5-E instructional model. Objectives must be clearly stated and evaluated in the lesson and must reflect "hands-on/minds-on" learning. Explicit use of science manipulatives and technology must also be included in the lesson. Follow the format posted on Sakai. Your cooperating teacher or university supervisor will evaluate these lessons using an LTE evaluation forms.

Lesson Plan Commentary and Evaluations (50 Points): After implementation of the lesson, you will complete and submit a professional commentary. Cooperating teacher/supervisor evaluations will be submitted along with the commentary. Follow the guidelines posted on Sakai.

Science Notebook (20 Points): Throughout the semester you will keep a science notebook. In addition, you will complete science notebook training online (AMSTI)

Science/Math Integrated Team Lesson Plan (TBL) (50 Points): You will work with your team to create a science/math integrated lesson plan. Then, you will present your lesson plan to a group of your peers.

Individual Readiness Assurance Test (iRAT) (TBL) (10 points per iRAT): There are 4 Readiness Assurance Tests (RATs) given during the course. They cover the material as indicated on the course outline. RATs may not be taken at a later date.

Team Readiness Assurance Test (tRAT) (TBL) (10 points per tRAT): Team performance will be evaluated with Team RATs. Also, in-class team activities may be graded throughout the semester. Specific instructions and grading criteria for each activity will be provided. Each member of a team will receive the same team performance score for each team RAT and activity.

Team Contribution (TBL) (10 Points): Each individual will evaluate the contributions of all the other team members at the completion of the semester. Individuals will be asked to provide differential ratings that will produce differences in grades within the team. This means that team members cannot help everyone in the team get an A by giving everyone high peer evaluation scores. The only way for everyone in a team to earn an A is by doing an outstanding job on the individual and team exams and activities. Specific criteria for peer evaluation will be presented in class.

**This course will be using a Team-Based-Learning (TBL) format (www.teambasedlearning.org). This instructional method aims to help develop your workplace learning skills and will be done in a way that will hold teams accountable for using course content to make decisions that will be reported publically and subject to cross-team discussion/critique. You will be assigned to a team with approximately 5-8 members during on the first day of class. You will sit with your team during most classroom sessions.

ASSIGNMENT	POINTS
Interdisciplinary Learning Segment	170
Commentary	50
Midterm	50
Interdisciplinary Learning Segment (TBL)	50
Sakai Units and Labs	TBA
Classroom Activities	TBA
iRATS (4 at 10 pts. each)	40
tRATS (4 at 10 pts. each) (TBL)	40
Peer and Self Evaluations (2 at 5 pts. each)	10
Science Notebook (w/online training)	50

***Please note that the instructor has the right to raise or lower grades due to subjective matters. Lack of professionalism will result in loss of points based on the instructor's discretion.

A	93-100
B	85-92
C	75-84
D	70-74
F	0-69

Assignments and Responsibility

Late Work Policy: All out-of-class assignments are due in SAKAI at 8 a.m. on the assigned date. If it is an assignment that cannot be submitted through SAKAI, it will be due at the beginning of class on the date specified. If an assignment is turned in anytime during the 24 hours after the due date and time, one-half of the total point value of the assignment will be deducted before it is graded. Assignments will not be accepted after this 24-hour period. If you are tardy, you forfeit the right to begin a quiz/activity, turn in an assignment for full credit, or begin your presentation.

All assignment responses are to be professionally written in complete sentences.

All assignment responses will be evaluated on content and writing mechanics (up to 10% deduction for grammatical mistakes).

Each group assignment is to be completed collaboratively and jointly by each group member, not "individually" by splitting the assignment into component parts. All names are to be included in the assignment header in alphabetical order.

It is the candidate's responsibility to read, comprehend and ask questions about all assigned course readings/chapters. Class time will be used primarily for demonstration lessons and engaging in research-based activities appropriate for K-6 classroom use, as well as follow-up discussions.

All assignments, including daily class activities and homework, must be completed and submitted to the instructor in order to pass the course with a "C" or higher (this includes class work missed because of an excused absence). Candidates cannot choose to not do an assignment or class activity.



Please visit the CEPS's [LiveText](#) web page for information regarding purchasing instructions and technology support:

EDU 337 Course Standards

Alabama Core Teaching Standard	Activities and Resources
Standard 1: Learner Development	
(b) The candidate creates developmentally appropriate instruction that takes into account individual learners' strengths, interests, and needs and that enables each learner to advance and accelerate his/her learning.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(h) The candidate respects learners' differing strengths and needs and is committed to using this information to further each learner's development.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(i) The candidate is committed to using learners' strengths as a basis for growth and their misconceptions as opportunities for learning.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(j) The candidate takes responsibility for promoting learners' growth and development.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
Standard 2: Learning Differences	
(a) The candidate designs, adapts, and delivers instruction to address each student's diverse learning strengths and needs and creates opportunities for students to demonstrate their learning in different ways.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Informal Evaluations
(b) The candidate makes appropriate and timely provisions (e.g., pacing for individual rates of growth, task demands, communication, assessment, and response modes) for individual students with particular learning differences or needs.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Accommodations within instruction as well as assessments
(c) The candidate designs instruction to build on learners' prior knowledge and experiences, allowing learners to accelerate as they demonstrate their understandings.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Identification of prior knowledge and possible misconceptions.
Standard 3: Learning Environments	
(i) The candidate understands the relationship between motivation and engagement and knows how to design learning experiences using strategies that build learner self-direction and ownership of learning.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Engage
(j) The candidate knows how to help learners work productively and cooperatively with each other to achieve learning goals.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Explore

Standard 4: Content Knowledge	
(h) The candidate creates opportunities for students to learn, practice, and master academic language in their content.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(j) The candidate understands major concepts, assumptions, debates, processes of inquiry, and ways of knowing that are central to the discipline(s) she/he teaches.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(k) The candidate understands common misconceptions in learning the discipline and how to guide learners to accurate conceptual understanding.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Identification of prior knowledge and possible misconceptions
(l) The candidate knows and uses the academic language of the discipline and knows how to make it accessible to learners.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Academic language embedded in higher order questions
(m) The candidate knows how to integrate culturally relevant content to build on learners' background knowledge.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Commentary and Lesson Evaluations
(n) The candidate has a deep knowledge of student content standards and learning progressions in the discipline(s) she or he teaches.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(o) The candidate has deep knowledge of current and emerging state initiatives and programs including, but not limited to, the Alabama Reading Initiative (ARI); the Alabama Math, Science, and Technology Initiative (AMSTI); Alabama Learning Exchange (ALEX); Alabama Connecting Classrooms, Educators and Students Statewide (ACCESS); and RTI (Response to Instruction) and their relationship to student achievement.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
Standard 5: Application of Content	
(a) The candidate develops and implements projects that guide learners in analyzing the complexities of an issue or question using perspectives from varied disciplines and cross-disciplinary skills (e.g., a water quality study that draws upon biology and chemistry to look at factual information and social studies to examine policy implications).	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration
(b) The candidate engages learners in applying content knowledge to real world problems through the lens of interdisciplinary themes (e.g., financial literacy, environmental literacy).	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration

(c) The candidate facilitates learners' use of current tools and resources to maximize content learning in varied contexts.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration
(e) The candidate develops learners' communication skills in disciplinary and interdisciplinary contexts by creating meaningful opportunities to employ a variety of forms of communication that address varied audiences and purposes.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration
(i) The candidate understands the ways of knowing in his/her discipline, how it relates to other disciplinary approaches to inquiry, and the strengths and limitations of each approach in addressing problems, issues, and concerns.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration
Standard 7: Planning for Instruction	
(b) The candidate plans how to achieve each student's learning goals, choosing appropriate strategies and accommodations, resources, and materials to differentiate instruction for individuals and groups of learners.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Accommodations within instruction and assessments
(c) The candidate develops appropriate sequencing of learning experiences and provides multiple ways to demonstrate knowledge and skill.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Commentary and Lesson Evaluations
(g) The candidate integrates Alabama-wide programs and initiatives into the curriculum and instructional processes.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Commentary and Lesson Evaluations
(i) The candidate understands content and content standards and how these are organized in the curriculum.	Three-Day Interdisciplinary Science and Mathematics Unit Plan
(j) The candidate understands how integrating cross-disciplinary skills in instruction engages learners purposefully in applying content knowledge.	Three-Day Interdisciplinary Science and Mathematics Unit Plan: Evidence of Authentic STEM Integration
Standard 8: Instructional Strategies	
(l) The candidate knows when and how to use appropriate strategies to differentiate instruction and engage all learners in complex thinking and meaningful tasks.	Three-Day Interdisciplinary Science and Mathematics Unit Plan

EDU 337: Teaching Science

Tentative Schedule: Monday and Wednesday

Date	Due	Class Topics
M 1/8		-Syllabus and Schedule -NOS Tubes -Science Notebooks
W 1/10	Sakai Unit 1	-RAT #1 -Science Literacy -Inquiry
M 1/15		MLK DAY
W 1/17		ONLINE ASSIGNMENT -LAB 1 (Individual) Science Notebooks
M 1/22	Sakai Unit 2	-Science Standards -Inquiry
W 1/24		-Ecosystems Lesson 4 and 5 (Aquarium Animals) -Standards (continued) -Reading in science
M 1/29		-Co-Teaching Workshop: Standards and Learning Progressions
W 1/31	Sakai Unit 3	-RAT #2 -5E Instructional Cycle
M 2/5		-Questioning -5E Instructional Cycle
W 2/7		-What is Technology?
M 2/12		ONLINE ASSIGNMENT -Science Notebooks
W 2/14	Sakai Unit 4	-RAT #3 -STEM and EDP
M 2/19	Sakai Unit 5	-STEM and EDP
W 2/21		-Co-Teaching Workshop: STEM -LAB 2 (Team) Unpack team standards and create a planning wheel
M 2/26	Midterm (Online)	-Co-Teaching Workshop: STEM -LAB 3 (Team) Team Lesson Planning
W 2/28	Sakai Unit 6	-Assessment and Evaluation in Science
M 3/5		FIELD WEEK 1
W 3/7		FIELD WEEK 1
M 3/12		-Central Focus—Objectives—Evaluation
W 3/14		-Planning
M 3/19	Team learning segment (3 hard copies)	-Co-Teaching Workshop: Lesson Planning Stations -LAB 4 (Team) Lesson Planning
W 3/21	Team Learning Segment and Presentation	-Co-Teaching Workshop: Team Presentations

M 3/26		SPRING BREAK
W 3/28		SPRING BREAK
M 4/2		-Planning: Instruction
W 4/4		-Planning: Instruction -Commentary Questions
M 4/9	Sakai Unit 7	-TRAT #4 -LEGO Robotics
W 4/11	Science Notebooks (Notebook and Online Training)	Planning Workshop
SUN 4/15	3-Day Integrated Learning Segment	
M 4/16		FIELD WEEK 2
W 4/18		FIELD WEEK 2
M 4/23		FIELD WEEK 3
W 4/25		FIELD WEEK 3
M 4/30	-Commentary -Self Assessment	

***On days with "Co-Teaching Workshops and Labs" you will come to the Science Lab to complete your "Lab" for the day during science time. We will have full instruction during your math time.

*All assignments and Sakai Units are due online by 8am (unless otherwise noted) on the date specified by your instructor (Late Work Policy is located in the Syllabus).

*All courses progress at different rates, so this schedule is subject to change.

APPENDIX L – Sample Integrated STEM Learning Segment

Three-Day Integrated Science and Mathematics Lesson Plan Format Spring 2018

Vital Information – 3-5 Day Unit			
Author		Subject(s)	Science and Math
Grade Level	K	Central Focus	Science: Weather Patterns Math: Categories (Counting)
Standard(s) <i>List the full standard with its number.</i>	<p>ALCOS Math 16. Classify objects into given categories; count the number of objects in each category, and sort the categories by count. (Limit category counts to be less than or equal to 10.) [K-MD3]</p> <p>Standards of Mathematical Practice 1. Make sense of problems and persevere in solving them. 3. Construct viable arguments and critique the reasoning of others. 4. Model with mathematics. 7. Look for and make use of structure.</p> <p>ALCOS Science 9. Observe, record, and share findings of local weather patterns over a period of time (e.g., increase in daily temperature from morning to afternoon, typical rain and storm patterns from season to season).</p> <p>Scientific and Engineering Practices Analyzing and interpreting data</p> <p>Crosscutting Concepts Patterns</p>		
Student Learning Objective(s) <i>List all objectives for the lesson. Objectives must be measurable, observable, and based on lesson content.</i>	<p>Science Given a calendar with weather data, students will sort the weather types (sunny, cloudy, partly cloudy, rainy) within the month into four categories on a chart.</p> <p>Math Given a calendar with weather data, students will sort the different weather types into four</p>		

	categories, count how many are in each category, and add/subtract to find out how many days had certain weather types.
Justification for Goals and Objectives – All 3 Days	
<i>Description of what the students already know about the topic and their gaps in knowledge.</i>	
Prior Academic Knowledge and Conceptions <i>What prior knowledge, skills, and concepts must students already know to be successful with this lesson?</i>	<p>Science</p> <ul style="list-style-type: none"> Students must know what sunny, cloudy, partly cloudy, and rainy weather is. <p>Math</p> <ul style="list-style-type: none"> Students must know how to count in order from 1 to 10.
Common Errors <i>What are common errors or misunderstandings of students related to the central focus of this lesson?</i> <i>How will you address them for this group of students?</i>	<p>Science Misconceptions</p> <ul style="list-style-type: none"> Students may confuse partly cloudy weather with cloudy weather. <p>Address</p> <ul style="list-style-type: none"> I will explain that we have partly cloudy weather when we can see the sun along with the clouds. I will show them a picture of what partly cloudy looks like. <p>Math Misconceptions</p> <ul style="list-style-type: none"> Students may not know what a category is. <p>Address</p> <ul style="list-style-type: none"> I will give an explanation and an example related to the lesson.
Instructional Strategies and Learning Tasks – Day 1	
<i>Description of what the teacher (you) will be doing and/or what the students will be doing.</i>	
Launch <u> 5 </u> Minutes <i>How will you assess prior knowledge?</i> <i>How will you start the lesson to engage and motivate students in learning?</i> <i>State the objectives in student terms.</i>	<p>Engage</p> <ul style="list-style-type: none"> “During our carpet time this morning, we noticed that it was sunny/cloudy/partly cloudy/rainy today.” “Will the helper of the day please stand up and come with me to see what the weather looks like now?” Start singing the weather song as a class while the helper checks the weather. Student will announce the weather and go back to the carpet. (If the weather is the same as it was in the morning, I will tell the students that sometimes the weather stays mostly the same during the day. If the weather is different than it was in the morning, I will tell the students that sometimes weather changes throughout the day).

<p>Instruction __20__ Minutes</p> <p><i>List (numbered steps or bullets are fine) the steps for your instruction, based on the student learning objective and assessment.</i></p> <p><u>Make sure you address/demonstrate the following:</u></p> <p><i>How will students participate in inquiry-based (hands-on/minds-on) learning?</i></p> <p><i>How will you link the new content (skills and concepts) to students' prior academic learning and their personal/cultural and community assets?</i></p> <p><i>What will you say and do? What questions will you ask? How will you monitor students and provide feedback?</i></p> <p><i>How will students engage with one another?</i></p>	<ul style="list-style-type: none"> • "Today, we will review types of weather that we have had this month and count how many times each type has occurred." <p>Explore</p> <ul style="list-style-type: none"> • "Why do you think it's important that we check the weather every day?" (Students will respond). • "It's important to check the weather because we need to make sure that we are prepared for it. If I turned on the news and I saw that it was going to rain, what would I need to bring with me when I leave my house?" (Students will respond). • "Why do you think that I would need a jacket?" • "What other type of weather would someone need an umbrella for and why?" • Display weather and clothing cutouts • Start with the rain cutout. Hold it up and ask students which article of clothing would be needed when it's raining outside. • Do this again with the sunny cutout. • "We're going to be seeing more sunshine as it gets closer to summer." <p>Explain</p> <ul style="list-style-type: none"> • "Let's take a look at the month of April on our calendar and see how the weather changed throughout the month." • List types of weather on the big chart (on board). Count the number of sunny days. Write the number on the chart under sunny. • "Let's count how many cloudy days there has been this month." Class will count. I will write the number on the chart under cloudy. • "Why do you think it's important to sort the weather into categories like this?" • Complete partly cloudy and rainy together. • "We have had 8 sunny days and 6 cloudy days this month. I want to see how many more sunny days we had." Write 8-6. • "Why do you think I decided to subtract?" • Draw 8 dots. Cross out 6. I see that we had 2 more sunny days than we had cloudy days. (Write and say 8-6=2). • Count rainy and partly cloudy days with the class. Write numbers on chart. Subtract. • "Which type of weather have we had the most of this month? Which one have we seen the least?" • "Why would we add to find the least amount?"
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<p>Closure __5__ Minutes</p> <p><i>How will you end the lesson?</i></p> <p><i>How will you determine if students are meeting the intended learning objectives?</i></p>	<ul style="list-style-type: none"> • "It was fun to look back at the past few weeks and see what types of weather we have seen!" • "What's something that you have learned today?" • "Today, we made categories for the different types of weather from this month and counted how many were in each category." • "I would like you all to go home and find items that can represent each season."
<p>Instructional Strategies and Learning Tasks – Day 2</p> <p><i>Description of what the teacher (you) will be doing and/or what the students will be doing.</i></p>	
<p>Launch __5__ Minutes</p> <p><i>How will you assess prior knowledge?</i></p> <p><i>How will you start the lesson to engage and motivate students in learning?</i></p> <p><i>State the objectives in student terms.</i></p>	<p>Engage (Spring temperature)</p> <ul style="list-style-type: none"> • "I'm sure that everyone is noticing that it's getting warmer outside. You won't be needing your jackets to go out to recess much longer." • "What are some things that we can do outside now that we couldn't do when it was cold? Why is warmer weather better for that activity?" • "Today, we are going to look at the temperatures that we have had so far this month, see how the temperature has been changing, and place these temperatures into categories."
<p>Instruction __30__ Minutes</p> <p><i>List (numbered steps or bullets are fine) the steps for your instruction, based on the student learning objective and assessment.</i></p> <p><u>Make sure you address/demonstrate the following:</u></p> <p><i>How will students participate in inquiry-based (hands-on/minds-on) learning?</i></p> <p><i>How will you link the new content (skills and concepts) to students' prior academic learning and their personal/cultural and community assets?</i></p> <p><i>What will you say and do? What questions will you ask? How will you monitor students and provide feedback?</i></p> <p><i>How will students engage with one another?</i></p>	<p>Explore</p> <ul style="list-style-type: none"> • "What is temperature?" (Students will respond). • "Do the numbers get bigger or smaller when it gets warmer and why do you think that?" • "Why do you think it's important to know an exact number for temperature instead of just saying it's warm?" • Review how the weather has changed since winter. • "When I think of spring, I think of flowers because I know people that want to plant some right now. What is something that makes you think of spring and why?" (Write answers on the board). • Read <i>And Then It's Spring</i> • Talk about the ways that the weather changes in the book. • "What do you think would happen if it was spring all year long and why?" <p>Explain</p> <ul style="list-style-type: none"> • "Let's look at the calendar for this month. The temperatures for each day are written in the day's box. We are going to look at the temperatures that are in the 60s, 70s, and 80s."

	<ul style="list-style-type: none"> ● Label chart on board with temperatures. ● “These temperatures are common for spring in our area. We are starting to feel heat outside.” ● “We are starting to have warmer weather in Alabama, but that doesn’t mean that it’s getting warmer in every state. This time of the year in New York can actually be quite different. This time of year is usually warmer here than it is there. Let’s see where New York is on the map.” (Point out where New York is). ● “Why do you think that different places may have different temperatures?” (Students will respond). ● “Let’s go back to the temperatures from Saraland, Alabama on the chart.” ● “I’m going to count the number of days that has a temperature in the 60s.” ● Count aloud and write the number on the chart. ● “Let’s do the same for the 70s and 80s.” (We’ll do this as a class). ● “How many more days were in the 60s than in the 70s?” ● “Why is it important to know this number?” ● “How many more days were in the 70s than in the 80s?” ● “Why did I subtract?” ● “How many days were in the 60s and the 70s? Would we add or subtract and why would we do that?” (Students will respond). ● “The temperature has been the highest this last week. Why do you think the temperature is getting higher as the month goes on?”
<p>Closure __5__ Minutes</p> <p><i>How will you end the lesson?</i></p> <p><i>How will you determine if students are meeting the intended learning objectives?</i></p>	<ul style="list-style-type: none"> ● “Today, we have learned about the weather in the current season.” ● “What did you learn today?” (Students will respond). ● “We also looked at the temperatures from this month and counted the days that were in the 60s, 70s, and 80s. I’d like you all to think about how the temperature will change as we get closer to summer.”
<p>Instructional Strategies and Learning Tasks – Day 3</p> <p><i>Description of what the teacher (you) will be doing and/or what the students will be doing.</i></p>	
<p>Launch __5__ Minutes</p> <p><i>How will you assess prior knowledge?</i></p> <p><i>How will you start the lesson to engage and</i></p>	<p>Engage (Other seasons and temperatures)</p> <ul style="list-style-type: none"> ● “Yesterday, we talked about spring and how the weather is getting warmer.” ● “Summer comes after spring. When I think of summer, I think of the beach! What do

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<p><i>motivate students in learning?</i></p> <p><i>State the objectives in student terms.</i></p>	<p>you think of when you think of summer?” (I will write student answers on chart paper). “It sounds like everyone is ready for summer!”</p> <ul style="list-style-type: none"> ● “Today, we are going to talk about the different seasons and how the weather and temperature changes during each season.”
<p>Instruction __30__ Minutes</p> <p><i>List (numbered steps or bullets are fine) the steps for your instruction, based on the student learning objective and assessment.</i></p> <p><u>Make sure you address/demonstrate the following:</u></p> <p><i>How will students participate in inquiry-based (hands-on/minds-on) learning?</i></p> <p><i>How will you link the new content (skills and concepts) to students’ prior academic learning and their personal/cultural and community assets?</i></p> <p><i>What will you say and do? What questions will you ask? How will you monitor students and provide feedback?</i></p> <p><i>How will students engage with one another?</i></p>	<p>Explore</p> <ul style="list-style-type: none"> ● Show students items (related to weather) associated with different seasons. These are the items that I will show: a bottle of sunscreen, a scarf, and flower seeds. ● Students will guess for remaining items (gloves, a pumpkin, a beach towel, and an umbrella). ● Talk about why these items are associated with the season. Make the connection with temperature for some items. ● “What other season would gloves be used in and why?” ● Read <i>Seasons</i>. Point out words that relate to a season’s weather. ● “After seeing how nature changes during the seasons, what do you think would happen if it was winter all year long and why?” <p>Explain</p> <ul style="list-style-type: none"> ● Display June 2017 calendar and temperatures ● Discuss season and activities for season ● Create categories for temperatures ● “Why were June’s temperatures higher than April’s?” ● Display October 2017 calendar and temperatures ● Discuss season and activities for season ● Create categories for temperatures ● “Why do you think that there were the same number of days in the 80s in both of these months?” ● “Why were October’s temperatures lower than June’s?” ● Display December 2017 calendar and temperatures ● Discuss season and activities for season ● “How many days were in the 80s in all three months? Do you add or subtract?” ● “Why do we add to find the total number of days in the 80s?” ● “Now that we’ve looked at months in different seasons, which two seasons have more temperatures in common and why do you think that?” ● “Why would I add to figure this out?”

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<p>Closure <u> 5 </u> Minutes</p> <p><i>How will you end the lesson?</i></p> <p><i>How will you determine if students are meeting the intended learning objectives?</i></p>	<ul style="list-style-type: none"> • “It’s been so much fun learning about <u>weather</u> these past few days!” • “What are some things that you’ve learned about?” (Students will respond). • We have talked about types of weather and how the weather affects our lives. You’ve had the chance to look at a calendar and sort weather types in categories. Next time you look at weather data, look for patterns within the weather types and temperatures.”
Additional Requirements- Only complete once for the unit	
<p>Elaboration (math and science)</p> <p><i>At completion of the three days</i></p> <p><i>How will you extend students’ learning in a new way?</i></p> <p><i>How will you connect these concepts to the real world?</i></p>	<p>Meteorologists (5 Day Forecast)-</p> <p>When this unit is over, students can pretend to be meteorologists and make their own 5 Day Forecast. We will talk about what a meteorologist is and what they do. I will show the students examples of 5 Day Forecasts. We will talk about how weather is predicted and the students will make their own predictions. They will present their 5 Day Forecast in front of the class. We will count how many people predicted sunny, cloudy, partly cloudy, or rainy weather during the week. We will also talk about why it’s important to predict weather.</p>
<p>Higher-Order Questions</p> <p><i>Copy and paste the questions from throughout the unit.</i></p>	<p>12 Science Questions:</p> <ul style="list-style-type: none"> • Why do you think it’s important that we check the weather every day? (Day 1:Explore) • Why do you think that I would need a jacket? (Day 1:Explore) • What other type of weather would someone need an umbrella for and why? (Day 1:Explore) • Why is warmer weather better for that activity? (Day 2:Engage) • What is something that makes you think of spring and why? (Day 2:Explore) • What do you think would happen if it was spring all year long and why? (Day 2:Explore) • Why do you think the temperature is getting higher as the month goes on? (Day 2:Explain) • Why do you think that different places may have different temperatures? (Day 2:Explain) • What other season would gloves be used in and why? (Day 3:Explore) • After seeing how nature changes during the seasons, what do you think would happen if it was winter all year long and why? (Day 3:Explore) • Why were June’s temperatures higher than April’s? (Day 3:Explain) • Why were October’s temperatures lower than June’s? (Day 3:Explain)

	<p>12 Math Questions:</p> <ul style="list-style-type: none"> • Why do you think I decided to subtract? (Day 1:Explain) • Why do you think it’s important to sort the weather into categories like this? (Day 1:Explain) • Why would we add to find the least amount? (Day 1:Explain) • Do the numbers get bigger or smaller when it gets warmer and why do you think that? (Day 2:Explore) • Why do you think it’s important to know an exact number for temperature instead of just saying it’s warm? (Day 2:Explore) • Why is it important to know this number? (Day 2:Explain) • Why did I subtract? (Day 2:Explain) • Would we add or subtract and why would we do that? (Day 2:Explain) • Why do you think that there were the same number of days in the 80s in both of these months? (Day 3:Explain) • Why do we add to find the total number of days in the 80s? (Day 3:Explain) • Now that we’ve looked at months in different seasons, which two seasons have more temperatures in common and why do you think that? (Day 3:Explain) • Why would I add to figure this out? (Day 3:Explain)
<p>Differentiation/Planned Support</p> <p>Over all three days</p> <p><i>How will you provide students access to learning based on individual and group needs?</i></p> <p><i>How will you support students with gaps in the prior knowledge that is necessary to be successful in this lesson?</i></p>	<p><i>Groups of students with similar needs:</i></p> <p>If more than one student is having trouble subtracting the numbers from the categories, I will model how to complete something similar to what they are working on in a small group.</p> <p><i>Individual students:</i></p> <p>If a student is becoming confused by the different categories, I will explain the concept of a category and review how we are using them in this lesson.</p>
<p>What Ifs</p> <p>Over all three days</p> <p><i>What might not go as planned and how can you be ready to make adjustments?</i></p>	<ul style="list-style-type: none"> • If one of the books are misplaced, I can show the students a video that covers the same material. • If a student is absent on a day during this unit, I will go to the student during center time and review the material with them.
<p>Plan for Transitions</p> <p><i>How will you plan for seamless</i></p>	<p><i>Pre-corrections:</i></p> <p>I will give students a task to think about when we are making transitions.</p>

<i>transitions? (Academic and social behaviors)</i>	
Positive Reinforcement of Expected Behaviors	I will praise positive behavior.
Resources and Materials Over all three days <i>What materials are needed for this lesson?</i>	Day 1: <ul style="list-style-type: none"> Calendar with April's weather data (big calendar with weather types and temperatures) Big weather chart (on board) Weather and clothing cutouts Day 2: <ul style="list-style-type: none"> Calendar with April's weather data (big calendar with weather types and temperatures) Big weather chart (on board) Season items Book- <i>And Then It's Spring</i> Map Day 3: <ul style="list-style-type: none"> Calendars with weather data (big calendar with weather types and temperatures) Big weather charts (on board) Chart paper Book-<i>Seasons</i> 21 assessment calendars 21 assessment charts
Assessments (Evaluation)- One Summative Evaluation for the Unit	
<i>Describe the tools/procedures that will be used in this lesson to monitor students' learning of the lesson objective(s). Attach a copy of the completed assessment to this document.</i>	
Description of the Assessment <i>Describe the tools/procedures that will be used to evaluate whether students met the learning objective.</i> <i>Make sure that both the science and math concepts are assessed.</i>	Students will be given a calendar of April 2017. This calendar will include weather data. The students will just use the first three weeks of the month. The students will be given a chart with weather types listed at the top (sunny, cloudy, partly cloudy, and rainy). Students will count the types of weather in the month and place that number in the weather category that it belongs in on the chart. There will be three questions for math that involve adding and subtracting the types of weather in the month. I will read the questions aloud to the whole

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<i>Does the assessment match the learning objective and central focus?</i>	class. Math questions- How many more days were sunny than cloudy? How many more days were cloudy than partly cloudy? How many days were sunny and partly cloudy?
Modifications to the Assessment <i>How can you modify the assessment for students with identified learning needs?</i>	Students with identified learning needs will be given a calendar with two types of weather instead of four. They will only be required to count the two weather types.
Evaluation Criteria <i>How will you evaluate your assessment? Attach a completed assessment (with the answers filled in) showing the criteria.</i>	Students will look at weather types for days of a month on a calendar. The students will count the number of particular types (sunny, cloudy, partly cloudy, and rainy) and write the number of days with this weather type in it's category on a chart. They should record that there were ten sunny days, five cloudy days, three partly cloudy days, and three rainy days. They will answer the math questions related to the number of days in the categories. After the students complete this assessment, I will know if they understand these concepts.

APPENDIX M – Final Quantitative Phase Recruitment Email

Details



EDU-335-701 Spring Semester 2018: My dissertation research questionnaires

Cc: Kelly Byrd,

Reply-To: Brannon 🤔 Byrd

Hi everyone!

I want to thank you again for being an integral part of my dissertation study titled "Elementary Preservice Teacher Preparation to Teach Mathematics and Science in an Integrated STEM Framework." Now that you have reached the halfway point in your internship semester, and as my study enters into the final data collection phase, I would greatly appreciate you completing the questionnaires and answering the open-ended questions that have been added to the original questionnaires. I know how busy you are, and I sincerely appreciate your time in helping me with my study. You have no idea how much this means to me. Thank you all so very much!! The links to both questionnaires are included.

Math love,

Ms. Byrd

STEM Attitude Questionnaire Tier 4

https://southalabama.az1.qualtrics.com/jfe/form/SV_4YC85QtmZH7zxP

STEM Confidence Questionnaire Tier 4

https://southalabama.az1.qualtrics.com/jfe/form/SV_9RKrwAzifooWA6x

APPENDIX N – Focus Group Recruitment Email

Kelly Byrd (kbyrd@southalabama.edu)

Inbox - Google April 24, 2018 at 1:53 PM

KB

EDU-335-701 Spring Semester 2018: Tier 3 focus group participationCc: Kelly Byrd,

Reply-To: kbyrd@southalabama.edu

Good morning!

We would like to ask a professional favor. As you know, we've been conducting research this semester on integrated STEM and co-teaching. We are trying to make Tier 3 the most meaningful experience it can be! We would like to talk to you in a focus group with your peers to ask your opinions about this semester. We will talk about integrating mathematics and science in a STEM framework, co-teaching, and anything else you want to share!

We would like to do this focus group next Wednesday from 11:00 - 12:00 (since you'll already be on campus for your exam).

We will have snacks and drinks for you!

Please respond back to this email and let us know if you can (or cannot) be a part of the focus group. We would be so appreciative if you are able to help us with this process!

Thank you,

Dr. Allison, Dr. Johnson, and Ms. Byrd

APPENDIX O – Questionnaire Mean Item Responses

Table A1. *STEM Attitudes Questionnaire Mean Item Responses (N = 24)*

Item Number	Time 1	Time 2	Time 3
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
1	6.42 (1.02)	6.42 (0.72)	5.83 (1.37)
2	6.46 (0.59)	6.42 (0.65)	5.83 (1.20)
3	5.75 (0.94)	6.17 (0.82)	5.87 (1.26)
4	4.08 (1.82)	4.83 (1.93)	5.17 (1.62)
5	4.29 (1.71)	4.96 (1.65)	5.46 (1.47)
6	3.96 (1.08)	4.50 (1.29)	4.13 (1.39)
7	5.38 (1.31)	5.33 (1.63)	5.58 (1.56)
8	4.75 (1.19)	4.50 (1.62)	4.92 (1.64)
9	5.29 (1.33)	5.50 (1.22)	5.37 (1.14)
10	4.46 (1.53)	4.92 (1.53)	4.88 (1.48)
11	5.92 (0.88)	6.00 (0.83)	5.88 (0.95)
12	5.54 (1.44)	5.71 (1.49)	6.13 (1.30)
13	6.29 (0.86)	6.08 (0.72)	6.12 (0.80)
14	4.13 (1.80)	4.71 (1.52)	4.63 (1.77)
15	5.29 (1.57)	5.83 (0.87)	5.83 (1.34)
16	4.75 (1.45)	5.25 (1.36)	5.17 (1.20)
17	3.88 (1.45)	4.46 (1.38)	4.25 (1.65)
18	5.42 (1.14)	5.75 (1.07)	5.75 (1.19)
19	5.63 (1.10)	5.92 (0.78)	5.92 (1.02)
20	4.92 (1.35)	5.46 (1.22)	5.17 (1.90)
21	6.04 (0.90)	6.08 (0.72)	5.83 (0.92)
22	2.25 (1.11)	2.38 (1.01)	2.79 (1.50)
23	6.17 (1.17)	6.17 (0.70)	6.13 (1.15)
24	4.25 (1.60)	4.33 (1.69)	4.54 (1.72)

25	5.96 (1.30)	5.92 (1.02)	5.00 (1.35)
26	3.96 (1.71)	4.83 (1.61)	5.25 (1.54)
27	5.83 (1.17)	6.12 (0.74)	6.08 (0.83)
28	2.75 (1.29)	2.83 (1.17)	3.38 (1.47)
29	6.25 (1.03)	6.17 (0.70)	6.29 (0.81)
30	5.83 (0.92)	6.08 (0.72)	6.13 (0.85)
31	6.21 (1.06)	6.00 (1.25)	6.04 (1.43)
32	3.16 (1.52)	2.79 (1.41)	3.04 (1.40)
33	4.67 (1.69)	4.58 (1.61)	5.04 (1.49)
34	3.13 (1.36)	3.92 (1.56)	3.17 (1.47)

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

Table A2. *STEM Confidence Questionnaire Mean Item Responses*($N = 24$)

Item Number	Time 1	Time 2	Time 3
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
1	2.75 (0.61)	3.29 (0.55)	3.33 (0.57)
2	2.92 (0.78)	3.17 (0.48)	3.21 (0.51)
3	2.79 (0.72)	2.92 (0.65)	3.21 (0.59)
4	2.96 (0.75)	3.00 (0.51)	3.21 (0.59)
5	2.92 (0.83)	3.17 (0.57)	3.17 (0.64)
6	3.17 (0.70)	3.46 (0.51)	3.38 (0.58)
7	3.04 (0.62)	3.38 (0.71)	3.30 (0.64)
8	3.33 (0.70)	3.54 (0.51)	3.50 (0.51)
9	3.17 (0.64)	3.42 (0.58)	3.25 (0.53)
10	3.12 (0.80)	3.33 (0.57)	3.25 (0.61)
11	2.79 (0.72)	3.38 (0.58)	3.39 (0.58)
12	2.88 (0.61)	3.29 (0.62)	3.33 (0.64)
13	2.75 (0.74)	3.33 (0.57)	3.25 (0.53)
14	2.75 (0.68)	3.33 (0.48)	3.17 (0.57)
15	3.13 (0.74)	3.38 (0.58)	3.29 (0.62)
16	3.25 (0.68)	3.54 (0.51)	3.50 (0.59)
17	3.08 (0.78)	3.50 (0.59)	3.33 (0.64)
18	3.17 (0.76)	3.42 (0.58)	3.42 (0.65)
19	3.04 (0.62)	3.50 (0.51)	3.42 (0.65)

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.

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