Beyond the Acronym of STEM: Experiential Learning Professional Development for Integrative STEM Education

Christine Mitchell

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Beyond the Acronym of STEM: Designing Experiential Learning Professional Development for Integrative STEM Education

by

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Dedication

This dissertation is dedicated to my husband, Johnathan. I couldn’t have accomplished this without your love and encouragement. Thank you for believing in me, always being there to celebrate my wins, and supporting me when I need it the most.
Acknowledgements

Thank you to my family for always motivating me to work hard to achieve my dreams. I am thankful for your continued love and support throughout this journey.

I am so grateful for my work family. Thank you for all the love and support you’ve given me the past three years. You all are the best cheerleaders a person could ever have.

I couldn’t have done this without the support of my advisor, Dr. Yee. Thank you for taking me on as your advisee and for always being supportive during my doctoral journey.
Abstract

STEM education and integrative STEM education are increasingly popular in the K-12 domain. However, there is not a consensus on their definitions, nor a sufficient amount of instructional support to help teachers that are unfamiliar with these learning approaches. This study examined how an intentionally designed experiential professional development model impacted the application of integrative STEM practices and teachers’ perceptions of this student-centered approach. A qualitative approach allowed for an integration of various perspectives over multiple cycles of professional development, reflection, and application. Data was collected from a focus group discussion, pre- and post-classroom observations, teacher reflection journals, and a post-study Google survey. Results revealed that an intentionally designed PD for integrative STEM education helped transform potential barriers relevant to this learning approach. This led to an increase in teachers’ confidence and competence for integrative STEM applications in the classroom. This study contributes to the existing studies relevant to experiential learning theory applications in education, professional development, and integrative STEM education.

Keywords: engineering design process, experiential learning, integrative STEM education, professional development
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Chapter 1: Introduction

There are two STEM related questions I often ask educators at state and national conferences: “What is STEM?” and “Does your district provide STEM opportunities?” I ask this to anticipate three answers I hear too often:

- STEM is Science, Technology, Engineering, and Mathematics,
- zero support in STEM opportunities, and
- hearing that different districts and educators observe various acronyms that they believe build on STEM, such as “STEAM” (adding “A” for arts), “STREAM” (adding “R” for reading), “STREAMER” (adding an additional “R” for religion and an “E” for economics), “STREAMA” (adding an additional “A” for agriculture), and in one case, “HAMSTER” (adding a “H” for humanities).

This is indicative of a major problem in K-12 education as this shows that there is no universal understanding of STEM education. I have experienced this lack of clarity regarding STEM education firsthand earlier in my career and in present time, observe other educators experience the same unclarity of STEM education.

Math and science are two areas that I have always had an interest in throughout school. When I attended college, I decided to pursue a degree in Middle Grades Education with concentrations in math and science. I graduated
with my bachelors in 2009 and was immediately granted the opportunity to teach middle school math and science. As a researcher, I always tried to find differentiated ways to increase my students' engagement in class that did not come from a textbook or worksheet. My goals were to help my students build their lifelong skills by creating learning opportunities for them to communicate with one another, collaborate effectively, problem-solve, and find real-world connections to math and science. However, the only experience I had in providing instruction is what I experienced as a student working from worksheets and learned from my clinical teachers during student teaching, which was to teach from the textbook with an aim focused on passing scores on the end of year summative exam. My personal experience as a student with extremely limited access to hands-on learning or labs provided me the motivation to explore different learning approaches to engage my own students to prevent them from losing interest in learning.

I spoke with my administrator about my interest in attending a workshop focused on understanding and applying Science, Technology, Engineering, and Mathematics (STEM) instructional approach into the classroom setting. The training was provided by an educational research institute, and they modeled how an integrative STEM activity could transform the classroom to create an engaging and authentic learning experience for teachers and students. This opportunity provided me with the foundational knowledge of how an integrative STEM educational approach could help students develop skills that will help students work towards becoming 21st century learners. Despite the depth of
useful information shared, it was a one-time training. Without any additional support, feedback, or coaching, I ultimately reverted to teaching math and science with limited integrative STEM integration. However, I recognized the potential that integrative STEM education has in the classroom and worked to establish a strong knowledge base through research journals, articles, and participating in a professional learning community with other educators. My self-directed learning approach was in response to a lack of integrative STEM professional development in my county. As my knowledge of integrative STEM grew, I was able to apply this into my own classroom and experienced student successes through this student-centered approach. Observing the developing inquiry in my students and noticeable absence of support for integrative STEM education motivated me to move into a district role to work with teachers to make a bigger impact in my county. My passion for integrative STEM education has grown as I have progressed throughout my teaching career, which ultimately led me to a current role in my county as the district STEM coordinator.

My position allowed me the opportunity to work in all schools and observe teachers in their classroom setting. A noticeable trend I observed was the absence of classroom practices that are commonly present in an integrative STEM pedagogical approach, particularly at the elementary level, such as collaborative groups, interdisciplinary teaching, inquiry investigations, and connections to real-world problems (Bybee, 2010). Inquiry and transdisciplinary learning experiences rooted within integrative STEM activities were not evident in lessons. After engaging in conversations with elementary teachers and support
personnel, I learned that teachers did not know what integrative STEM education was, nor did they know that STEM was an acronym for Science, Technology, Engineering, and Mathematics. Some teachers attempted to incorporate what they believed were integrative STEM hands-on activities despite not having proficient training and guidance on practical implementation, if at all. Teachers developed an overall misconception of what it means to take an integrative STEM approach, as supported by Kelly & Knowles (2016) where hands-on instruction involving activities and labs were misconstrued as high-quality inquiry instruction. The disconnect between what integrative STEM education entails and what was observed in the classroom setting were apparent, and activities focused more on having fun than providing instructional value and real-world connections. For example, one observation was made in a classroom where students were building structures using Legos without an established learning goal or connection to curriculum. Teachers grew increasingly frustrated with the lack of support which generated mixed perceptions regarding integrative STEM education. This frustration, along with the conversations I have had with other educators from national conferences, highlights a problem in our instructional structure for districts that need to be addressed, thus providing the need and foundation for this action research study.

**Problem of Practice**

The problem of practice for this study centered around the lack of understanding and instructional support, such as effective professional development, to cultivate teacher knowledge and understanding of integrative
STEM education for our upper elementary classrooms. Without accurate foundational knowledge of integrative STEM learning approaches with instructional support, frustrations from teachers who bear the expectation to implement an initiative without effective training and resources can negatively influence the perception of integrative STEM education for teachers, which could hinder the implementation of student-centered learning practices. This problem of practice is not indicative of my professional context and is supported by research as a bigger issue in the field of integrative STEM education (Al Salami et al., 2017; Havice et al., 2018; Kelley & Knowles, 2016). Implementing a strong STEM cognitive task requires instructors to (1) know what to look for, (2) how to facilitate learning, (3) how to ask effective questions, and (4) how to allow that task to grow cyclically with student understanding so students can apply critical thinking skills to understand the problem in question. Thus, teachers will need support not only in understanding what the integrative STEM approach is but knowing how to use this approach as the foundation to instructional practice, adjust from a traditional classroom mindset to a student-centered classroom where teachers facilitate the learning, and formatively assess student understanding during the task.

Addressing this problem of practice will grow the field’s knowledge and options for helping teachers build an understanding of the integrative STEM approach and to provide support in the integration of the STEM learning approach. This is a critical need in education because of the frameworks or models that help teachers learn how to effectively use the integrative STEM
approach in their classroom setting (Wang et al., 2011). This is the foundation needed for the teachers in my district to move forward in providing learning opportunities that are needed for students to become STEM-literate members of society. To address this problem, I designed and implemented two professional development opportunities to immerse teachers in a cycle of training, implementation, and reflection where they will receive support in understanding the integrative STEM approach to learning.

**Theoretical Framework**

Experiential Learning Theory, developed by Kolb (1984), is the theoretical framework of this study. Experiential learning theory emphasizes that as learners go through different experiences, they continually reform their understanding of a belief or idea. This theory, supported by the foundational works of Lewin, Dewey, and Piaget, was designed by combining the similar characteristics of their experiential learning models. Kolb’s four stage learning cycle includes a cyclical spiral of experiencing, reflecting, thinking, and acting. As learners progress throughout the spiral, the depth of understanding and skillsets grow (Kolb & Kolb, 2018). This learning theory aligns with the study as qualitative data was collected while teachers were engaged in hands-on, interactive professional development training that experientially modeled integrative STEM activities as a student. This study observed a cyclical design of two professional development sessions, ongoing reflections throughout the duration of the study, and active experimentation as supported by this theory. I provided an authentic environment where teachers will learn and apply design challenges centered around
integrative STEM education approaches. Throughout this process, they were encouraged to reflect upon their learning using a teacher reflection journal. This journal provided them with an opportunity to engage in the reflective and thinking nature of experiential learning theory. These experiences provided data to determine if intentionally designed experiential PD has any impact on teacher understanding of integrative STEM, changes in instructional practices, and transformations of teacher perceptions towards this student-centered approach. Extensive literature support on experiential learning theory can be found in the literature review in Chapter 2.

**Purpose Statement and Research Questions**

The purpose of this study was to explore changes in teacher understanding of integrative STEM education and instructional practices after participating in ongoing support cycle of professional development, implementation, and reflection. This study yielded informative data to gain an understanding on whether an intentionally designed learning experience can affect a teacher’s understanding of integrative STEM education, as well as teacher changes, if any, to instructional practices. It also contributed to ongoing research regarding the integrative STEM education approach, professional development, and experiential learning theory applied in the field of education.

Based on my current problem of practice provided, I have developed the following research questions relevant to my interest of study:
**RQ 1:** How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom?

**RQ 2:** How do teacher perceptions for integrative STEM transform over several experiential learning cycles?

Data collection tools used within the study included focus group transcripts, classroom observations notes, teacher reflection journals, and post-study Google form questionnaire. The purpose of the data collected was used to provide further context on how to move forward for application and research purposes.

**Positionality**

According to Herr and Anderson (2015), research positionality is an essential part of a research study as it distinguishes the role of the researcher throughout the study. They propose a continuum framework to interpret one’s positionality as an insider, outsider, or variations of insiders and outsiders working collaboratively. Through their framework on continuum and implications of positionality, my positionality for this case study would be considered an insider and in collaboration with teacher participants.

My positionality as an insider has allowed me to observe issues within my professional context as the district STEM coordinator at the elementary school level. I have had the opportunity to work directly with teachers in planning activities and frequently conduct classroom visits to observe the implementation of integrative STEM education. This role has provided me the opportunity to discover and identify gaps in learning throughout the district within instructional
practices to analyze and determine a plan of action for improvement. My passion for the integrative STEM approach to learning and helping teachers grow within their capacity inspires me to want to conduct research and collect data to analyze to design and implement effective and practical training. Identifying the need to study the outcome of professional development that could impact teacher and student growth supports my role as an insider in my action research study.

In my Dissertation in Practice (DiP), participating elementary teachers range from third to fifth grade. Teachers expressed interest in implementing integrative STEM activities in their classrooms and have identified the lack of training as a barrier to their implementation. Participating elementary teachers in this case study have volunteered to receive professional development on integrative STEM educational approaches to bring forth innovation and change within their school culture and improve their instructional practices to include authentic, hands-on activities that are relevant and transdisciplinary.

Working collaboratively as an insider with participants had positive and negative implications. I anticipated hesitation and reluctance from participants due to the idea of teachers working outside of their realm of traditional classroom instruction. The shift from a traditional way of learning to a student-centered educational approach took a change in attitudes and beliefs, consistent implementation, and time. However, professional development opportunities that are centered on experiential learning will provide the experience needed to encourage teacher change by highlighting the potential personal and student growth, thus shaping their own understanding of this pedagogical approach.
Methodology

Efron & Ravid (2013) define action research as an exploration of practices within a researcher’s own context to improve their learning and practice. They believe that practitioners use strategies, such as reflections, problem-solving, and investigations to improve their professional growth and classroom instruction. Interventions, such as developing a plan of action, implementing said plan, making observations and reflecting on the cyclical progression throughout helps the researcher build upon their knowledge within action research (Herr & Anderson, 2015). In my role as a district STEM coordinator, I recognized the immediate need for integrative STEM professional development. I reflected on classroom observations and teacher planning sessions where teachers expressed their unfamiliarity with this educational approach in their classrooms. This action research study is significant in that it provided knowledge and data relevant to addressing the problem of practice. In addition, it contributes to existing research relevant to integrative STEM education and professional development for educators using a design process supported by experiential learning theory.

Yin (2021) describes a case study as a comprehensive method of investigating a case to understand and explore phenomena in its real-world context. A case study allows the researcher to conduct an in-depth exploration to collect data and gain a robust understanding of a complex issue or entity (Efron & Ravid, 2020). A case study would be appropriate for my DiP which aims to better understanding of how strategic professional development specifically
designed with experiential learning theory as its foundation could impact
teachers’ understanding of integrative STEM education and change in
instructional practices. The data collected could be used to improve the issue of
limited or ineffective PD for elementary teachers. In reflecting on my own work
towards establishing accurate integrative STEM education in our schools, I can
anticipate other school districts struggling with implementation due to the lack of
training or ineffectiveness. The data collected from this case study provided
knowledge for me as the researcher and other school personnel who work with
teachers in building a solid foundation for integrative STEM education on a
district level. As part of vital information collected from this research study, focus
group discussions, classroom observations, responses from teacher reflection
journals, and responses from the post-study Google questionnaire provided
insight into teacher hesitation and barriers helpful for district personnel to take
into consideration when introducing a new initiative. This case study enabled the
researcher to analyze all data collected, develop a plan of action, and apply it to
their professional context to determine effectiveness. In addition, there is minimal
research published that focuses on a cyclical professional development model
supported by the experiential learning theory and building teacher understanding
of integrative STEM education for upper elementary teachers.

**Significance and Limitations of Study**

There is limited research on the topic of taking an experiential learning
approach to professional development specific to integrative STEM education.
The significance of this study provides future researchers with insight and data
findings that would be beneficial in the world of academia. In addition, this study contributes to the limited studies on using an experiential-based PD for elementary educators as the driving force for instructional change. Limitations of the study included time and sample size of the participants. The brief time frame provided to conduct this study prevents the researcher from observing long-term changes in teachers’ understanding toward integrative STEM education based on an ongoing PD timetable. In addition, other district initiatives take precedence over voluntary PD opportunities such as this study, which impacted the number of teachers willing to participate in additional training throughout the year.

**Organization of the Dissertation**

There are five chapters included in this dissertation in practice. This chapter provided foundational information on integrative STEM education, the problem of practice, and the research questions and purpose of the study. Chapter 2 reviews the existing literature relevant to the theoretical framework and the problem of practice addressing integrative STEM education, professional development, engineering design process, and experiential learning theory. Chapter 3 provides details of the study’s methodology, setting, structure of the study, and methods of data analysis used during the coding process. Chapter 4 includes data collected from the participants, as well as the analysis, synthesis, and findings from the data. Lastly, Chapter 5 consists of a summary of the findings, the alignment of findings to the research questions and existing literature, recommendations, implications, and suggestions for future research.
List of Definitions

**Engineering Design Process (EDP)** – A design process where learners work to problem-solve like an engineer by applying conceptual skills given criteria and constraints. (Fan & Yu, 2017)

**Experiential Learning** – A learning theory developed by David Kolb that emphasizes the cyclical process of learning through ongoing experiences. (Kolb, 1984)

**Integrative STEM Education** – A pedagogical approach to learning centered around the applications of technology and engineering with the intentionality of incorporating other subject areas, such as mathematics and science for enhancement. (Sanders, 2009)

**Professional Development (PD)** – Career training provided to learners to grow in their capacity to bring perspective and change in practices and views. Within an educational context, educators seek PD to improve their instructional practices to produce higher student outcomes. (Guskey, 2002)
Chapter 2: Literature Review

To date, there is a critical need for teachers to learn how to apply an integrative STEM approach in their classrooms. However, these are limited and often ineffective professional development opportunities to foster teacher knowledge and understanding of integrative STEM education for our elementary classrooms (Nadelson, 2013). Without accurate foundational understanding of what defines integrative STEM education, frustrations from teachers who bear the expectation to implement an initiative without effective training and resources can influence the application of integrative STEM into classroom instruction. This study was designed to explore transformations in teachers’ understanding of integrative STEM using an experiential learning PD approach, as well as instructional practices. This chapter includes an extensive review of existing literature that supports the problem of practice and purpose of the study, beginning with a close examination of the theoretical framework, followed by literature regarding STEM education, integrative STEM education, engineering design process, and professional development.
Theoretical Framework

Experiential learning theory serves as the theoretical groundwork for this case study and is a cyclical process in which adult learners build upon their understanding of a concept based on experiences, reflection, and implementation. Kolb (1984) describes experiential learning theory as a vigorous learning model that focuses on adult development through learning experiences. Neubert, Rams & Utikal (2020) describes experiential learning as an immersive learning cycle that involves the application of knowledge to generate new experiences for the adult learner. The experiential learning theory was proposed by Kolb (1984) for learners to develop skills needed for problem-solving in the 21st century. The development of experiential learning theory was inspired by what Kolb describes as the “foundational scholars of experiential learning”, which includes William James, John Dewey, Kurt Lewin, Jean Piaget, Lev Vygotsky, Carl Jung, Mary Parker Follett, Carl Rogers, and Paulo Freire (Kolb & Kolb, 2017).

Historical Foundations of Experiential Learning Theory

Experiential learning theory was influenced using works of theoretical researchers whose scholarly works focused on human learning and development over the past century (Kolb & Kolb, 2017). Although experiential learning theory was inspired by many scholars, three main theorists and the commonalities in their learning models were viewed as having a direct influence due to their emphasis on experience in the learning process (Kolb, 1984). The three theorists and models of learning include Kurt Lewin’s model of action research and
laboratory training model, John Dewey’s model of learning, and Jean Piaget’s model of learning and cognitive development that provides a continuous process for learning (Kolb, 1984).

Lewin’s model of action research and laboratory training is identified as a cycle of learning that places emphasis on the learning process. Known as “a cycle of action research”, this process begins with establishing a first-hand experience that serves the purpose of providing visual and physical context to abstract concepts (Kolb, 1984). The direct experience yields data to make informed decisions that influence potential change in the learning cycle (Adelman, 1993). This iterative process includes reoccurring cycle of steps where research is conducted to collect information that leads to taking an action until an objective is met (Burnes, 2020). Data collected is then analyzed and feedback is provided as an essential aid to a learner’s conceptual development and in result, implementing and testing newly developed understanding from the learning process (Kolb, 1984).

Dewey’s model of learning is similar to Lewin’s model in that the learning process includes a cycle of concrete experiences, observations, and action (Kolb, 1984). However, emphasis is placed a learner’s impulse, feeling, and experiences to provide change in action (Kolb, 1984). Dewey’s model of learning is a cyclical process where knowledge is produced through direct learning experiences and opportunities for observation and reflection (Kolb, 1984). Dewey believed that in a learning by doing approach where learners build their own understanding based on their own experiences and meaning versus a teacher-
directed approach (Schiro, 2013; Williams, 2017). Once learners' cycle through reflection of experiences, they develop conclusions and apply their newly developed knowledge constructed through the learning process (Kolb, 1984).

Piaget's modeling of learning and cognitive development is similar to both Lewin and Dewey's learning models in that experiences, reflection, and action act as the foundational basis of learning (Kolb, 1984). Piaget's model of learning is dependent on student's hands-on interaction during the learning process. He believed that a learner's own experiences served as a vital component for one's ability to think abstractly (Wang, 2016). His process of learning is based on four events: schema, adaptation, assimilation, and accommodation (Sanghvi, 2020). Schema is identified as building blocks of learning to understand one's environment (Sanghvi, 2020). Kolb (1984) defines assimilation as a way for learners use their own personal experiences and knowledge to make connections. Adaptation is the period of which a learner readjusts schema based on their experiences and interactions with the world around them (Sanghvi, 2020). Learners then experience the accommodation phase, where internal conflict occurs between what learners know and the new knowledge obtained (Kolb, 1984).

Kolb & Kolb (2018) summarizes all three learning models and their alignment with Kolb’s experiential learning theory with the following propositions:

1. Learning is best conceived as a process, not in terms of outcomes.
2. Learning is a continuous process grounded in experience.
3. Process of learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world.

4. Learning is a holistic process of adaptation to the world.

5. Learning involves transactions between the person and the environment.

6. Learning is the process of creating knowledge.

These six propositions that ultimately serve as the foundation of experiential learning theory provide characteristics that show what differentiates experiential learning compared to traditional learning, emphasizing that there is a focus on the learning process through experiences and not necessarily the result (Kolb, 1984; Kolb & Kolb, 2017). According to Kolb (1984), all three learning models of Lewin, Dewey, and Piaget identify learning as a process that is continuously improved upon as learners are immersed in learning experiences. More specifically, Dewey (1938) expresses how learners continuously modify their own conceptual understanding based on experiences and how this can influence future situations, sharing that “…the principle of continuity of experience means that every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after…” (Dewey, 1938, p. 35). Thus, the experiential learning theory views learning as a process of creating and recreating knowledge based on the learner’s experiences.

In addition, Kolb (1984) argues that the foundational model of experiential learning suggests that for transformation of learning to occur, conflict between
concrete experiences, abstract conceptualization, reflective observation, conceptualization abilities, and active experimentation must be experienced. Kolb also argues how the learning process is an adaptive, lifelong process that involves interactions between humans and their environment. According to Kolb (1984), the three foundational models of experiential learning from Lewin, Dewey, and Piaget view the scientific method to be applicable to human adaptation and acts as a bridge that connects all aspects of human interactions and the learning that occurs in real-life contexts.

In summary, the scholarly works from Lewin, Dewey, and Piaget served as the foundation of Kolb’s experiential learning theory. The historical context of each model of learning provided insight into how learning is viewed as a process and emphasis placed on the learner’s experiences that continuously work to shape and reshape any conceptual understanding as they continue to be immersed in learning experiences. The next section discusses Kolb’s experiential learning cycle as a result of exploring the Lewin’s action research model, Dewey’s model of learning, and Piaget’s model of learning and cognitive development.

**Experiential Learning Theory Cycle**

Kolb (1984) describes learning within the experiential learning theory as “a process whereby knowledge is created through the transformation of experience. Knowledge results from the grasping and transforming experience” (p. 41). Experiential learning theory focuses on the learner’s experience and provides a holistic environment by incorporating perception, cognition, and behavior in the
The origin of the term “experiential” not only stems from the foundational works of Lewin, Dewey, and Piaget, but adds an emphasis on the critical role that firsthand experiences have in one’s learning environment (Kolb, 1984). Applying this theory, a learner would progress through the cycle of learning, which enables them to experience, self-reflect, critically think, and apply what they have learned. Figure 2.1 illustrates how the experiential learning model is a cyclical process of learning through experience.

Figure 2.1 The Experiential Learning Cycle Model

Developed in the late 1960’s, the cyclical nature of Kolb’s experiential learning theory distances itself from the traditional classroom practices of transmission of knowledge from teacher to student (Kolb, 1984). This cycle places emphasis on both the facilitator and learners obtaining new information with the center of the subject being experiencing through the learning process (Kolb & Kolb, 2014). According to Kolb (2015), “knowledge results from the combination of grasping and transforming experience” (p. 41). The experiential learning cycle provided in Figure 2.1 shows the connection between concrete experience and abstract conceptualization, which both serve as the process of
learners grasping information. In addition, Figure 2.1 also shows a connection between reflection and active experimentation, which represents the transformation of experiences in the learning process. The connection of the dual dialectics of concrete experiences/abstract conceptualization and reflection and active experimentation is essential in the learning process (Kolb & Kolb, 2017).

Concrete experiences within the experiential learning cycle occurs when learners are essentially living through an experience in which they are engaged in a practice that builds onto prior understanding or creates new knowledge. One of the purposes of engaging in concrete experiences is to provide a common starting point for learners (Kolb & Kolb, 2009). However, for learning to be effective, Kolb believes that learners must approach concrete experiences without any biases and allow themselves to be fully immersed in learning with an open mind, as well as experience the entire cycle of experiential learning (Kolb, 1984).

Based on the learners’ experiences, they can reflect on what they observed and participated in during the reflective observation stage. According to Kuk & Holst (2018), reflection plays a vital role in the process that connects a learning experience and the learning process. Learners that undergo a process of reflection during and after the learning experiences develop a deeper meaning, which results in the newly developed knowledge (Green & Ballard, 2010; Kuk & Holst, 2018).

Next, learners can take their experiences and observations to form new knowledge and ideas within the abstract conceptualization phase, which will
provide the foundations for the next stage of experimentation to test their new understanding. This becomes an ongoing, iterative process of learning where learners continuously modify or construct new knowledge (Kolb, 2014). Experiential learning as the foundation for planning and implementing professional development for adult learning ties into the role of an educator to where they can take their newly constructed experiences to undergo a transformation of learning.

Although Kolb’s experiential learning model has been influential in academia for adult learning, there are many who believe that his model is one that is conflicting and vague. Bergsteiner, Avery, and Neumann (2010) conducted a review of literature relevant to studies that provide criticisms to Kolb’s experiential learning theory. One of their major criticisms of Kolb’s model was the structure and typology of the model itself. They believed that the model needed restructuring to follow key elements that model visual graphic scientific best practices (Bergsteiner et al., 2010). In addition, other researchers believed that Kolb failed to provide clarity in the definitions and distinctions between concrete experiences, active experimentation, abstract conceptualization, and reflective observations (Bergsteiner et al., 2010; Blenkinsop et al., 2016; Morris, 2020). Miettinen (2000) uses the term “eclectic” to describe Kolb’s model, concerned that his approach deflects from the historical context of experiential learning. To address the issues and flaws believed to cause confusion, this has led to researchers providing alternative models that modify Kolb’s experiential
learning cycle (Bergsteiner et al., 2010; Miettinen, 2000). These critiques highlight some of the concerns around using Kolb’s model unquestioningly.

Despite the critical analysis and flaws provided by various research studies, experiential learning has been found to be successful in integrative STEM education (Daher & Shahbari, 2020; Wells, 2016; Zainal et al., 2018). In addition, there is existing literature where studies have shown Kolb's experiential learning theory to be essential when applied in an educational context for teachers and students. Green & Ballard (2010) saw positive outcomes in using experiential learning as their model for training that they attribute to ownership, modeling, teamwork, and application. Klein & Riordan (2011) found that developing a PD experience using experiential learning theory had a positive impact in providing innovative learning experiences for teachers. Girvan et al. (2016) found one of the most significant themes from their application of an experiential PD was observing teacher change in the classroom. Wang et al. (2021) found that participants going through the experiential learning cycle for PD were more open to adopt a student-centered approach, stating that a key factor was the opportunity for learners to experience it to see value. This theoretical framework will provide the foundation needed to design an immersive PD experience that aligns with the research questions of this study: to explore how an experiential PD experience impacts teachers STEM instructional practices and teacher perceptions of integrative STEM education.
Review of STEM Education Literature

This section provides a detailed overview of existing literature of the design elements that shaped the professional development and learning experience of this study. This includes foundational literature and history of STEM education in comparison to integrative STEM education, the need for educators to experience effective professional development, and effective instructional design for integrative STEM education pedagogy.

STEM Education

In 2013, the Next Generation Science Standards emphasized science and engineering practices to provide a foundation for science and engineering in grades K-12 (NRC, 2012). STEM Education (Science, Technology, Engineering, and Mathematics) is a constructivist instructional approach that allows students to actively engage in learning through authentic experiences, collaboration, communication, investigations, and problem solving – all elements and skills needed for college and STEM career readiness in the fields of science, technology, engineering, and mathematics (Bybee, 2010; Krajcik & Blumenfeld, 2005; NRC, 2012). Kelly & Knowles (2016) define integrated STEM education as an approach in which two or more of the domains of science, technology, engineering, and mathematics are investigated in an authentic context for students to develop conceptual knowledge to enrich learning. This student-centered instructional method engages its learners through inquiry and investigations by identifying a question or problem in the fields of all four core areas (Kennedy & Odell, 2014). According to Bybee (2010), a true STEM
curriculum allows students to develop 21st century skills such as group work, engaging in lab activities, and projects that prepare them to make real-world decisions as citizens. In addition, STEM education allows students to take ownership of their learning and enables students to learn from one another (Sahin et al., 2014) as supported by Vygotsky’s social constructivist theory.

Despite STEM education being defined as a learning approach that immerses a learner into the multiple disciplines within the acronym of STEM (Bybee, 2010; Kelly & Knowles, 2016; Krajcik & Blumenfeld, 2005; NRC, 2012), not all learning opportunities accurately fall within its definition, nor is there a unified definition of what STEM education is. Wells (2012) identifies that the acronym of STEM presents itself as teaching science, technology, engineering, and mathematics in pillars, which contributes to the varying interpretations and perceptions of what STEM education is. Kennedy & Odell (2014) emphasizes the importance of students engaging in STEM activities that highlight science, technology, engineering, and mathematics as a whole and not as individual pillars. However, in some cases, science and mathematics tend to become the focus of learning, even though technology and engineering are both a vital part of our daily lives (Bybee, 2010). Bybee (2010) expresses that an accurate STEM approach to learning should allow students to discover how the world works, in addition to being knowledgeable of how technologies can be used to develop learning. To address this, Sanders (2009) recognized that all pillars of science, technology, engineering, and mathematics were not consistently practiced nor seen as equal, thus originating the integrative STEM education framework. To
align this study to an authentic transdisciplinary experience, an integrative STEM approach will be explored and implemented.

**Integrative STEM Education**

Integrative STEM education originates from an established graduate program at Virginia Tech University as a means to differentiate from the ambiguity of “STEM Education” and emphasize the integration of technology and engineering practices into other disciplinary areas beyond the acronym of STEM (Sanders, 2009). Sanders (2012) provides a definition of integrative STEM education that highlights how this instructional approach can supplement and support instruction beyond its acronym:

Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts practices of technology and engineering education. Integrative STEM education may be enhanced through further investigation with other school subjects, such as language arts, social studies, art, etc. (p. 2)

Facilitating a framework in which technology and engineering are at the forefront of learning supports the expedition of associations in mathematics, science, and other subject areas, which emphasizes importance of all subject areas (Havice et al., 2018; Wells, 2016). Sanders (2009) found that with an integrative STEM education, instruction is proven to be effective when compared to other instructional methods in which science, technology, engineering, and mathematics are not taught in an integrative manner. In addition, integrative
STEM education can involve the extension of including other disciplines, such as social studies, the arts, reading, and more, thus making this pedagogy a true transdisciplinary approach (Sanders & Wells, 2010). With technology and engineering serving as the foundation of this approach, this potentially eliminates the issue of STEM education taught in silos, as well as only having mathematics and science drive the learning. By using integrative STEM education as the lens of instructional design, learning within other subject areas is enriched and students can build cross curricular connections.

**Engineering Design Process**

The engineering design process (EDP) can be described as a cyclical process in which learners build upon their conceptual knowledge through problem solving within an authentic context (Donna, 2012). The EDP allows students to make connections between scientific inquiries and engineering, work collaboratively with others, and engage in a student-centered pedagogy that allows students to go through a cycle of questioning, designing, building, testing, redesigning, and sharing results while applying content area knowledge as shown in Figure 2.2 (Donna, 2012; Margot & Kettler, 2019; NRC, 2012; Ting, 2016).
Figure 2.2 The Engineering Design Process Cycle

Adapted using NASA’s BEST engineering design model, the steps that contribute to the creation of the EDP model include ask, imagine, plan, create, test, and improve (National Aeronautics and Space Administration [NASA], n.d.). During the “ask” phase, learners are asked to identify a problem and be able to identify any criteria or constraints needed to solve the problem. Next, in the “imagine” phase, learners brainstorm ideas and potential solutions that could address the identified problem. Once learners have progressed through the imagine phase, they will move onto the planning stage. In the “planning” stage, learners work collaboratively to choose the best solutions or designs researched in the previous phase and develop a plan that can include sketching a prototype (NASA, n.d.). When learners have developed a plan, they are able to use the “create” phase of the EDP to build a model or prototype using the problem’s criteria, constraints, and plans. During the “test” phase, learners will use this time to test their designs, collect data, and analyze their results. This will allow
learners to use the “improve” phase of the EDP to make any changes, adjustments, and modifications for improvement of design.

With integrative STEM education being transdisciplinary in nature, the EDP provides educators with a design-based model for learners to progress through the learning process (Kelley & Knowles, 2016). The inclusion of engineering in an integrative STEM education pedagogy allows the EDP to highlight the process of how engineers make decisions based on organizing their thoughts, developing a design, and making improvements (Ting, 2016). This is essential in the learning process for integrative STEM education in that the EDP offers students a method in which they can apply content knowledge within an authentic context that is hands-on and experiential to build conceptual understanding and design a product (Dym et al., 2005; Long, 2020; Rajbanshi et al., 2020). Disciplinary areas such as mathematics and science can be enriched by employing a design-based methodology such as the EDP due to the reinforcement of learning through application and active engagement (Kelley & Knowles, 2016; Ting, 2016).

Research has shown positive data in studies where the EDP was embedded within an integrative STEM lesson (Donna, 2012; Fan & Yu, 2015), however, not all educators are aware of this learning design and its potential impact. In addition, educators that do not have an engineering background may share hesitation about implementation (Lo, 2021). It is essential for teachers to attend PD that targets an overarching need about how to implement engineering resources and how engineering can be applicable to curriculum and instruction
(Porter et al., 2019). There needs to be an emphasis on providing training on the EDP for teachers for them to visualize connections between engineering challenges, their curriculum, and the connections between multiple subject areas (Donna, 2012; Estapa & Tank, 2017; Herro & Quigley, 2017; Reimers et al., 2015). Providing professional development that immerses teachers in this design-based model empowers them to have a student and engineer perspective that illustrates how their curricular content could be enhanced through the EDP and design challenges (Ivey et al., 2016).

Integrative STEM education and the EDP both serve the purpose of providing learners an outlet to engage in an authentic learning experience that builds upon their social skills, critical thinking skills, and creativity. By providing a PD that is centered around integrative STEM education and the EDP design model, teachers are provided the opportunity to experience learning through the lens of their own students (Klein & Riordan, 2011). The combination of this student-centered learning approach and the EDP design-based model offers an ideal learning environment supported by Kolb’s experiential learning theory as it organically immerses participants in transforming prior knowledge based on their immediate experiences (Kolb, 2014). Using the EDP as the instructional design for this case study will help participants go through the iterative process of thinking and learning. The EDP contains elements of Kolb’s experiential learning theory. Through teachers experiencing the EDP themselves during the case study, they can take what they have learned to modify their practices, implement
design challenges in their classrooms to observe student learning outcomes, and thus, lead to a change in teacher beliefs and instructional change.

**Professional Development**

With educational changes, it is critical for educators to receive adequate training throughout their teaching careers to stay informed of best classroom practices. Professional development is a program designed to influence change in teacher beliefs to improve instructional practices with the goal of making an impact on student learning (Guskey, 2002). Darling-Hammond, Hyler, & Gardner (2017) define professional development as structured learning opportunities that aim to increase teaching practices to support student instruction. Professional development in education provides opportunities for teachers to grow as educators to bring forth change to impact student learning (Guskey, 2002; Darling-Hammond et al., 2017).

Professional development is essential to provide opportunities for improvement in education and educators in general. Teachers as learners require fundamentals for PD to be considered effective. However, not all professional development results in immediate or guaranteed change. Guskey (2002) identifies two factors that are commonly found lacking in the planning of professional development sessions: knowing what teachers need to be motivated to engage in training and knowing the development of teacher change. As shown in Figure 2.3, Guskey (2002) developed a model of change for educators to show the progression from professional development to teacher change in their beliefs and attitudes because of experiencing success in student outcomes.
Guskey’s Model of Change

Guskey’s Model of Change places emphasis on evidence of student outcomes being the catalyst that drives change in teacher beliefs and attitudes versus taking an approach of changing instructional practices with just the delivery of PD. Darling-Hammond & Richardson (2009) provided insight on instructional change through teachers’ experiences with effective PD that include elements such as being coherent, based on content knowledge, and active learning through hands-on exploration, all of which are connected to local curriculum standards (Garet et al., 2001). According to Darling-Hammond et al. (2017), existing research relevant to PD has led to the development of seven characteristics that they believe are present in effective PD:

1. Focused on content.
2. Applies adult learning theories while embedding active learning opportunities.
3. Integrates opportunities for collaboration.
4. Demonstrates modeling to show effective practices.
5. Includes instructional support from coaching experts.
6. Provides opportunities for reflection and feedback to and from learners and facilitators.
7. Consistent length of time and duration.

The works of Guskey and Darling-Hammond both provide essential elements that contribute to the overall change in beliefs and attitudes of teachers that can guide how leaders can intentionally design and implement effective PD.

Although research has identified the main themes that contribute to what successful professional development entails, other factors may inhibit teachers from retaining and applying what they have learned through training. Studies have found that teachers need time, collaboration, access to resources, and support from instructional leaders (Avery, 2013; Du et al., 2018; Goodnough et al., 2014; Kartal et al., 2018). For example, in a study conducted by Kartal et al. (2018), teachers indicated the need for additional support in applying what they have learned in their classroom after PD training.

In addition to learner needs, the duration of professional development has been shown to be influential in the effectiveness of training. Du et al. (2018) reported findings that showed an increase in teacher growth and STEM integration after a three-year implementation training. In a study conducted by Yang et al. (2018) teachers that are engaged in longer professional development sessions have an increased positive attitude and are more passionate about what they are learning. Powell-Moman & Brown-Schild (2011) discovered an increase in teacher efficacy and inquiry-based implementation after a two-year professional development cohort. Facilitators of training need to be aware of research that shows positive impacts on professional development and be
strategic in how they create and deliver their training to build an effective environment conducive to learning.

These studies provide merit to the concept of strategically designed and delivered professional development. However, the remaining questions identify a need for additional research relevant to strategically designed PD. More specifically, a study that will explore the impact on teachers' understanding of integrative STEM education and instructional practices through multiple cycles of experiential PD that include opportunities to experience this learning approach, reflection, implementation, and a collaborative environment where teachers experience learning with one another.

**Professional Development in Integrative STEM Education**

There is a critical demand for professional development opportunities that center around integrative STEM education. Research has shown that there is a need for ongoing professional development to support integrative STEM initiatives to encompass the true interdisciplinary aspect of STEM integration (Avery, 2013; Callahan et al., 2013; Goodnough et al., 2014; Nadelson, 2013; Shernoff et al., 2017). Educators in the United States must be a part of the change for students to acknowledge the impact of integrative STEM education for their future. As stated by Al Salami et al. (2017), “to enhance students’ perceptions of and interests in STEM, teachers need to develop positive attitudes toward teaching beyond their disciplines, positive attitudes toward collaboration with other teachers, and willingness to change current instructional strategies” (p. 2). PD centered around the integrative STEM educational approach provides the
instructional means for teachers to explore various teaching pedagogies (Avery, 2013). If the goal for integrative STEM is to provide students with authentic learning experiences that are transdisciplinary and centered on a pedagogical approach that is student-led, teachers need to understand the significance of instructional change (Al Salami et al., 2017).

In addition to the general need and purpose of professional development, studies have shown that teachers also need support to enhance their instruction, including how to take an integrative STEM approach to learning and what integrative STEM look like when implemented. PD is essential in addressing the lack of understanding among teachers pertaining to integrative STEM education and its benefits to learning (Becker & Park, 2011). This is a critical need to support teachers may feel uncomfortable teaching subject areas related to STEM because of their general background in education (Goodnough et al., 2014). For example, educators who specifically major in science education may have more exposure to STEM integration than teachers who study to be general educators. PD focused on an integrative STEM education approach should begin by developing an understanding of its pedagogy, methodology, and established research on its impact on instruction and learning, as well as identifying that this learning approach extends beyond its acronym (Kelley & Knowles, 2016; Navy et al., 2020).

To address this, Nadelson et al. (2013) expressed that PD is a critical component for teachers to learn how to take an integrative STEM education approach into their instructional practice. This can include educators observing
the implementation of a lesson that promotes integrative STEM to experience the classroom environment (Estapa & Tank, 2016; Shernoff et al., 2017), providing a learning experience for teachers to learn as students (Goodnough et al., 2014), and modelling purposeful alignment of integrative STEM with curricular content (Estapa & Tank, 2016; Gardner et al., 2019). Studies have shown that effective PD centered around STEM education provides educators supports to address potential barriers and contributes to increased teacher perceptions and confidence towards this student-centered approach (Cotabish et al., 2011; Du et al., 2018; Estapa & Tank, 2017; Gardner et al., 2019). As such, intentionally designed PD, using effective characteristics defined by Guskey and Darling-Hammond, is a critical need to support teachers understanding of integrative STEM education.

**Professional Development and Experiential Learning**

One crucial responsibility of educators is to experience learning cycles for professional advancement by undergoing new and improved instructional practices to replace existing beliefs through professional development (Kolb, 1984). Kolb recognized that learners construct a resistance to new information when they find inconsistencies in their own principles (Kolb, 1984). In this case, a process of learning occurs if the learner examines and processes their current self-beliefs, tests them, and applies new knowledge that refines their old understanding. This process of learning is essential for educators to work towards professional growth as education continues to transform. The experiences that teachers will engage in during professional development will
place them in the perspective of their students. However, for teachers to make a meaningful change within their instructional practice, they will need specialized PD that will move beyond an outdated “sit and get” model (Klein & Riordan, 2011). Traditionally, PD is offered to educators where a lecturer transmits information to teachers as they listen and observe (Girvan et al., 2016). Designing a PD centered around an experiential learning model in mind allows teachers to actively participate to ease any discomfort that they may feel due to the unknown (Klein & Riordan, 2011; Wang et al., 2021). In addition, the active, hands-on nature of a PD specifically designed to cycle through learning, implementation, and reflection focused on integrative STEM education develops an understanding and knowledge needed for teachers to transform their classrooms into ones where students want to be (Klein & Riordan, 2011). Modeling a PD designed with experiential learning as the foundation aids in expanding teachers' pedagogy on integrative STEM education to design and implement a similar learning environment for their students (Klein & Riordan, 2011). Providing training to educators that immerses learners in the hands-on aspect of integrative STEM education enables them to develop conceptual knowledge of this practice, thus organically allowing reflection to occur based on their experience to recreate the experience in their classroom (Rajbanshi et al., 2020; Wang et al., 2021). Teachers engaged in an ongoing PD opportunity, such as one that is created to model experiential learning, allows for a scaffold for teachers to make minor changes within their instructional practices (Girvan et al., 2016). The transdisciplinary nature of integrative STEM education aligns with the
engineering design process and the framework of an experiential PD model, which all serve as vital components to this case study.

**Conclusion**

Professional development, as discussed in this chapter, is held to be a cornerstone of growing teaching practices throughout a teacher’s career. Chapter 2 highlighted the existing literature relevant to professional development, integrative STEM education, and experiential learning theory, as well as identifying any gaps in literature that exists. Chapter 3 provides the methodology and the context of the study. Rationale of the chosen methodology is provided, in addition to the setting, breakdown of the planning and implementation of the seven-week experiential learning experience, and the data collection methods used. Lastly, chapter 3 provides specific details regarding the process of developing codes from the data collected, the progression of each coding cycle, and the development of emerging themes.
Chapter 3: Methodology

This chapter aims to present the research methodology for this single-case study. Chapter 3 is organized into different sections that follow the iterative process of a case study. The research design section provides detailed information regarding the method selected, descriptions of the study setting, and a detailed explanation of the development and implementation of the seven-week cycle of PD, reflection, and observations. Next, the data collection section provides a narrative on the data collection instruments used for this study which include focus group transcripts, classroom observations notes, teacher reflection journals, and a post-study questionnaire using Google forms. The data analysis section includes a brief description of how the data collected was disaggregated and analyzed using codes to identify similarities, themes, and trends. A thorough overview of the multiple rounds of coding and the development of themes based on codes is provided. Lastly, procedures for trustworthiness, ethical considerations, and potential study limitations conclude this chapter.

Overview of the Study

The purpose of this study was to explore teacher perceptions of integrative STEM and instructional change before, during, and after participating
in ongoing professional development and instructional support that highlights experiential learning. This is a need as supported by existing literature in the field of integrative STEM education (Al Salami et al., 2017; Havice et al., 2018; Kelley & Knowles, 2016).

Based on the current problem of practice, the following research questions were explored:

**RQ 1**: How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom?

**RQ 2**: How do teacher perceptions of an integrative STEM approach transform over several experiential learning cycles?

**Research Design**

I chose to take a qualitative approach to my study as it involves collecting, analyzing, and synthesizing data and using emerging themes and details to make sense of a phenomenon. Patton (2015) emphasizes that qualitative method of research is a kind of inquiry that is personal. All procedures, details, decisions, and interpretations are based on my personal and professional experiences. In alignment with my positionality as an insider, researcher, and my role as a district STEM coordinator, this study allowed me to be personally invested in the planning, implementation, data collection, and results of the study to build upon my own understanding.

Yin (2014) describes a case study as being an iterative process that involves planning a study, preparing for the study, collecting data, data analysis,
sharing conclusions and findings. According to Yin (2014), a case study allows researchers to develop a holistic perspective of an event to study and understand a particular phenomenon. In addition, a case study is a design in which researchers can study an event or situation within a given time (Creswell & Creswell, 2018). In addition, a single-case study is useful to closely examine, in this case, a small group of individuals, as they are immersed in the experiential learning PD cycle. A single-case study allows the research to collect rich data on an individual, organization, or small group of individuals (Yin, 2014). Most specifically, a holistic single-case study allows for the researcher to view the outcomes of the study as a whole entity versus looking at each participant individually (Yin, 2014).

A single-case study best aligns with this Dissertation in Practice because I was interested in exploring the data from multiple participants as a whole entity to analyze and develop a clearer understanding of how an experiential professional development could make an impact on teachers' perceptions of integrative STEM education and change in instructional practice. Thus, the data collection types that were most appropriate for this include a focus group, classroom observations, teacher reflection journals, and a post-study Google questionnaire. The variety of sources for this study produced a plethora of data from multiple perspectives to provide a holistic view of the outcomes. Data collected was meticulously analyzed and used to identify connections to existing literature and the theoretical framework of this study, as well as to establish emerging themes. This methodological approach supports both the research questions of the study,
as well as my positionality as an insider and researcher to gain insight into perceptions regarding integrative STEM education after experiential professional development to develop my own instructional practice with other educators.

This single-case study uses action research to answer the research questions, which seek to identify and address challenges and changes relevant to the problem of practice. Action research can be viewed as a cyclical process of planning, acting, observing, and self-reflection to develop an understanding of their practice (Kemmis et al., 2014; Shanks et al., 2012). Originating by Kurt Lewin, action research examines issues within a professional context and uses reflection and action to discover practical solutions for improvement (Salman, 2015). An action research design is most suitable for this study because it allows me to recognize a problem, identify participants and study setting, collect, and analyze data to actively participate in the research study and find solutions.

Research Setting

This case study took place in a school district located in the Southeastern region of the United States. This urban school district consists of over 10,000 enrolled students dispersed amongst 13 elementary schools, five middle schools, five high schools, and one alternative school. The demographic makeup of the district is composed of 46% White students, 40% African American students, 11% Hispanic students, 1% Asian students, and 2% Mixed/Other Race students (National Center for Education Statistics, 2023). 11 out of the 13 elementary schools qualify for free and reduced lunch due to having student populations that exceed the 70% poverty threshold. These schools are considered Title 1 schools,
which allows them to receive additional funding for instructional improvement. Two out of the 13 elementary schools are identified as low performing schools. These schools are recognized as lower performing schools, or restart schools, due to yielding consistent negative growth data from summative assessments over a span of three or more years.

Professional development offered in this school district often occurs within each school or at the district PD room. However, the collaborative nature of this engaging, hands-on training required an open space and access to district STEM materials. Therefore, in-person professional development sessions and the focus group meeting took place in the district STEM lab. This was used to accommodate the number of participants visiting from other schools, provide the space necessary to work collaboratively, and provide access to materials needed for the activities participants would be engaged in. The location of the STEM lab served as a neutral meeting place for all teachers and the space of the lab was structured to model a collaborative learning environment. Individual teacher observations were conducted within the teacher’s school buildings. In addition, the STEM lab housed all the instructional materials, as well as STEM resources that participants used during the study.

This single case study took place over the span of seven weeks. Recruitment began in the early Fall of 2022 and five participants were secured to begin the study at the end of October 2022. The study concluded with a final observation at the beginning of December 2022. Throughout the seven weeks, participants were engaged in two cycles of PD, implementation, and reflection, as
shown in Table 3.1. A full overview of each week is provided later in the chapter in the data collection section.

Table 3.1 A Weekly Overview of Study Activities

<table>
<thead>
<tr>
<th>Week</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week One</td>
<td>Pre-Observations</td>
</tr>
<tr>
<td>Week Two</td>
<td>Face to Face PD</td>
</tr>
<tr>
<td>Week Three</td>
<td>Implementation/ Reflection</td>
</tr>
<tr>
<td>Week Four</td>
<td>Implementation/ Reflection</td>
</tr>
<tr>
<td>Week Five</td>
<td>Face to Face PD</td>
</tr>
<tr>
<td>Week Six</td>
<td>Implementation/ Reflection</td>
</tr>
<tr>
<td>Week Seven</td>
<td>Implementation/ Reflection</td>
</tr>
</tbody>
</table>

Participants

Over 600 K-12 classroom teachers are currently employed in the district. Out of the 600 teachers, approximately 400 teachers were working as elementary school teachers (NCES, 2022). A flyer was designed and shared with elementary teachers employed with the county that included a form for teachers to express interest in participating in the study. A total of 11 teachers expressed interest in participating. However, after an informational session of the research study and criteria expected for the seven weeks of participation, six teachers respectfully declined resulting in five willing participants. All participants were presented with a consent form prior to the start of this research study (see Appendix A). Participants in a study that are purposefully selected based on their predetermined qualities can offer rich data to help understanding the study’s
purpose (Patton, 2015). Therefore, purposive sampling was used to choose participants for this study because the grade span is specific to 3-5 elementary school teachers and their shown interest in STEM education.

With the in-depth nature of providing training and conducting in person observations for each training, the target audience for this case study focused on five elementary educators that teach grades three, four, and/or five within a single school district in the Southeast within the United States. These educators vary in demographics, age, teaching assignment, years in education, experiences in education, and experiences with integrative STEM education (see Table 3.2).

Table 3.2 Participant Demographic and Experience

<table>
<thead>
<tr>
<th>Participant</th>
<th>Demographic</th>
<th>Teaching Assignment</th>
<th>Years in Education</th>
<th>College Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>White Female</td>
<td>Media Coordinator</td>
<td>15+ years</td>
<td>Education</td>
</tr>
<tr>
<td>2</td>
<td>White Female</td>
<td>3rd Grade Teacher</td>
<td>15+ years</td>
<td>Education</td>
</tr>
<tr>
<td>3</td>
<td>White Female</td>
<td>STEM Teacher</td>
<td>0-5 years</td>
<td>Non-Education field</td>
</tr>
<tr>
<td>4</td>
<td>White Female</td>
<td>4th/5th Grade Teacher</td>
<td>15+ years</td>
<td>Education</td>
</tr>
<tr>
<td>5</td>
<td>White Female</td>
<td>Elementary Facilitator</td>
<td>15+ years</td>
<td>Non-Education field</td>
</tr>
</tbody>
</table>

All participants identified as White females. One participant was in her mid-twenties and had the least number of years of experience in education. The other four participants all had 15+ years in education and were approximately between the ages of 35-60. Two participants did not major in education in
college; however, one did begin their career as a teacher. Three out of the five participating teachers taught at a Title 1 school and one teacher served at one of the top performing schools in the county. One participant worked on the district level and taught at multiple elementary schools. All participants have varying daily classroom focuses, which include teaching a STEM class, teaching media and technology, teaching science, and teaching all core subject areas. Out of the five participants, only one teacher identified as having a strong understanding of integrative STEM education.

Data Collection

The instruments used to collect data from the study were chosen based on the research questions, study interest, and the qualitative nature of this study. Focus group transcripts, classroom observations notes, teacher reflection journals, and a post study Google form questionnaire were used to record and collect data before, during, and after the research study process. Dialogue recorded during the focus group were transcribed using Google meet, field notes from observations, copies of the reflection logs, and responses from the post-study Google form questionnaire were reviewed to identify overarching themes relevant to the study (see Table 3.3).
Table 3.3 Timeline of Data Collection Activities

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Researcher Data Collection Activities</th>
<th>Participant Data Collection Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td>Completed pre-observation using observation template.</td>
<td>Completed teacher reflection journal #1.</td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td>Collected and reviewed teacher journal entries.</td>
<td>Completed teacher reflection journal #2.</td>
</tr>
<tr>
<td><strong>Week 3 &amp; 4</strong></td>
<td>Completed observations using observation template.</td>
<td>Completed teacher reflection journal #3.</td>
</tr>
<tr>
<td><strong>Week 5</strong></td>
<td>Collected and reviewed teacher journal entries.</td>
<td>Completed teacher research journal #4.</td>
</tr>
<tr>
<td><strong>Week 6</strong></td>
<td>Conducted classroom observation visits for all participants.</td>
<td>Completed teacher research journal #5.</td>
</tr>
<tr>
<td><strong>Week 7</strong></td>
<td>Focus group collection. Collected and reviewed teacher journal entries. Created and deployed a post study Google form survey. Compiled all classroom observation templates.</td>
<td>Completed teacher research journal #6. Focus group. Post Study Google Form Survey Member checking – opportunities for further discussion for clarification of data collected.</td>
</tr>
</tbody>
</table>

All data collection methods were designed with the study’s research questions at the forefront of development. The observation template (see Appendix D) provided space to record both factual and interpretive observations during the classroom visit and used to observe changes, if any, in instructional practices in alignment of the first research question of the study. The reflection journal entries included writing prompts that will yield data for both research questions (see Appendix E). These prompts specifically focused on teachers reflecting on their experiences to provide the researcher with any insight in the
shift of instructional practices and perceptions towards the integrative STEM approach. Questions of the focus group were generated based on both research questions (see Appendix C). Observing a semi-structured interview protocol, conversations within the focus group steered in the direction that provided useful and relevant data. To provide an additional opportunity for clarification, I decided to create a Google form questionnaire with the option for participants to complete after the focus group meeting (see Appendix M). The questions added in the questionnaire were open ended questions that provided a space for teachers to share any information with me after going through the entire study. Table 3.4 provides the alignment of the research questions of the study, the data collection tools, and the method of analysis.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Collection Tools</th>
</tr>
</thead>
</table>
| RQ 1: How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom? | • Focus Group (1 at the end)  
• Observations (3 total)  
• Reflection Journal (Weekly)  
  o Prompts #2, #4, #5  
• Post-study Google form questionnaire |
| RQ 2: How do teacher perceptions of an integrative STEM approach transform over several experiential learning cycles? | • Focus Group (1 at the end)  
• Observations (3 total)  
• Reflection Journal (Weekly)  
  o Prompts #1, #3, #6  
• Post-study Google form questionnaire |

A data collection program named Quirkos was used as a data warehouse for all information gathered using various methods for data collection. Quirkos is an
online software program that uses any text or media uploaded by the researcher to organize data.

**Focus Group**

Yin (2014) describes the use of focus groups as an approach to facilitate discussion to understand the perceptions and experiences of participants in a study. Focus groups involve a small group of individuals that provide their interviews at the same time (Mertler, 2019). Focus groups can be beneficial for recording thoughts and ideas from participants by answering a set of pre-selected interview questions (see Appendix C). The focus group will provide a platform for natural dialogue between the participants to interact and share their thoughts and experiences. As each individual shares their own perspective, this may leave an opportunity for the other participants to share similar or different views that may be useful for data analysis. This flexible environment may help participants feel more at ease if they are more comfortable talking within a small group versus a one-to-one interview. The purpose of the focus group is to collect information on each teacher regarding their background, professional context, educational experience, understanding of integrative STEM, and the impact of PD on their instructional practice.

For this study, a focus group was selected to collect data because of the reflective and collaborative nature of this study and the open-ended structure of the focus group discussion allowed for each participant to share their perspectives of their experiences during the study. Integrative STEM education, ongoing professional development centered around experiential learning,
instructional support, self-reflection, and shared experiences act as an agent for teacher change. The focus group discussion was conducted after the research study concluded during week seven. All five participants met at the STEM lab and were seated at a large table next to me and the device used to collect audio and transcribe the conversation.

Prior to starting, participants were read a script that provided the goal and expectations of the focus group discussion (see Appendix B). Following a semi-structured interview process, questions asked during the interview were in an open-ended format and were created prior to the interview based on the research questions of the study (see Appendix C). These questions were directly aligned to the research questions of the case study. A semi-structured interview allowed the interviewer to have pre-selected questions to facilitate discussion, but also provided the flexibility to add additional questions based on the direction of the group conversation. With permission, all interviews were recorded using Google Meet and transcribed to be used in the study’s findings. Google Meet was used to collect audio recordings only; therefore, no video or images were captured during the focus group discussion. As participants were asked a question, they were encouraged to share their personal experiences and views from the study. Audio and notes were documented to identify commonalities and discrepancies during the data analysis phase.

It is imperative to provide a safe environment for all participants to openly share their thoughts without judgement. Thus, it was essential that I was mindful in how I presented these questions to avoid a reflexive threat during the focus
group (Yin, 2018). I established at the beginning of the focus group by explaining my positionality, role as a researcher, and the purpose of the focus group. As participants answered questions openly with their own personal thoughts, I provided neutral responses and consciously set aside any personal biases to understand their perspectives of the study with an open mind.

**Observations**

A semi-structured observation was implemented as this provided me with the flexibility of moving between taking notes, making observations, and having brief conversations as needed. Creswell and Creswell (2018) define qualitative observations as an opportunity for researchers to collect information within a natural setting. During an observation, the researcher can document questions and observations to provide an idea of the behaviors and actions of the participant within their professional context. During the semi-structured observation, I took on the role of an observer as participant, as shown in Figure 3.1. By acting as an observer as participant, I was able to focus on recording documentation on what is seen and heard but provided the opportunity to interact with the participant to collect data.
Conducting classroom observations served multiple purposes for this study. First, it allowed me to observe the participants in their natural setting of the classroom as they provided instruction. This provided data relevant to the research question regarding instructional practices and integration of integrative STEM education. Secondly, this provided multiple data points within the observation notes to determine if there are any patterns and trends, as well as any behavioral and instructional changes towards integrative STEM education as it is being implemented. Thirdly, classroom observations provided me with the opportunity to physically see the transmission of knowledge from the professional development training to the classroom to observe teacher change, if any, of integrative STEM education.

Pre-observations were conducted before the first PD session. All other observations were conducted immediately after each PD session where participants were observed implementing the activity they experienced as a student. The purpose of the observations was to gain insight into participants’
classrooms before, during, and after the professional development began. All participants involved in the study were provided an opportunity to schedule a time to invite the researcher into the classroom to conduct their observation.

Each classroom observation was approximately one hour long. Observation notes were recorded using a template structured to record both factual observations and interpretative notes (see Appendix D). Under factual observations, I noted details such as instructional delivery, how teachers interacted with students, how students interacted with each other, what kind of classwork was assigned for students to complete. I also recorded specific behaviors, such as key words, phrases, physical behavior, and engagement from both teachers and students. For the interpretive notes, I was able to record my interpretations or ask questions of events or actions during the classroom observation. This allowed me to cross check my interpretations with the factual details and use member checking by asking teachers for clarity after the observation.

Reflection Journal

A reflection journal was provided for teachers with the expectation that they record their thoughts, feelings, and experiences throughout the study. Each participant was provided a direct link to a folder that contained a document with pre-constructed journal prompts (see Appendix E). Teachers were encouraged to complete the reflection journal at the end of each week throughout the seven-week study. Kolb’s experiential learning theory is grounded in the idea that experiences and reflections contribute to the continuous reshaping of conceptual
knowledge (Kolb, 1984). Therefore, teachers were provided a reflection journal template with pre-created prompts to facilitate thinking and encourage them to reflect on their own practices (see Appendix E). Each journal prompt was developed in alignment of both research questions, intentionally constructed to stimulate reflective thoughts pertaining to integrative STEM, current teaching practices, identifying and working through implementation challenges, and the professional development they experienced. Throughout the study, additional prompts were added after analyzing observations to obtain more information pertinent to the study. At the end of the study, all teacher reflection journals were collected from all participants and used to provide insight on teachers’ understanding of integrative STEM education and instructional change after two rounds of experiential learning.

Post-Study Google Form Questionnaire

A post-study Google form questionnaire was created and sent to all participants at the end of the seven weeks. The purpose of this Google form questionnaire was to provide an opportunity for participants to express any other thoughts regarding their experience. The Google form questionnaire consisted of five open ended questions, two yes/no questions, and one checklist. The data collected from the Google form was provided in narrative form to align with the qualitative nature of this study. This was optional for participants to complete, and three out of the five participants chose to complete all sections.
Research Procedure

The professional development design for this case study was developed using Kolb’s experiential learning theory as the foundation of the learning process. Teachers were immersed in a cycle of actively participating in PD, transferring knowledge from their PD to their classroom for implementation with their students, and opportunities for reflection on their practice. This timeline and cycle of learning is provided below (see Table 3.5).

Table 3.5 Timeline of Study Implementation

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Researcher Activities</th>
<th>Participant Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week One</td>
<td>Conducted pre-observation classroom visits for all participants chosen to be a part of the study.</td>
<td>Teachers taught a planned lesson during a pre-observation. They completed the teacher reflection journal prompt #1.</td>
</tr>
<tr>
<td>Week Two</td>
<td>Facilitated face-to-face professional development training for participants (design challenge #1).</td>
<td>Teachers actively participated in professional development training focused on a STEM challenge. They completed the teacher reflection journal prompt #2.</td>
</tr>
<tr>
<td>Face-to-Face PD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week Three &amp; Four</td>
<td>Conducted classroom observation visits for all participants. Observed implementation of design challenge #1.</td>
<td>Teachers implemented the design challenge that they learned about into their instruction during week three and four. Teachers were observed implementing the challenge by the researcher. They completed teacher reflection journal #3.</td>
</tr>
<tr>
<td>Week Five</td>
<td>Facilitated face-to-face professional development training for participants (design challenge #2).</td>
<td>Teachers actively participated in professional development training focused on a STEM challenge using the Engineering Design Process. They completed the teacher reflection journal prompt #4.</td>
</tr>
<tr>
<td>Face-to-Face PD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Week Six
Conducted classroom observation visits for all participants. Observed implementation of design challenge #2.

Teachers implemented the design challenge that they learned about into their instruction during week six. Teachers were observed implementing the challenge by the researcher. They completed teacher reflection journal #5.

Week Seven
Completed focus group. Distribute post-study Google form questionnaire.

Teachers completed the last teacher reflection journal prompt. In addition, they were invited to participate in a focus group with other participants about their experience. Lastly, they were provided a link to a post study Google form questionnaire to add any additional thoughts pertaining to the study.

For the duration of the study, teachers were provided a total of two face-to-face professional development opportunities, two opportunities for implementation with students, and six reflection journal entries over the course of seven weeks. Before teachers attended the first PD session, a pre-observation was conducted for each participant. Teachers were instructed to teach a lesson during an announced time where I could come and observe them in their natural element. I emphasized to teachers that the purpose of me coming to observe before the study is to gather information about how they would normally plan and implement an interactive lesson. As I observed teachers during their pre-observation, I completed the observation template (see Appendix D) to record both factual and interpretive notes. This would serve as a starting point to compare to future observations after their PD sessions.
After the first week of pre-observations, participants gathered in the STEM lab for their first face to face PD training during week two. The purpose of this training was to provide a scaffold approach to build their knowledge of integrative STEM education. This involved a hands-on learning experience that they would be expected to implement with their own students. The first PD was 75 minutes long and was structured to give teachers a clear definition of what integrative STEM education is, provide an opportunity to engage in a hands-on activity within groups, preview what the EDP is, and give teachers time to reflect on the PD experience. The outline of the PD is provided below (see Appendix J).

Teachers were introduced to what integrative STEM education is and how this learning approach looks like for their district. This was intentional to provide a consistent definition that represents how the district views integrative STEM across all grade levels. Next, teachers were instructed to split up into grade level groups and were provided with a roll and ramp kit. Once they were provided with ramps with different surfaces and cars, their task was to work in collaborative groups to investigate how their cars perform on different surfaces (see Figures 3.2 and 3.3).
Figure 3.2 Participants Exploring the Different Surfaces of Ramps

Figure 3.3 Participants Testing Ramps and Cars to Record Data

As participants worked together on this hands-on investigation, they were provided a recording sheet and measuring tools and asked to record their data (see Appendix F and G). I facilitated around the room and asked questions to model my role as the facilitator in an integrative STEM environment. They were given the same materials and handouts from this STEM activity and instructed to implement the same activity with their students during the first official observation, which was conducted during weeks three and four.

During observation #1, teachers were observed for one hour as they implemented the same force and motion activity, they experienced during their PD session. As teachers facilitated the activity, I used the observation template (see Appendix D) to record both factual and interpretive notes.

During week five of the study, teachers gathered back to the centrally located STEM lab in the county for their second PD session (see Appendix K).
Participants were given ten minutes to share their experiences with implementing the first activity with each another using the platform AnswerGarden. AnswerGarden is a platform where users can input words given a question. As users add words, it generates a word cloud and repeated words gradually become bigger, as shown in Figure 3.4.

![Image of Word Cloud Generated Through AnswerGarden](image)

**Figure 3.4 Image of Word Cloud Generated Through AnswerGarden**

After their reflection, we had a whole group discussion on their experience and why they chose the terms they provided in the word cloud. They were then immersed in their second integrative STEM experience, which focused on using the EDP to plan and build a plane that would fly the furthest distance. They were presented with a short video clip of the furthest paper plane traveled and were asked to discuss and reflect on what they saw to incorporate inquiry and curiosity for their own builds. Participants were provided a template of the EDP to work in collaborative pairs (see Appendix H). To familiarize participants with the EDP, I walked them through the elements of the EDP that included thinking of the problem they are trying to address (ask), thinking of potential solutions (imagine),
designing what they’d like to create (plan), building a model of their design (create), testing their paper planes (test), and making improvements to their designs (improve/retest). As they worked with their partner, I facilitated around the room to model my role as the facilitator of learning. Once they built their planes, tested, redesigned, and retested, we had a whole group discussion that served as a reflection of the activity itself. They were provided the materials for this activity and were instructed to implement this with their students for their next observation (see Appendix L).

During weeks six and seven, teachers facilitated the paper plane activity as experienced in their PD session with their students in their building. I visited each participant for an hour and recorded descriptive and interpretive notes using the observation sheet (see Appendix D).

At the end of the study, participants were invited back to the central STEM lab location to participate in a focus group discussion. They were also provided an optional exit questionnaire using Google forms (Appendix M).

Data Analysis

For this study, the transcript from the focus group discussion, field notes from classroom observations, all teacher reflection journals, and responses from the post study Google form were used for analysis through triangulation and cross-checked to see if participants were implementing what they shared. Inductive analysis is a data-driven approach where key concepts and insights are developed by discovering patterns and overarching themes from the raw data collected (Saldana, 2021). With the focus of this study on teachers’
understanding of integrative STEM education and instructional change through experiential PD, utilizing inductive analysis provided a process to sort, categorize, and identify significant and relevant themes to develop a framework for sharing key points of this study.

Throughout the study and coding process, I used analytic memo writing in multiple capacities to provide any kind of thoughts, reflections, and ideas (Saldana, 2021). I used six analytic memo writing strategies to reflect on and write about (Saldana, 2021):

- participants' actions, reactions, and interactions
- anything intriguing, surprising, or disturbing
- code choices and operational definitions
- possible connections to themes, categories, patterns, etc.
- future directions of the study
- tentative answers to the research questions

I applied these writing strategies when analyzing the focus group transcript, observation field notes, all teacher reflection journals, and responses from the post-study Google form and used these descriptions as part of the triangulation analysis process. Using these strategies helped me in identifying patterns and trends in the data, which led to a deeper understanding and view of how the participants made shifts throughout the cyclical nature of this study. The memos served as contextual guidance during the coding process.

I began the analysis process using my theoretical framework and research questions and took a thematic coding approach. One theme was developed
based on the research questions and the theoretical framework of this study before data analysis began. As data was collected and reviewed, an inductive approach was found necessary as two additional themes were evident and added. The Quirkos program offered a variety of ways to visualize data collected by using color coding and structures.

**First Round of Coding**

The first round of data analysis began with an initial reading of each of the data sources, focused on one participant at a time. I chose to read all data relevant to each participant first to view their experience in this study through their perspective and within their professional context (see Figure 3.5).

![Figure 3.5 Visual of First Round of Coding Structure](image)

I found it essential to immerse myself into each of the participants point of view since all the participants have varying teaching assignments at different schools across this district and have different level of experiences with integrative STEM education. This would aid in providing a stronger foundation in data analysis when triangulating all data during a future round of coding and set aside my own biases as the researcher. In addition, I chose to highlight any data that I thought could potentially be relevant to my research questions and theoretical
framework. I considered each piece of data collected on an individual scope and developed codes that would best support and answer the research questions. I documented all preliminary codes using the coding software Quirkos. This provided me with the initial structure needed to begin the process of establishing codes, categories and develop overarching themes as the analysis phase progressed (Saldana, 2021). I analyzed each piece of data collected individually to familiarize myself with each participant, reading their journal reflections in alignment to their classroom observations and reading each of their own responses during the focus group.

After reading through all data sources collected from each participant, I then reviewed each data collection instrument one at a time to analyze and compare each response with one another. For example, I compiled all responses for journal prompt #1 to analyze and looked for any similarities, differences, and anomalies across all participants. I repeated this for procedure when analyzing all journal prompts. I applied the same procedure for classroom observations. I compiled all pre-observations for all participants into one document, all observation #1 notes together, and all last observation notes together to see the progression of PD and any change in instructional practices of integration across all participants. This allowed me to review the data from different perspectives, look for patterns and trends, and make connections across all participants within the same data collection tool (see Figure 3.6).
I used a variety of coding types throughout the inductive process. I used holistic coding, where I applied a single code to dialogue or teacher reflection journal entries to note a broad theme (Saldana, 2021). For example, any data that had a negative connotation would be coded as a “barrier”. I used structural coding to organize data based on the theoretical framework and research questions developed for this study. For example, all PD experiences recorded through data collection were organized under “concrete experiences” as part of the theoretical framework that supports this study. I applied inductive coding to capture the authenticity of my participants (Saldana, 2021). An example of this is the term “confidence” was mentioned multiple times by participants. I also applied emotion coding to capture any words or phrases that imply any type of emotion, such as “feeling scared” or the tone of frustration during the focus group discussions. Lastly, I used descriptive coding to help summarize data into words or phrases to describe the topic (Saldana, 2021). For example, applying codes such as “hands-on” and “engaging” as part of a narrative describing the application of a STEM activity. Exploring an inductive approach was necessary
as many codes emerged more dominantly than others. Table 3.6 shows the direct alignment between each research question, the data collection source used, and the method of analysis.

Table 3.6 Alignment between RQ’s, Data Collection Tools, and Analysis

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Collection Tools</th>
<th>Method of Analysis (Qualitative)</th>
</tr>
</thead>
</table>
| RQ 1: How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom? | • Focus Group (one at the end)  
  • Observations (three total)  
  • Reflection Journal (Weekly)  
    o Prompts #2, #4, #5  
  • Post-study Google form questionnaire | • Memo writing  
  • Descriptive coding  
  • Emotion coding  
  • Holistic coding  
  • Inductive coding  
  • Structural coding |
| RQ 2: How do teacher perceptions of an integrative STEM approach transform over several experiential learning cycles? | • Focus Group (one at the end)  
  • Observations (three total)  
  • Reflection Journal (Weekly)  
    o Prompts #1, #3, #6  
  • Post-study Google form questionnaire | • Memo writing  
  • Descriptive coding  
  • Emotion coding  
  • Holistic coding  
  • Inductive coding  
  • Structural coding |

The first round of coding yielded a total of 29 codes (see Table 3.7). The definitions and exemplar for each of the codes identified in the first round of coding can be found in Appendix I.1.
Table 3.7 First Round of Coding with Frequency

<table>
<thead>
<tr>
<th>Codes</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract Conceptualization</td>
<td>13</td>
</tr>
<tr>
<td>Active Experimentation</td>
<td>15</td>
</tr>
<tr>
<td>Adapting</td>
<td>5</td>
</tr>
<tr>
<td>Activities</td>
<td>15</td>
</tr>
<tr>
<td>Barriers</td>
<td>29</td>
</tr>
<tr>
<td>Behaviors</td>
<td>2</td>
</tr>
<tr>
<td>Change in Instructional Practices</td>
<td>33</td>
</tr>
<tr>
<td>Class Discourse</td>
<td>2</td>
</tr>
<tr>
<td>Communication</td>
<td>2</td>
</tr>
<tr>
<td>Concrete Experiences</td>
<td>13</td>
</tr>
<tr>
<td>Confidence</td>
<td>31</td>
</tr>
<tr>
<td>Conflict</td>
<td>1</td>
</tr>
<tr>
<td>Creativity</td>
<td>4</td>
</tr>
<tr>
<td>Design Process</td>
<td>12</td>
</tr>
<tr>
<td>Engagement</td>
<td>11</td>
</tr>
<tr>
<td>Excitement</td>
<td>11</td>
</tr>
<tr>
<td>Fear</td>
<td>7</td>
</tr>
<tr>
<td>Implementation</td>
<td>9</td>
</tr>
<tr>
<td>Modeling</td>
<td>10</td>
</tr>
<tr>
<td>Professional Development (PD)</td>
<td>18</td>
</tr>
<tr>
<td>Planning</td>
<td>6</td>
</tr>
<tr>
<td>Reflection</td>
<td>13</td>
</tr>
<tr>
<td>Resources</td>
<td>29</td>
</tr>
<tr>
<td>Scheduling</td>
<td>2</td>
</tr>
<tr>
<td>Social Emotional Learning (SEL)</td>
<td>1</td>
</tr>
<tr>
<td>Structure</td>
<td>7</td>
</tr>
<tr>
<td>Student Outcomes</td>
<td>25</td>
</tr>
<tr>
<td>Time</td>
<td>42</td>
</tr>
<tr>
<td>Training</td>
<td>5</td>
</tr>
</tbody>
</table>
Second Round of Coding

Building on the initial coding structure, I took an axial coding approach, which led me to consolidate codes and create categories that branch off relevant themes (Saldana, 2021). Saldana (2021) defines axial coding as a means to group similar coded data and reorganize them to develop categories that are more focused. For example, I noted that many of initial emerging codes could be consolidated into broader categories, thus leading to a revision of initial codes documented during the first round of coding and organized codes using categories. I chose to edit “design process” to “modeling design process”. This change was necessary as the first theme highlights more of the act of modeling design process than the implementation of design process. I initially added “conflict” as a code, however, I decided to explore this further in chapter 5 under recommendations for future research. I also chose to remove “SEL” as a category as this was not as dominant as other codes.

I noticed that “PD”, “time”, “resources” and “fear” were elements that were reoccurring throughout the analysis to warrant moving from codes to categories. In addition, “structure” and “scheduling” fell into the category of time, and “planning” was designated as part of the resources category. The codes “confidence”, and “student outcome” were all indicative of positive change and were established as categories. Lastly, “fear” was designated as a negative emotion that was determined to be a category that best fit the overall theme of barriers. Finally, after analyzing the definition of “active experimentation”, I determined that it was appropriate to move and merge this category because
active experimentation of integrative STEM focuses on the application of the practice after the PD experience.

Through inductive analysis, the following categories were developed: design process, concrete experience, reflection, abstract conceptualization, active experimentation, PD, time, resources, fear, active experimentation, and student outcomes. These categories were essential in observing any change in instructional practices after an experiential learning professional development, as supported in research question #1. In addition, these categories also were essential in finding changes in perceptions towards integrative STEM education during or after experiencing cycles of experiential learning, as supported by research question #2.

**Third and Final Round of Coding**

For the third and final round of coding, I used the triangulation method to make distinct connections between reflection journals, focus group transcripts, classroom observations, and the post survey Google form for all participants. This provided me with a clear visualization of all data and analysis to finalize themes that best align to my theoretical framework and each of the research questions (Saldana, 2021).

Based on the codes and categories, three overarching themes were developed. The first theme established was instructional design for integrative STEM education PD. This was shaped using the categories of modeling design process, concrete experiences, reflection, and abstract conceptualization, which are elements that provide the foundation of the theoretical framework used in this
study. In addition, the categories “PD”, “time”, “resources”, and “fear” were indicative of barriers and were used to establish the second theme of transformation of barriers relevant to integrative STEM education. Finally, “active experimentation” and “student outcomes” were all indicative of a transformation towards integrative STEM. This shaped the third theme of increased confidence and competence for integrative STEM application. Table 3.8 shows a visual of the progression from categories to themes.

Table 3.8 Progression from Codes, Categories, and Themes

<table>
<thead>
<tr>
<th>Codes</th>
<th>Categories</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Abstract Conceptualization</td>
<td>• Modeling Design Process</td>
<td>Instructional Design for Integrative STEM Education PD</td>
</tr>
<tr>
<td>• Concrete Experiences</td>
<td>• Concrete Experiences</td>
<td></td>
</tr>
<tr>
<td>• Design Process</td>
<td>• Reflection</td>
<td></td>
</tr>
<tr>
<td>• Modeling</td>
<td>• Abstract Conceptualization</td>
<td></td>
</tr>
<tr>
<td>• Professional Development (PD)</td>
<td>• Reflection</td>
<td></td>
</tr>
<tr>
<td>• Reflection</td>
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<td>• Barriers</td>
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<td>Transformation of Barriers Relevant to Integrative STEM Education</td>
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<td>• Fear</td>
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<td>• Professional Development (PD)</td>
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<td>• Active Experimentation</td>
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<td>Confidence and Competence for Integrative STEM Education</td>
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<td>• Student Outcomes</td>
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<td>• Change in Instructional Practices</td>
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• Confidence
• Engagement
• Excitement
• Implementation

**Trustworthiness**

To preserve the trustworthiness of this research study, multiple qualitative procedures were implemented and documented.

Using the procedure of triangulation, data collected from the different data collection tools (transcripts from the focus group, observations, teacher reflections, and the post Google form questionnaire) were reviewed and used in analysis to identify strong, overarching themes. This is important as the multiple sources of data strengthen the study’s validity and evidence of findings (Yin, 2018). Researcher reflexivity enabled me to openly share my role and biases throughout the study through self-reflection as the researcher. Member checking was observed by allowing all participants the opportunity to participate in a focus group together, in addition to reviewing notes, transcriptions, and narratives to verify accuracy. During data analysis and constructing findings, participants were available for further questioning if clarification was needed as a method of member checking to reinforce trustworthiness and to collect constructive feedback. A rich description provided thorough details on the setting and procedures of the study, as well as narratives that included examples of conversations, observations, and interactions between participants.
Ethical Considerations

Upholding participant permissions and confidentiality was prioritized by utilizing various tools and procedures. Consent for all participants was recorded by providing a consent form to sign (see Appendix A). To ensure the privacy of participants, pseudonyms and general descriptors were used to represent them throughout the study and the use of identifying information was avoided. Recordings are limited to audio only. General descriptions were used to protect the identity of the school district and school site. For additional security, all digital files and recordings pertaining to this study were kept secure within a password-protected, encrypted medium. The researcher was the only person to have access to the passwords, as well as the files. The anonymity of the district and participants were upheld throughout the data collection and analysis phase. The functionality of the application helped in the process of organizing, describing, and interpreting the data collected. For example, color coding provided through this program was used to search for frequently used words, phrases, characteristics, traits, feelings, and behaviors and used to create initial categories based on patterns and trends.

Summary

This single-case study aimed to explore how an experiential PD model impacts teachers’ understanding of integrative STEM education. This qualitative case study implemented a semi-structured interview process during the focus group discussion that was recorded and transcribed. Questions were developed prior to the focus group were open-ended and the structure of the discussion
allowed for additional questions to be added to build upon participant responses. In addition, classroom observations were conducted prior to the study and after each PD training where factual and interpretive notes were recorded. Participants were provided with a teacher reflection journal that included six journal prompts to answer each week of the seven-week study. These journal prompts were created with the study’s theoretical framework in mind to encourage teachers to reflect throughout the experience. Lastly, a post-study Google form questionnaire was provided for participants to include any thoughts or comments regarding the study in general. Data analysis of this study included an inductive approach after further coding rounds as patterns and trends were evident, thus shaping three overarching themes. Findings and key themes from the comprehensive dataset collected are presented in the next chapter.
Chapter 4: Findings

Overview of Study

My role as a district STEM coordinator for a county located in the southeastern part of the United States led me to discover gaps in knowledge relevant to integrative STEM education within our elementary education population. To address this, the design of this study was to explore teachers’ perceptions of the integrative STEM instructional approach while immersed in a professional development opportunity specifically designed to mirror the cyclical nature of my theoretical framework. As such, Kolb’s experiential learning theory was at the forefront of the planning and implementation. To address the identified challenges and gaps within the school system, I developed the following research questions to support the design and implementation of the study:

**RQ 1:** How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom?

**RQ 2:** How do teacher perceptions of an integrative STEM approach transform over several experiential learning cycles?

A qualitative single case study approach was used as the design of the study to address each of the research questions provided. Qualitative data were collected through transcripts from the focus group meeting, classroom observation notes,
teacher reflection journals, and responses from the post-study Google form questionnaire. I conducted a pre-observation for each participant before the study began and two classroom observations during the study. Both factual and interpretive notes were recorded during each observation. Participants were also expected to reflect through journal prompts assigned in a teacher journal during the seven-week study. Lastly, all participants had the option of completing a post-study Google form questionnaire, where questions were open ended for participants to share their thoughts.

This chapter includes a thorough analysis of the qualitative data, highlighting themes with supporting evidence. Descriptive detail is provided in alignment with the research questions and theoretical framework. Data was collected throughout the duration of the study in the Fall semester of 2022 and analyzed during the Spring and Summer semesters of 2023. Using a non-linear cyclical process (Williams & Moser, 2019), all data collected were meticulously analyzed through triangulation and multiple rounds of coding. The progression through each stage of analysis allowed the filtration of data until final overarching themes were identified.

Provided below are general descriptors of the participants and their chosen pseudonym that shape the overall context of the participants that contribute to the key themes identified.

Jane is a veteran teacher with more than 15 years of experience in the field of education. She identifies as a White female and currently works at a small, rural Title 1 elementary school. She graduated college with an education
degree and began her teaching career teaching as an elementary classroom teacher. She has since transitioned into an elementary media teaching role that allows her to teach all K-5 students in the school. She has a comfortable understanding of integrative STEM but has indicated that she is always looking to learn more. For the purposes of this study, Jane was only observed working with her students in grades 3-5.

Maggie is a veteran teacher with more than 15 years of educational experience. She identifies as a White female and currently teaches at one of the top elementary schools in the district that is a non-Title 1 school. She teaches the same group of 3rd grade students all day and is responsible for planning and teaching all core subjects. Even though she is responsible for teaching all core subjects, she doesn’t always have the time to explicitly teach science and social studies consistently. She has a degree in education and has spent her entire career in education. Maggie does not have much knowledge regarding integrative STEM education, however, she indicated that she is interested in learning how to incorporate this instructional approach into her classroom and hopes that the transdisciplinary nature of this approach will help integrate science and social studies on a consistent basis.

Lola is a beginning teacher and has been teaching for less than five years. She is in her mid-twenties and identifies herself as a White female. Although education is her first and only career choice, she did not graduate college with an education degree and is currently working towards pursuing a teaching certificate. With her educational background in science, she has a strong interest
in the integrative STEM approach. She has the highest experience out of all participants in her instructional approach with her classes. In her current role, she teaches all students at her school. Her school is a title one school and is deemed low performing by the state and thus comes with extra responsibilities for teachers to endure.

Molly is a veteran teacher that has more than 15 years of teaching experience. She identifies as a White female. Graduating college with an education degree, she has spent her entire career teaching at a K-5 level. As a science teacher, she focuses on one subject area and has implemented integrative STEM approaches sporadically. This school year, she has the challenge of teaching at a low performing Title 1 school and having a combination class that consists of 4<sup>th</sup> and 5<sup>th</sup> graders.

Piper is a White female veteran teacher with more than 15 years of experience. Education was not her first career choice, and she did not graduate with an education degree. Teaching was a second career choice later in life after working in corporate for several years. After teaching in the classroom, she moved into a media coordinator role before settling in a district level position where she works with co-teaching with elementary school teachers for five different schools in the county. All the schools that Piper serves are considered low-income, Title 1 schools.

After analyzing all data sources, using the method of triangulation, and multiple rounds of coding and categorization, three themes were established. Theme 1 focuses on the instructional design for integrative STEM education PD.
Theme 2 highlights the transformation of barriers relevant to integrative STEM education. Lastly, theme 3 shares evidence of increased confidence and competence of integrative STEM application. Table 4.1 shows the three overarching themes and supporting evidence from the data that best represent each theme. Additional quotes that support each theme can be found in Appendix N.

Table 4.1 Themes and Supporting Evidence

<table>
<thead>
<tr>
<th>Theme</th>
<th>Supporting Evidence</th>
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<tr>
<td><strong>Theme 1: Instructional Design for Integrative STEM Education PD</strong></td>
<td>&quot;as a class, we are more cognizant of the process rather than the final product. We are looking at the how instead of just the what.&quot; -Maggie</td>
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<td>&quot;it [EDP] helps me allow them to reflect while they were doing it versus at the end. Even if it's giving them time to think and to process.&quot; -Lola</td>
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<td>&quot;I've noticed that if I do a STEM PD or I do just a STEM activity acting as a student...I know what the student is supposed to be thinking about.&quot; -Lola</td>
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<td>&quot;I liked being able to take the PD activities and use them with my students. Putting myself in the place of the students helped me with guiding questions in the classroom.&quot; -Maggie</td>
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<td>&quot;I am a hands-on learner so actually doing the activity provided me with the visuals I need to understand the topic, steps, and expectations of teaching the activity. I enjoyed completing the activity myself with other adult learners.&quot; -Jane</td>
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“each component of the STEM study was powerful and important. Rarely do teachers get a chance to implement what they learn – especially hands-on.” -Piper

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<tr>
<th>Theme 2: Transformation of Barriers Relevant to Integrative STEM Education</th>
<th>“more support is needed for science, there needs to be some mandatory training, PD, workshops, something in small groups.” -Maggie</th>
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<td>“they’ll say oh, I tried this. It was cool, why don’t you try? This is what my kids got out of it. It would be more impactful coming from someone that I know.” -Molly</td>
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<td>“they’re [teachers] scared because they didn’t grow up with it… I think that’ll [PD and training] help a lot of teachers too because they’re scared to do it.” -Molly</td>
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<td>“I felt a little more confident in what I was doing because I had played around with it and had time to practice it.” -Molly</td>
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<td>“don’t teach science and don’t harp on it the way we do with math and reading – there isn’t enough time.” -Lola</td>
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<th>Theme 3: Increase Confidence and Competence for Integrative STEM Application</th>
<th>“I am also building my knowledge on doing STEM with lower grades. K-2nd grade planning has been a challenge for me so I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons for those grades.” -Jane</th>
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<td>“Students responded eagerly and enthusiastically when I taught STEM…they were engaged… Being able to touch, explore, use, and see results in real time led to more active and concrete learning. They were better able to retain what they were experiencing and apply that knowledge in other areas”. -Piper</td>
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"I was always second guessing myself and I think it's because I didn't have as much experience with it. I feel like from the beginning to now, I'm a bit more confident in doing my own lessons and creating them myself.” - Piper

"I have learned more during this experience that has made me see elements that I didn't really see before and has opened my mind on how to create and plan better STEM lessons. I am now also building my knowledge on doing this with my lower grades classes.” - Jane

“I felt a little more confident in what I was doing because I had played around with it and had time to practice it. And I think that'll help a lot of teachers too because they're scared to do it.” - Molly

“it [STEM activity] boosted their confidence. They're like we want to do this, and I was like We're going to do more and that's what that's their learning style. They are hands-on and the boost of confidence for those students is amazing…it allows children who normally don't excel at like a standardized test to really show what they know and what they can do.” - Molly

This section will walk through the findings through the three thematic categories, providing evidence from data collection that supports the development of each theme.

**Theme 1: Instructional Design for Integrative STEM Education PD.**

Instructional design for integrative STEM education PD was established as the first foundational theme. The PD was designed for participants to experience a cycle of learning about the integrative STEM approach. The structure of the seven-week study consisted of several cycles of receiving PD,
reflecting whole group, implementing the STEM activity within their classroom, and reflecting via teacher journal. In the analysis, participants found elements of this instructional design approach to be foundational to their development as professionals. The categories that contribute to this theme include modeling design process, concrete experience, and abstract conceptualization. Each category will begin with a discussion of the practices and PD components that informed the category, followed by the discussion of how the participants applied and understood these practices.

Modeling Design Process. The design process that was utilized, modeled, and explored during professional development and implementation is identified as the engineering design process. In applying the EDP, learners are encouraged to think as engineers to solve problems by going through a cycle of learning: ask, plan, do, test, improve, test/share results. In developing this category, this was evident through participants learning about the engineering design process, as well as implementing this design process into their instructional practice.

The engineering design process was used as the design thinking structure for all the STEM activities shared and implemented in the study. All teachers learned about the EDP during the PD and were provided a graphic organizer of the district EDP template to use during their time as the learner. They were able to take this template and incorporate it during their implementation with their students. During classroom visits, factual observations were recorded that students used the engineering design process template to organize their thoughts during their STEM activity. All participants were observed reviewing
each step with their class to help students with progressing through and understanding the EDP.

Journal prompt #4 asked participants to reflect on instructional planning and implementation and to record any changes in student outcomes in learning. Molly shared her opinion on their usage of the engineering design process stating:

I really think having them plan using the engineering design process helps with thinking through what their design needs to be and how to use the materials effectively. It also allows them to work as a group when making decisions. In the past when I didn’t use this planning sheet, students would just jump into making something without thinking about it and there was not as much collaboration, just one person using their idea. I have also noticed that students don’t know how to think. (Molly’s response in journal)

Molly’s finding of the EDP planning sheet helping students organize their work to collaborate and work more effectively was reflected by the focus group.

Classroom observation notes aligned with these findings, observing that the implementation of the engineering design process helped students with planning and organizing their thoughts. For example, in Piper’s first observation notes, it was recorded that she walked through each step of the EDP with the whole class to help her students acquainted with the new process. By the end of the last observation, Piper’s students were observed working collaboratively with their peers, applying the EDP to plan their builds for the STEM activity, which
allowed her to facilitate around the room to help students as they needed it. These observations lead to an understanding that a design thinking model is needed for students and teachers to organize their thoughts when planning and working collaboratively to solve a problem.

Another participant, Maggie, shared that she found a learning opportunity to show how the engineering design process can be applicable to real world situations outside of classroom instruction. She said “even if we’re having a problem like we had one in PE today or last week where we’re getting frustrated, they’re getting upset. So, we talked through it. What is the problem? What can we try? Let's try it. Let's see if it works. Came back together and talk about the strategy.” In addition to the focus group, when answering journal prompt #4, she stated “as a class, we are more cognizant of the process rather than the final product. We are looking at the how instead of just the what.” This excerpt from the focus group transcript aligned with teacher journals in reflecting on how EDP can be used in various contexts, including real world challenges in future careers. This is encouraging in that it shows that participants found the engineering design process to be useful in helping their students solve real world issues when integrating STEM activities into their instruction.

Throughout the cycle of learning that participants experienced, there were multiple opportunities throughout to allow them to reflect on their own experiential learning process. This was intentionally incorporated throughout each week of the learning cycle. One participant recognized the significance of reflection and how the EDP naturally incorporates this into the learning process. During the
focus group discussions, Lola shared with her peers that reflection is essential in the learning process, however, it doesn’t get implemented to fidelity. However, she recognized that the EDP is useful in integrating reflection throughout the process, stating "it [EDP] helps me allow them to reflect while they were doing it versus at the end. Even if it’s giving them time to think and to process." The evidence provided from Lola displays how teachers’ concrete experience during the PD sessions helped develop their abstract conceptualization of various elements regarding integrative STEM education. In this example, Lola was able to use her learning experience to reinforce the importance of reflection in general, as well as make the connection that a design process, such as the EDP, encourages learners to constantly reflect on their learning.

In each of the data collection phases, from the focus group to the post-study Google form, the importance of modelling the design process was emphasized as a key element to effective experiential PD. Each of the data sources reflected ways in which modeling design process was important and uncovered a need for training on the design processes, such as the EDP. This shows that many teachers are not familiar with the design process or how it applies to integrative STEM education. However, they found that having EDP modeled was helpful.

Concrete Experiences. This category involves learners gathering firsthand knowledge of what they’re learning through direct engagement. In this study, this is represented in any data that involved hands-on learning during professional development training, direct engagement in learning, learning in the perspective
of a student, and collection and applying knowledge to develop their understanding of integrative STEM education. All five participants were involved in two face-to-face professional development opportunities where the focus was to be fully immersed in a hands-on STEM experience. They took on the role of a student, using this opportunity to experience this STEM lesson before they facilitate this to their own students. When asked what part of the study was most impactful in developing their understanding of integrative STEM, all participants shared that the PD and experiencing the activities before teaching, as well as the implementation of the activity after receiving the PD was impactful for them.

Participants articulated how the intentional design of the PD helped shape their understanding of integrative STEM education, one specifically stating that PD designed to be hands-on and reflective is helpful to complete as a participant versus a teacher. During the focus group discussion, Lola shared how being immersed into a learning session in the role of a student enables her to see their perspective before implementing in her classroom, stating “I’ve noticed that if I do a STEM PD or I do just a STEM activity acting as a student…I know what the student is supposed to be thinking about.” In alignment with Lola’s response, Maggie shared a similar opinion in the post-study Google form questionnaire, stating “I liked being able to take the PD activities and use them with my students. Putting myself in the place of the students helped me with guiding questions in the classroom.” The evidence provides important insights for the need of intentional structure of PD and how this could contribute to the development of a learner’s perception of a concept.
As learners made sense of what they’ve learned, they were able to reflect on their experience. As participants were immersed in the PD as learners, they shared that working through the PD as a student was beneficial in helping them visualize how an integrative STEM experience looks like when implemented. For example, when asked what made the most impact in her understanding of integrative STEM education throughout the study in the post study Google form questionnaire, Jane wrote “I am a hands-on learner so actually doing the activity provided me with the visuals I need to understand the topic, steps, and expectations of teaching the activity. I enjoyed completing the activity myself with other adult learners.” Piper also shared in the post-study Google form questionnaire that “each component of the STEM study was powerful and important. Rarely do teachers get a chance to implement what they learn – especially hands-on.” In addition to evidence provided, when asked how this experience made an impact on their instructional practices during the focus group discussion, Jane responded with “this really helped me take each step…we did it here first, and it helped me really see it. And then I felt more confident in teaching that with my kids and getting them to do it.” These responses provided by the focus group participants and responses in the post-study Google document are indicative of two ideas: the professional development experience made a positive impact on their instructional practices and perception toward integrative STEM, and the intentionality of the PD design to highlight the hands-on aspect of STEM was beneficial and provided a sense of empowerment for conceptualization and implementation.
Abstract Conceptualization. Abstract conceptualization is essential in the learning process because learners take their experiences and reflections and form conclusions by making sense of what they’ve learned. This part of the cycle contributes to the transformation of teachers’ ideas and thoughts of what they knew previously through making comparisons to their new understanding of integrative STEM education. In other words, they will form conclusions about what they learn based on the reflection from the concrete experience, which can influence integration and implementation. This was identified using all data collected regarding learners reflecting on their own instructional practices and thinking about future implementation.

While reflecting on their experience during the focus group, Lola shared with her peers how the PD on integrative STEM allowed herself to visualize how she could improve their instruction. She stated, “I have become very aware of ways that I can try to differentiate some of my instruction to help meet the needs of all of my students… STEM is great because it encourages students to become independent and active learners.” In response to this, Maggie agreed, stating that “I think this helped me to process the steps and understand how to break down the steps for my students so they can be successful.” Teachers reflecting on their learning experience during this study and making connections to be proactive in implementation demonstrates the importance of instructional design for integrative STEM PD.

Once learners have progressed through experiencing the PD as a learner, reflecting on what they learned, and building upon their prior knowledge of
integrative STEM, they apply what they’ve learned in their classrooms. It is within this stage that learners take what they’ve experienced and their newly developed understanding of a concept and implement it on their own. In this study, teachers were expected to implement the integrative STEM activities learned from PD with their students on their own.

During classroom observations, factual observation notes collected during their pre-observation, observation 1, and observation 2 are indicative of instructional change in practice for each participant. Prior to their PD experience, it was noted in each participants pre-observation records that many lessons were teacher-centered and limited to traditional classwork. These observations include watching videos, teachers teaching for most of the class period, lack of class discourse, and students not working in collaborative groups. For example, Molly was observed playing videos from the internet while students were instructed to write notes. Maggie found an activity on a website for her students to work on while she pulled groups in the back for remediation. Jane showed an effort of trying to implement a STEM activity with a picture book. However, because of the structure of the lesson plan that day, a lot of time was spent on students checking out books and reading a book out loud as a whole group, which did not leave any time for the actual STEM activity.

By the last observation and end of study, it was noted in the observation notes for all participants that the lessons observed were more student-centered and collaborative. These observations include students working in collaborative groups, teachers facilitating around the room, students involved in class
discourse, the incorporation of hands-on activities, students asking questions, and teachers promoting inquiry through questioning strategies. For example, Jane structured her class to read and check out books on a different day, so students had the full 40-minute class to work on their STEM activity. Molly provided more opportunities for group work and hands-on activities outside of the classroom versus having students work on a worksheet or write notes. Maggie facilitated discussions with each group, helping them think through their learning process by asking questions and encouraging her students to ask questions. In comparing the observation notes and findings of the pre-observation, observation #1, and observation #2, I found that participants developed a growing understanding of student-centered instruction through modeling and their own experience through the study. The data collected is indicative of an impact of teachers’ instructional practice because of their experience in the experiential PD model.

The first theme focused on providing evidence and excerpts from data collected regarding the participants engaged in the PD itself, highlighting needs for intentional design for integrative STEM PD. The collected data provides supporting evidence needed for strategically planned PD for teachers to build upon their conceptual understanding of integrative STEM education. Experiencing the EDP in the instructional design of the PD allowed for educators to embrace the process practically, as well as conceptually. At the same time, this allowed participants to identify barriers to incorporate integrative STEM as an instructional practice and document their personal transformations.
Theme 2: Transformation of Barriers to Integrative STEM Education

The process of adopting integrative STEM practices required participants identification of barriers, as well as a practical transformation through PD. Participants shared their thoughts on what they believe contribute to the hesitation of STEM integration within classrooms. Based on the responses provided in the focus group discussion, teacher journals, and the post-survey Google form, the data showed that lack of PD, fear, resources, and time are all factors that cause hesitation in teachers to apply this learning approach.

Thus, barriers and their transformations include a breakdown in data that provides evidence relevant to said barriers for lack of PD, fear, resources, and time. The identification of barriers from participants was evident, however, data reflected a transformation as participants progressed through the professional development and application of integrative STEM education. These categories were essential in answering both research questions, particularly research question #2 which focuses on transformation of perception regarding the integrative STEM approach. Provided in the next section are the findings that identified each barrier and evidence of factors that transformed their ability to apply this student-centered approach pertaining to PD, fear, resources, and time.

Barriers and Transformations Regarding PD. A common view amongst the participants was that there is a need for required established PD for integrative STEM in the district and an intentional design of the PD to model this student-centered learning approach. This view aligns with the evidence provided in theme one, which focuses on intentional design of a PD model for integrative
STEM. Participants collectively expressed that there is a focus more on math and reading in education because they are tested areas, and this affects the frequency of training offered for other subject areas. One participant, Molly, indicated in the focus group that training should start in the earlier grades, stating “Starting in kindergarten…We got all this mandatory reading and math training. There needs to be some mandatory science training.” In response to this, Maggie stated that “more support is needed for science, there needs to be some mandatory training, PD, workshops, something in small groups.” The dialogue between the two participants shows that teachers recognize there is a district-wide need for training that should begin from the elementary level and progress through each grade level. In addition, Maggie’s response deserves further exploration in which she states that PD training should be in small groups and what factors contributed to her suggestion.

Although all participants agreed that PD is needed, Molly proceeded to share her opinion that although PD is essential for developing conceptual understanding, the delivery should be strategic and that may not necessarily include the main facilitator of the PD. She stated to “have a person from each school that goes back and shares in small groups. That would be your go-to person.” In expanding her rationale, Molly expressed that there could be an increase in teachers viewing PD favorably if they personally know the facilitator or a colleague that has experience in implementation, stating “they’ll say oh, I tried this. It was cool, why don’t you try? This is what my kids got out of it. It would be more impactful coming from someone that I know.” Molly’s perspective
was an unexpected observation, though, insightful of how teachers perceive traditional professional development and the facilitator of the PD. This evidence suggests that some teachers are more receptive to new initiatives and ideas if they have established rapport with someone that has firsthand experience with positive student outcomes.

When designing the PD and learning experience for participants, cross curricular integration was intentionally embedded to model that integrative STEM education can be extended beyond the disciplinary areas included in its acronym and to provide teachers a visual and immersive model of what it could look like when integrating an activity that incorporates multiple curricular areas. Participants had varied levels of initial integration for STEM education, ranging from little experience to daily integration. When asked about integrative STEM education and incorporating multiple subject areas into an activity, some participants were able to share their attempts in integration, while others expressed challenges in the planning and implementation of a STEM activity. For example, during one of the observations, it was noted that Jane implemented a STEM activity where students were tasked with building a garden structure based on the problem presented in their picture book they read in class. Once students built the structure, they were instructed to calculate the area and perimeter of the garden. In correlation to her observation, Jane expressed in her response to journal entry #2 that she is cognizant of the state standards for when she plans STEM activities and incorporating picture books help with addressing literacy standards. In reference to her observation, she shared her experience
with cross-curricular STEM integration, stating that “the book helps with literacy to hit on those standards as well. An example, the 4th grade lesson involves perimeter, which is what math skills they are working on in the classroom.”

However, not all participants found this to be easy. Maggie shared in response to journal entry #2 that she has attempted to integrate other subject areas within a STEM activity but finds it difficult. She shared that she tries to integrate other subject areas within her daily classroom instruction, but finds challenges in planning and time, stating “It can be difficult to plan and execute activities that merge science, math, reading, writing, and technology.” An example she provided was a force and motion activity that involved creating a pumpkin catapult where students had to develop a simple machine and use math to measure and divide materials to incorporate math, science, and engineering in one lesson. The evidence from the data collected regarding cross curriculum integration and Maggie’s response is in direct correlation with theme 1 and theme 3, in that her challenges reflect low confidence in integration even though her provided example was indicative of a cross curricular STEM lesson.

In alignment with Maggie’s challenges, Molly shared a similar concern during the focus group discussion, where she expressed what is needed for her and other colleagues to incorporate cross curricular activities within a STEM activity, stating “training to show … how you can tie it in [to other subject areas].” She even offered what she believed could be a solution, stating that she thinks it would be helpful to have a make and take session for all teachers that can have theme easily see how STEM can be integrated into multiple curricular areas.
within state curriculum. The data illustrates ways teachers are open to learning how to incorporate other subject areas in their instruction, however, they may not have the knowledge or confidence to know how to do so. This indicates a need for modeling and co-teaching opportunities for teachers, as well as resources and lesson plans that provide teachers activities that already have cross curricular resources embedded within for implementation.

Participants indicated that lack of intentionally designed PD focused on integrative STEM was a barrier. The data showed that their direct experiences participating in the study has transformed their outlook in the value of PD. Interestingly, the evidence produced a range of confidence pertaining to the cross curricular integration when taking an integrative STEM learning approach between classroom teachers and STEM teachers. This piece of evidence is worth exploring further to determine what factors contribute to this observation. This may have some implications involving teachers’ educational backgrounds and teaching experience that deserve further research. It is not only practical barriers that were found, but also lack of confidence.

Barriers and Transformations Regarding Fear. During the focus group with all five participants, a question was posed by Lola regarding why they think there is hesitation in STEM implementation for teachers. Molly shared that “they’re [teachers] scared because they didn’t grow up with it… I think that’ll [PD and training] help a lot of teachers too because they’re scared to do it.” Molly also expressed that an additional factor that could cause fear in teachers is the required standardized tests at the end of the year. She shared concern that there
is always a strong push for test scores that it deters teachers from wanting to try a different approach to learning, stating that data collected from a traditional assessment is easier to assess student learning versus a non-traditional assessment. In addition to feeling a sense of fear in taking a student-centered approach to learning without training, Piper shared that control could possibly be a factor, stating “you have to let go of that control…with STEM I don't really know exactly what's going on…You don't know what’s going to happen. It can make you anxious, it can make you a little worried.” Molly’s response to Lola’s question is one that is worth exploring in future research. It is indicative of how the lack of integrated STEM in education in general can cause a cyclical pattern of limited exposure, lack of training, fear, and hesitation for implementation, that potentially stems from teacher’s own experiences as a K-12 student and the continued feeling of fear being a barrier for STEM integration. In addition, it exposes a disconnect of an understanding of how integrative STEM education can provide teachers and students instructionally and what it truly means for students to show growth and outcomes in learning beyond a traditional way of learning and assessing learning. The dialogue between Molly, Piper, and Lola provided insight into what barriers exist for teachers regarding integrating student-centered practices, such as integrative STEM, into their instruction. The feeling of fear provided by the evidence is a clear indication that teachers who feel a sense of fear can have a negative effect on teachers, thus, serving as a barrier for STEM integration.
One participant, Lola, shared during the focus group discussion that she has observed another aspect of fear in her students that could potentially impact them as adults. In her STEM class, she has observed students getting frustrated and upset when they don’t solve a problem right the first time. She states, “I would tell my students, you’re not going to get this right the first time. And that is okay, this is a safe place for you to fail. Try again, try, that's fine. You know, all your emotions are fine. But you got to try again. That's hard. Like it is hard… we as adults… don’t have those skills.” This excerpt is significant in that this shows potential correlation between the fear of failing when taking risks and it effects how adults’ approach something new, such as integrating a student-centered learning approach.

Although fear was shared as a feeling that could be a barrier in teachers facilitating a student-centered learning approach such as integrative STEM, a transformation of this barrier was one that was observed as participants progressed through the PD design and experiential learning cycle of integrative STEM education. One participant shared what she believes would be a solution to help work through those barriers. Molly shared during the focus group discussion that she believed having a facilitator show them how to plan and implement integrative STEM into their instruction helps with building self-confidence that could help address feelings of fear. She stated that this experience “I felt a little more confident in what I was doing because I had played around with it and had time to practice it.” The data shows an alignment between providing adequate training that is intentionally designed to model and immerse
participants as a learner can contribute to the transformation from the barrier of fear to the building of confidence and competence towards integrative STEM education.

Barriers and Transformations Regarding Resources. In addition to PD and fear being identified as barriers towards integrative STEM education, all five participants expressed that not having access to the appropriate resources and materials needed for a STEM activity has been a restriction for them. Focus group discussions from the transcript revealed various struggles that teachers identify as barriers relevant to STEM resources. Data regarding STEM resources shows that the two main barriers for resources are lack of STEM lessons available for teachers and the lack of materials that are needed for implementation.

In reference to STEM lessons, activities, and materials, Jane explained her personal challenges in securing materials needed for her lessons include both having to gather supplies and using her own money to purchase any materials for STEM activity to be able to lead any STEM related activities. In response to this, Maggie shared during the focus group discussion that she also has similar struggles with finding STEM activities that allow her to use materials she already has so that she doesn’t have to purchase more. She indicated that issues such as this can deter her from STEM activities, even though she knows that this student-centered learning approach would be enriching in the classroom. During the duration of the PD and implementation of STEM activities, it was share with participants that there is a district website that provides STEM
lessons and activities. This was received with frustration, to which Maggie responded that “we don't always know all the resources that are available to us.” However, by the end of the experience and participants having the opportunity to explore these activities and resources through their experiential learning PD, their insight transformed into a willingness to take more of an integrative STEM approach to learning. In addition, this discovery of resources available led participants to encourage other teachers to try. Molly shared that she went back to the teachers in the building to spread awareness of these teaching resources. She stated that they were excited to hear all that was available, stating “they were like, really? I was like, well let me tell you! You could use these activities and consumables that will make STEM easier for you and use if you want to!” In addition to other teachers outside of this study showing interest about these available resources and lessons, all five participants shared approval of this website. One participant in particular, Jane, wrote in response to journal entry #1 that she really likes the STEM website and that it shares activities for each grade level. She even saw an opportunity for sustainability, stating “it would be great to continue adding activities to go with standards.” This suggests that even though the district has a plethora of consumables and learning models for use, there needs to be a procedure in place to share out what materials are available, how they can be used and incorporated into lessons, and how to check these in and out. The data highlights that teachers are willing to try and implement STEM activities despite experiencing obstacles. However, it uncovered a need for
school or district support relevant to budgeting, securing materials, and instructional support.

Barriers and Transformations Regarding Time. The final barrier identified by participants is the lack of time for implementation during the school day. During the focus group discussion, the conversation regarding lack of time for implementation yielded unexpected dialogue. When asked if there was anything anyone would like to share before the conclusion of the focus group, Lola shared frustrations of how the implementation of integrative STEM in her classes as a specials teacher are negatively impacted by other teachers. “I have 45 [minutes] … I know other specialty areas teachers are like, oh, I don't care if they're 10 minutes late. I do because if they're 10 minutes late I'm cutting out something. Whether it's a mini lesson, whether it's vocabulary, whether it's our reflection piece, they don't have as much time to create or design and like, for me, it's [time] all precious. And so, time is very, very hard for me. I wish that my special time was longer. I always run out of time.” Jane shared similar challenges. She stated that in her role as a media coordinator, she also only has 45 minutes to check out books and implement a STEM activity and their time would be affected if classroom teachers were late in bringing their kids to specials class.

This generated a bit of dialogue that resulted in the sharing of differing perspectives. In response to Lola and Jane, Maggie, and Molly, who both serve as classroom teachers, revealed that the focus of instruction during the day is math and reading and thus, does not sufficiently leave any time for science, if at all. Lola shared her observation of the classroom teachers in her building, stating
they “don’t teach science and don’t harp on it the way we do with math and reading – there isn’t enough time.” She then asked the focus group if they’ve observed similar issues in their building. In response to this, Maggie said “we [classroom teachers] only get 10 minutes for science…I just don’t have time to do it.” Lola expressed that her role as a STEM teacher would enable her to come in and help integrate STEM activities and alleviate the stress of lack of time for classroom teachers. However, Maggie responded with frustration by asking Lola if “she is a classroom teacher” and proceeded to share that she does not have extra time to reach out for her STEM teacher to come into her classroom, stating that “the curriculum is so packed that I don’t seem to have time to complete everything.” In addition, Maggie expressed that “I’ve got so much to do, and I’ve got to fit this in, and I’ve got to do this and it sometimes it becomes more of a problem…I do see the value.” After both Lola and Maggie shared their different viewpoints and gained insight into each other’s perspectives, they both expressed appreciation to each other for being open with one another and their conflict was quickly resolved.

The findings for the category of barriers, specifically time, was unexpected. This highlighted the need for intentional training on how integrative STEM education can be incorporated into all subject areas. In addition, the participants that were engaged in the conflict and dialogue regarding implementation and time have different teaching roles in their buildings. Two participants, Molly, and Maggie, serve as classroom teachers and Jane and Lola serve as specials teachers. The evidence and data collected from the focus
group discussion provided insight of how integrative STEM could look different based on teacher roles and school structure and expectations. This finding is worth exploring further and will be detailed in Chapter 5.

This theme identified the barriers relative to integrative STEM education and documented the transformative process necessary to support this student-centered approach. Although PD, fear, resources, and time were shared as acting barriers that affect the implementation of STEM, the data showed that progression through the intentionally designed experiential learning PD training contributed to the transformation of said barriers, thus, building the confidence of participants. This segues into the final theme, which focuses on the teacher’s increased confidence and competence for integrative STEM application.

**Theme 3: Confidence and Competence for Integrative STEM Application**

The final theme that emerged was the increased confidence and competence for integrative STEM application while teachers progressed through cycles of the experiential PD, reflection, and implementation. Analysis found that the intentional professional development structure from theme 1 transformed barriers addressed in theme 2. Thus, the categories provided in theme 3 show findings of increased confidence and perceived competence relevant to STEM education application in result of the first two themes. The practical application of integrative practices and observed positive student outcomes helped to build teachers’ confidence and sense of competency for integrative STEM education in the classroom over time.
Change in Instructional Confidence through Active Experimentation

Active experimentation allows learners take their newly developed knowledge and apply it to their context. In addition, they can make connections and decisions through analyzing the needs of their students. This is identified throughout the analysis phase by classroom observations after PD, participants sharing thoughts about moving forward after the research study and observing any efforts in making instructional changes regarding integrative STEM implementation.

In addition to the examples of shifts in instructional practices from the beginning of the PD to the end, it was observed that each participant took a different approach to implementing the same STEM activity from their training. I recorded in my observation notes that every participant implemented the same STEM activity in the same manner that was presented to them during their first professional development training. However, by the last observation and last PD training, all participants organically made slight modifications to supplement their activity to fit their needs of their students and transform it into an even more robust lesson without my guidance as the trainer and researcher. Using the example of the paper plane activity from the last PD session, the observational data provided below shows how each participant transformed their instructional practice for the same lesson.

During each of their final observations and recorded on their classroom observation template, Jane found and incorporated a picture book related to paper planes to read to her class before introducing their STEM activity and
made connections to the Wright brothers who invented the plane. Maggie was observed facilitating discussion about force and motion to make connections between the science concept and the paper plane activity they were going to work on that day. Lola was observed providing differentiated instruction by providing extra support in walking her students through each step of the engineering design process as she noticed they needed more guidance and structure from the planning stage to the test stage of the paper planes. Molly was observed taking the approach of changing the learning environment for the students to give them more room to test their planes.

In addition to the instructional adjustments to the same STEM activity implemented, it was observed that participants grew more confidently in facilitating a STEM activity from the pre-study observation to the last classroom observation. For example, during Maggie’s initial pre-study observation, it was recorded that during her instructional time, students were tasked with working with partners while she pulled groups to work with at her table. During the first observation after receiving the first PD, Maggie was observed walking around the room and answering any questions that student may have. By the last observation, Maggie was observed facilitating around the room and asking her students questions and connecting what they were currently learning to real-world contexts. This example of each participant adjusting instruction to enhance their own implementation of a STEM activity and Maggie adapting the role of a facilitator are indicative of change in instructional practices and in understanding of integrative STEM education.
In addition to the observation changes noted, reflections from teacher journal responses reported growing confidence based on their experience and implementation from the study. Jane expressed wanting to extend her learning into her K-2 classes, stating “I am also building my knowledge on doing STEM with lower grades. K-2nd grade planning has been a challenge for me so I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons for those grades.” The reflection from Jane shows personal growth and reflection from her experiences through the seven-week study and confidence to extend her learning to other grade levels. All these observations and notes document the increasing sense of confidence that participants had through active experimentation after experiencing the process of integrative STEM education PD. However, measures of perceived competence were found primarily in educators’ observations of positive student outcomes.

It is evident in all data collection sources that all participants found their experiences of participating in the PD as a learner was a positive one and that they found it to be beneficial in building their knowledge and confidence in implementing integrative STEM activities for their students. The progression of their growing confidence towards this learning approach from the pre-study observation to the end of the seven-week study is distinct in their application and modifications of the provided activity.

Student Outcomes Perceived as Demonstrated Competence. All participants reported that their perceptions of an integrative STEM learning approach
transformed from the beginning of the study to the end of the seven weeks. This was evident through student outcomes observed during classroom observations collected and participant experiences shared during focus group discussions and reflection journal entries. For example, during all five teacher observations, verbal, and physical expressions from students during the implementation of a STEM activity were recorded that indicate excitement. For example, one student punched the air in celebration while another clapped their hands waiting for instruction. Some students exclaimed “yes!” or “yay!” when it was shared with them that they would be engaged in a STEM activity that day.

The following excerpt from illustrates Piper’s experience with her student’s excitement and the outcomes she observed:

Students responded eagerly and enthusiastically when I taught STEM...they were engaged... Being able to touch, explore, use, and see results in real time led to more active and concrete learning. They were better able to retain what they were experiencing and apply that knowledge in other areas. (Piper reflecting during focus group discussion)

Piper shared that this was significant with her students because they normally don’t as much excitement during a regular classroom day. In correlation to this, Piper’s classroom observations documented the verbal and physical excitement of her students when engaging on the hands-on force and motion activity from the first PD session, as seen in Figure 4.1)
In response to Piper sharing about her students excitement for exploration time with the roll and race kit, Maggie shared that during her implementation of the paper plane activity after the second PD session, one of her students extended their exploration of the same activity during their personal time, stating “I really liked the activity stuck with them and we could have those conversations and they were so into it…Mine have actually taken paper to lunch [to make] the airplane…They’re continuing it outside of the classroom setting”. The observation data and conversation from the focus group from Maggie and Piper shows a connection between integrating a hands-on STEM exploration activity and an increase in engagement for instruction.

In addition to the evidence provided that display increased engagement in the classroom, the data provided from observations and teacher reflection journals show that the hands-on engagement of STEM education impacts students who may not accel academically or display behavioral challenges. In her journal, Maggie was reflecting on her implementation of the paper plane activity. She expressed that the paper plane activity was eye opening for her
because she was able to see a different side to her students as they showcased their critical thinking skills and creativity. She shared “they really enjoyed the activity, and I enjoyed their creative approach to the challenge. It gave me the opportunity to see a different side of my students. Some of my students struggle with academic subjects, such as reading and math, but I found that they are very creative with problem solving activities. I loved seeing that part of their brain being used in the classroom setting. I love integrating the STEM with science, math, reading, etc.” Another participant, Jane, shared in her teacher journal that the greatest outcome she’s seen when implementing STEM activities is student engagement and outcomes, stating “they are very focused and determine to figure it out.” She continues to share that during her first observation and implementation of the force and motion STEM challenge, there was one student that often struggles with getting along with her peers and completing tasks. However, by engaging in this hands-on activity, she saw a transformation of this student within the hour of that class. The student was given the role of timekeeper, and being a part of the group with a role made her receptive to working collaboratively with others, as shown in Figure 4.2. Jane explained, “she tried it out and she felt so good about herself…she was laughing and smiling with her group, which I’ve never seen before.”
These journal excerpts are significant because it shows a direct connection of student outcomes and the positive impact it has on teachers’ perception of integrative STEM. The data provided are essential in addressing both research questions. It aligns with research question #1 which explores how an experiential learning PD experience impacts instructional practice and integration, as well as research question #2 in that participants share their changes in perception of an integrative STEM approach throughout the duration of the seven-week study.

Throughout the study, participants shared their thoughts on their initial understanding of integrative STEM education. It was evident in reviewing, focus group transcripts, observation notes, journal entries, and the post-study Google form questionnaire that teachers’ perceptions of integrative STEM transformed over the seven weeks. Through the consistent cycle of PD, reflection, and implementation, participants felt that they gradually became more confident in being able to implement integrative STEM activities within their classroom.
instruction, thus leading to an increased competence towards this learning approach. For example, Piper shared that “I was always second guessing myself and I think it's because I didn’t have as much experience with it. I feel like from the beginning to now, I're a bit more confident in doing my own lessons and creating them myself.” In addition, Jane shared in her journal response to prompt #2 “I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons. I am now also building my knowledge on doing this with my lower grades classes.”

During our focus group discussion, when asked about how they were feeling before and after the PD experience, all participants were unanimous in that their confidence increased as their understanding of integrative STEM grew. Molly responded, stating “I felt a little more confident in what I was doing because I had played around with it and had time to practice it. And I think that'll help a lot of teachers too because they’re scared to do it.” These data points show a growth in their competence towards integrative STEM practices as their conceptual knowledge increased throughout the PD experience. The data collected from all participants showed that their level of confidence and competence grew as they continued to experience integrative STEM as a learner. In result, their growing competence led to a change in perception towards integrative STEM education that empowered teachers to implement STEM experiences for their students. In relation to teacher confidence and competence levels, this aligns with other evidence provided under previous
themes. For example, within theme 1, Jane’s thoughts on feeling more confident in teaching STEM because of their direct PD experience as learners. Also, in alignment with theme 2, evidence provided showed that their initial feeling of fear and feeling unsure about how to implement integrative STEM activities in their classroom had transformed into a sense of competence as their confidence increased.

In addition to the growing confidence and competence of teachers’ application of integrative STEM, many participants shared that their efforts had a positive effect on their own students’ confidence levels. One participant in particular, Molly, provided insight regarding her students' confidence levels and an incident that occurred in her class after the study ended. Her classroom is a fourth and fifth grade combination class where her students are reading at a first-grade level. Despite their academic challenges, she has found that their level of engagement increases when she integrates STEM activities in her classroom. She shared that she was facilitating a STEM activity where students were creating models of anemometers when visitors walked into her room to observe her students working. These adult visitors walked around and asked her students what they were working on, and her students were able to fully explain their activity using proper scientific vocabulary. The visitors were very impressed by her students, stating “it [STEM activity] boosted their confidence. They're like we want to do this, and I was like We’re going to do more and that's what that's their learning style. They are hands-on and the boost of confidence for those students is amazing… it allows children who normally don't excel at like a standardized test
to really show what they know and what they can do.” As can be seen, increased confidence levels of teachers through cycles of intentional experiential PD and observing positive student outcomes in learning has an impact on their instructional practices and application of student-centered learning approaches, such as the integrative STEM approach.

**Summary of Findings**

The purpose of this study was aimed to explore any changes in teacher perceptions of integrative STEM education and instructional application after several cycles of PD, implementation, and reflection. Data analysis using information collected from the focus group transcript, classroom observation forms, teacher reflection journals, and post-study Google form questionnaire led to the structuring of three themes:

**Theme 1:** Instructional Design for Integrative STEM Education PD

**Theme 2:** Transformation of Barriers Relevant to Integrative STEM Education

**Theme 3:** Confidence and Competence for Integrative STEM Application

The first theme of instructional design for integrative STEM education PD was found to provide a foundation to help with learners’ transformation of barriers relevant to this student-centered learning approach. Addressing these barriers aided in increasing conceptual knowledge, thus, leading to an increased confidence and competence for integrative STEM application. This empowered participants to engage in active experimentation where they were able to
confidently lead and modify integrative STEM activities in their classroom, which produced an increase in student outcomes.

In addition to the connections between all three themes, it was evident that each theme builds as a learner progresses through each learning experience, thus, showing the cyclical nature of this study (see Figure 4.3).

![Figure 4.3 Graphic Depicting the Cyclical Nature of Themes](image)

This figure can be interpreted as a continuous cycle of learning, improvement, and growth. A learner that is immersed in a PD that is intentionally structured to provide an experiential, hands-on experience could lead to a transformation of identified barriers, thus, leading to an increase of confidence and competence towards application. Similar to the experiential learning cycle and the engineering design process, this process is ongoing as learners continue to experience learning, reflect, build upon their conceptual understanding, apply what they've learned, and re-adjust as needed.

One takeaway from the overall findings is there is an essential need for intentionally designed PD to grow teachers’ confidence and competence towards
integrative STEM education. It is evident from the findings that establishing a foundational understanding of integrative STEM education can provide teachers with instructional support needed to address potential barriers and thus, leading to an increased confidence and competence to incorporate this learning approach into instruction. Recommendations to support this takeaway will be discussed further in chapter 5.
Chapter 5: Discussion and Implications

There is currently no universal consensus of what integrative STEM education looks like and how to plan, implement, and educate school districts and teachers on how to integrate this instructional approach into daily instruction. The purpose of this single-case action research study was to explore changes in teachers' perception of integrative STEM education and application after participating in several cycles of experiential PD, implementation, and reflection. In order to do this, these two research questions that were developed. The research questions are as follows:

RQ 1: How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom?

RQ 2: How do teacher perceptions of an integrative approach STEM transform over several experiential learning cycles?

The seven-week study was intentionally developed to provide educators that teach 3rd, 4th, and/or 5th grade students a learning experience that immersed them into multiple cycles of experiential learning PD focused on integrative STEM education. This included a pre-observation before the PD, followed by a total of two face-to-face PD sessions where participants were engaged in a hands-
on activity that they would then implement in their classroom. In between each PD session, participants were encouraged to reflect on their experience and practices and were observed implementing these STEM activities with their students. Data collected using the transcript from the focus group discussion, classroom observation notes, teacher reflection journal entries, and responses from a post-study Google form questionnaire were meticulously analyzed and triangulated to develop three themes:

**Theme 1:** Instructional Design for Integrative STEM Education PD.

**Theme 2:** Transformation of Barriers Relevant to Integrative STEM Education.

**Theme 3:** Confidence and Competence for Integrative STEM Application.

This chapter will provide discussions on key evidence from data collection and analysis from the previous chapter. In addition, this chapter will include connections to existing literature, theoretical framework, and alignment to the research questions of the study. Recommendations will be shared based on these findings, as well as implications of the study. Suggestions for future research will conclude this chapter.

**Summary of Research Findings**

This study yielded a plethora of data that may help address existing gaps in the field of K-12 education pertaining to integrative STEM education, professional development, and experiential learning theory in education. The summary of findings, discussions, and recommendations presented below could be used to support school districts in understanding the importance of
establishing a plan to structure integrative STEM education implementation for teachers. The next section provides a summary of findings and details of how they align to the research questions and existing literature.

**RQ 1: How does an experiential professional development model impact integrative STEM instructional practices and integration in an elementary classroom?**

The data revealed that the experiential professional development model designed for this study had a considerable impact on teachers’ instructional practices and integration of integrative STEM education. The data showed that participation in the experiential learning designed PD had a positive impact on participants instructional practices and integration of the integrative STEM learning approach. Consistent with the literature, this research study found that participants who are immersed in an experiential-based PD are provided with continuous experiences and opportunities to reflect on their learning and expand upon their knowledge of integrative STEM, which has contributed to their overall growth throughout the study (Kolb, 1984). In addition, the intentional focus of the PD provided was to model how integrative STEM learning can align to curricular standards that teachers are expected to cover during the instructional day in which this connection contributed to an increase in integration and instructional practices, as supported by existing literature (Darling-Hammond & Richardson, 2009; Garet et al., 2001). This not only gives learners the perspective of their own students before their own implementation, but provides a model that shows how, in this case, the integrative STEM approach should look and feel like and
thus, allows them to build up their conceptual understanding to implement the learning experience in their own classroom (Klein & Riodan, 2011; Rajbanshi et al., 2020; Shernoff, 2017; Wang et al., 2021). This is a particularly valuable finding that can be useful for educational leaders that are interested in developing a training plan specific to integrative STEM education for teachers. Suggestions for a training plan can be found in the recommendation section of this chapter.

In relation to the engineering design process, data reflected an increase of understanding how this could enhance instructional practices relevant to integrative STEM education after incorporating the EDP within the experiential-based PD. More specifically, teachers were exposed to and were highly receptive to integrating engineering concepts within multiple disciplinary areas due to the immersive, hands-on nature of the PD provided. This aligns with previous studies that have shown that the implementation of the EDP in an authentic context aligned to curriculum can help show connections between engineering and multiple disciplinary areas (Estapa & Tank, 2017; Herro & Quigley, 2017; Ivey et al., 2016; Kelley & Knowles, 2016; Long, 2020; Rajbanshi et al., 2020; Reimers et al., 2015; Ting, 2016).

Another finding from the data suggests that in addition to the cyclical nature of this study, the concrete experiences, reflections, abstract conceptualization, and active experimentation contributed to the impact that the PD learning experience had on their instructional practices and integration. Participants were able to expand their conceptual knowledge of what they
learned in PD trainings and their implementation of activities in their classroom through multiple avenues of reflection and implementation. Data collected from teacher journals and reflections from the focus group showed that participants were able to readjust instructional practices as needed to meet the needs of their students. This is reflective of the ongoing cycle of PD, reflection, and implementation, as supported by previous studies (Girvan et al., 2016). In addition, this reflective practice also contributed to the building of the confidence levels towards integrative STEM education, which led to participants integrating other STEM-related activities beyond the duration of this study. The findings that support research question #1 show a strong connection and alignment of the theoretical framework of this study and the development of theme 1. This also contributes to theme 3, which provided evidence of the increase of confidence and competence in integrative STEM application as a result of the PD design.

While the first research question examined how an experiential PD model impacted instructional practices, this study posed a second research question that explored any transformations of teachers’ perceptions of integrative STEM education over multiple PD cycles.

**RQ 2: How do teacher perceptions of an integrative STEM approach transform over several experiential learning cycles?**

Results of the study found that the impact of the experiential PD model led to a positive change and understanding of integrative STEM for all participants. Participation in this study provided teachers with the scaffold needed to continue building upon their understanding of the integrative STEM approach, as well as
their confidence in applying their newly constructed knowledge in their classroom setting, as supported by previous studies (Klein & Riordan, 2011; Wang et al., 2021). In addition, teachers demonstrated an increase in competence and understanding of the engineering design process and how to integrate this learning process into their instruction. In using the EDP to support their integration of STEM, they were able to observe changes in outcomes with their students. In result of this, the confidence in teachers leading a student-centered learning approach increased, as well as their competence towards integrative STEM education, leading to teacher change in their practices. This finding is consistent with that of existing literature that support teacher change as a result in presence of positive student outcomes (Darling-Hammond et al., 2017; Guskey, 2000).

Although participants personally experience barriers of integrative STEM education, findings showed that they were able to overcome said barriers and this was reflected through a transformation as they progressed through multiple cycles of experiential learning PD, reflection, and implementation. This allowed participants to engage as learners, which served as a different perspective for them as educators. Participants were able to learn about the different STEM resources available to them, how to implement them, and how the transdisciplinary nature of integrative STEM education helps with time for implementing, in which previous studies have addressed as barriers and needs for implementation (Avery, 2013; Du et al., 2018; Goodnough et al., 2014; Kartal et al., 2018). In addition, participants were able to envision how integrative STEM
activities could look like in their classrooms and how said activities could incorporate multiple curriculum standards. These learning experiences for participants were able to address any feelings of fear, as their conceptual understanding began to increase with exposure and modeling. As participants begin to visualize the alignment and connections of integrative STEM education and the expectations of their daily instruction, their confidence and competence began to transform. These findings are encouraging for STEM leaders in the educational realm in that intentionality of PD design, modeling, reflection, and implementation with instructional support can transform teacher confidence and competence of integrative STEM, thus resulting in an increase of integration in the classroom.

By the end of the study, an increase of teacher and student engagement, inquiry, class discourse, and collaborative groups were observed. All teachers worked to incorporate more time for STEM integration and took a more student-centered approach to learning. The findings provided under research question #2 served as the foundation of theme 2 in addressing barriers and transformation of integrative STEM education, which supported the development of theme 3 in observing an increase in confidence and competence for integrative STEM application.

In summary, the data collected aligned with prior research and expands on existing literature with confirmatory evidence. Additionally, this data resulted in the three overarching themes provided that ultimately shows that instructional design for integrative STEM education can help with the transformation of
barriers relevant to STEM education, which leads to the increase of confidence and competence for integrative STEM application. The next section provides recommendations based on the findings of this single-case research study.

**Implications for Practice**

*STEM Teacher Academy*

Providing an opportunity for educators to gain experience and an understanding of integrative STEM education through intentionally design PD is essential as shown in the data and findings of this study. I propose developing a district-level PD opportunity for teachers in school districts that are structured using multiple cycles of hands-on learning as the learner, reflection opportunities via teacher journals and discussions, and implementation of activities within their own classrooms. It is imperative that teachers experience this cycle in multiple rounds, ideally over a span of several months, as PD is shown to be more effective with a longer duration time (Darling-Hammond et al., 2017). To alleviate the potentially overwhelmingness of many teachers participating at once, I would propose starting with a smaller group of educators first, such as one representative from each school in the district. Not only would this develop teacher leaders within the building, but they would serve as advocates of STEM education to receive training and take back to their schools. The intentional planning and implementation of this recommendation will provide the structure and supports that are needed for school districts to establish a foundation for integrative STEM for teachers and create sustainability through adding cohorts every year with previous cohort members leading future sessions.
**District and State STEM Plan**

The analysis of this study showed that there is a need for an action plan to help school districts establish an accurate and thorough understanding of integrative STEM education for grades K-12. Although this study was focused on upper elementary teachers, there is a need for a district wide structure of STEM implementation to show progression from elementary STEM implementation to high school implementation for growth and sustainability in teachers and students. To address this, I would propose school districts to develop a mission and vision statement that represents what STEM education is for the district. I would also provide an overall idea of what integrative STEM education is so that consistency is observed across the district. This would serve the purpose of limiting confusion of what STEM is, especially within the school district. Lastly, the district STEM plan would establish a foundation for STEM within the district and provide ongoing goals to work towards growth and sustainability. As district leaders work on the development of a district STEM plan, I would strongly recommend the use of existing studies and literature as guidance to ensure that the district is conveying accurate information and understanding of a true, integrative STEM learning approach.

Although the purpose of this study is focused on one single district, the recommendations provided can be applicable to other school districts across the United States and globally. I would highly recommend that state leaders take a similar approach in developing a state STEM plan that uses existing literature and research to establish an accurate understanding of what integrative STEM
is, how does this look like in the classroom, and how to determine what supports, such as training and resources, to help districts begin planning and implementation at their level.

**District and State Resources Hub**

To address barriers shared by participants regarding implementation of STEM within their instruction, creating a STEM resource hub could help address both time and resource challenges. The purpose of this resource hub would be to provide teachers with any pre-created, vetted STEM lessons, activities and resources that are aligned to state curriculum, eliminating the need to try and find resources to use from the internet. Lessons will be provided that are directly aligned to state curriculum and district pacing guides, which alleviates barriers regarding time and planning. To provide sustainability for updated lessons and resources, it would be encouraged for teacher leaders that graduate from the STEM teacher academy will work towards developing and adding to the resource library of activities and lessons. Using this resource hub can show what resources are available for use would allow teachers to see availability of materials and provide exemplar models of how to effectively use these STEM materials and resources in the classroom. This will allow teachers to check out what items are available to borrow for lessons, which can help alleviate barriers relevant to resources.

**Implications for Research**

This research contributes valuable and evidentiary data to the existing literature pertaining to the experiential learning theory in education, integrative
STEM education, professional development, and engineering design process. Little research has been conducted that focuses specifically on intentional design of experiential learning PD, especially in designing said PD to build teachers’ understanding of integrative STEM education in the educational realm of K-12.

The data from this study yielded evidence that supports what Kolb’s experiential learning theory suggests. As participants progressed through each element of the experiential learning cycle, their understanding of integrative STEM education continued to be reshaped based on their experiences, reflections, and applications, as supported by the theoretical framework of this study (Kolb, 1984). Additionally, this study allowed me to expand on the experiential learning theory and how this is applicable to education. Based on the data analysis conducted, the three themes that emerged were found to be a cyclical process that could be used in other areas that involve student-centered teaching beyond integrative STEM education. This is a novel approach that appears to not be addressed in existing literature. For example, future research on designing and implementing a project-based learning (PBL) approach could be developed using the cycle provided in Figure 4.3. Specifically, the intentionally designed experiential PD focused on PBL could help address any identified barriers relevant to PBL, and lead to a change in confidence and competence towards PBL application.

This study contributes to the overall misunderstanding of STEM education and the benefits this learning approach has to student engagement, instructional practices, and learning in general (Becker & Park, 2011). The findings from this
study suggest that providing structured and intentionally experiential PD may address misconceptions and misunderstandings of the definition of integrative STEM education and how this is applicable in a K-12 setting. It is evident that for teachers to be successful in implementing new instructional approaches, a plan is needed that includes intentional, high-quality professional development to build confidence and competence for application. This includes a cycle of consistent PD sessions, time for reflection, opportunities for implementation, and providing instructional support with feedback. This cycle suggests a model for designing and modeling educational PD that could be applicable beyond integrative STEM education. Stakeholders and district leaders cannot assume that teachers are knowledgeable enough to implement new instructional approaches effectively and accurately. However, to address this, leaders can use the structure of this study to plan and apply a different approach to professional development beyond traditional training to provide a rich, robust learning experience that can address misconceptions of integrative STEM education and any existing barriers that may prevent implementation in the classroom.

**Limitations**

This single-case study was specific to elementary school teachers in an urban school setting in the Southeastern part of the United States. One limitation is this study was restricted to one school district. Since this study was limited to one school district, it is unknown how applicable this would be for other school districts. Outcomes could vary based on the geographical location of the study.
when considering differences such as region, culture, demographics, district size, and school structures.

Although the invitation was extended to all teachers that teach grades 3-5, the study expectations and workload deterred many teachers from participating. The main reason provided was lack of time to dedicate to the study and the expectations of their school duties that were beyond my control. As a result, I had five teachers willing to fully participate for the seven-week study. This is not a substantial number to represent the upper elementary teacher population within the district, nor the 3-5 population in general. Five participants is not a significant number of participants for saturation, however, is sufficient for exploratory research (Yin, 2014). In addition to the small sample size of this study, all teachers that volunteered to take part in the study all identified as White females that have lived in the Southeastern part of the United States all their lives. This is a major limitation observed, as this prevents the study from exploring any impact on teachers with varying educational and demographic backgrounds and cultures.

Additionally, the study focused on designing and delivering PD specifically for teachers in grades 3-5. The focus on these grade levels excludes other teachers in the lower elementary grades and secondary school teachers. Although participants found the experience impactful toward their confidence in implementing integrative STEM activities in their classrooms, it is unknown how this study would impact teachers who teacher grades K – 2, middle school, and
high school, especially with the difference in school structures for secondary settings.

Time constraints for the research study is another limitation to consider. It is difficult to measure sustaining impact of the experiential learning PD towards integrative STEM education in a short amount of time. Robust PD that provides a sustained amount of time to continuously learn, implement, reflect, and receive feedback are found to be effective (Darling-Hammond et al., 2017). This study only examined participants over the course of seven weeks, and a more longitudinal examination may provide more robust evidence.

Another limitation to this study is the location of the PD to accommodate all participants. Teachers were asked to meet and explore in a STEM lab outside of their natural instructional setting. This could potentially cause a disconnect in the transfer of knowledge between the teachers at their PD session versus when they implement the same lesson in their classroom. In addition, not all school systems are structured with STEM labs with access to the same resources that were made available for the integrative STEM activities observed in this study.

Another limitation to consider comes naturally with this study and in education in general. Since participants were able to choose the date and time, they knew ahead of time when I was coming in for all their observations. This may have altered the organic flow of their regular instructional day. For example, teachers could have prepared their students the day before that a guest was coming in to observe, and that could have changed behaviors of students during the observation while I was visible during the observation hour.
Lastly, my position as the district STEM coordinator presented a challenge in ensuring that I established myself without bias. Having worked with three out of the five participants professionally is a limitation. Procedures were in place to establish my positionality and preserve ethical considerations and trustworthiness for this study, but some impact may have been present. In addition to limitations relevant to my professional role in the district, another to observe is the amount of work that I endured as a lone researcher. In addition to my daily duties as my district’s STEM coordinator, I developed and implemented all the necessary components of this single-case study. If roles were dispersed to other leaders, I could focus solely on data collection and dissemination to grow research in integrative STEM education.

Although there are several limitations identified, it is imperative to note that the benefits of this study outweigh the limitations provided. The findings and future impact of these findings are significant and essential in adding to the growing literature relevant to professional development, experiential learning theory in education, engineering design process, and integrative STEM education. Specifically, Figure 4.3 illustrates a thematic cyclical model that has the potential to be transferrable to other studies.

**Future Research**

It is observable that there is a need for additional studies that focus on developing an understanding of STEM education in the K-12 realm for school districts, as well as the application of the experiential learning cycle as the structure for PD. It is evident that there still isn’t a clear understanding of what
integrative STEM education is or how this instructional approach may look like when implemented in schools. There were very few studies found where the experiential learning theory was used to provide a framework for professional development in education for teachers in general, and less pertaining to integrative STEM education. With experiential learning theory focusing heavily on building knowledge through experiences, reflection, and application, it is surprising that there isn’t much existing research as this aligns with the hands-on nature of STEM education.

With the focus of this study aimed specifically for teachers that teach grades 3-5, applying elements of this study K-2 teachers and secondary grade levels would provide a wider perspective to observe any similarities and differences in impact and instructional change after attending an experiential-based PD focused on integrative STEM education. It would be recommended for future research to include a diverse range of participants with varying socioeconomic statuses, race, culture, and gender.

In addition, as I continued to revisit all data, I discovered that elements of Guskey’s model of teacher change were present across the data collected and naturally worked parallel to my theoretical framework. Conducting future research with intentional alignment of Kolb’s experiential learning theory, Guskey’s model of change, and Darling-Hammond’s characteristics for effective PD could add significant data to the area of academia in terms of teacher development and teacher change.
To address some of the limitations of this study, it would be recommended to organize an unannounced pop in observation to observe consistent implementation of STEM education. This would deter any potential changes in classroom environment when there is an announced guest coming in for a planned observation. In addition, I would recommend being cognizant of different learning styles of participants. This would provide an opportunity to explore Kolb’s learning inventory in which learning styles are the focus of building conceptual understanding. Those learning styles include accommodating (feeling and doing), diverging (feeling and watching), converging (thinking and doing), and assimilating (thinking and watching) (Kolb, 1984). For this study, all participants were hands-on, visual learners. Having a more diverse pool of participants with various learning styles could expand this study to yield different or similar results.

Time was a factor that was a hinderance for me in applying my study. Ideally, I would have liked to extend the scope of my study to a whole school year, providing professional development every other month, with teacher reflections, opportunities for implementation, and towards the end, have teachers create their own integrative STEM lesson for their post observation. I believe this would have strengthen my findings, especially in showing the significance of the impact and change of the understanding of STEM. Moving forward, I plan to apply my own recommendation, which is to establish a district wide STEM leadership academy that will mimic the structure of this plan that will include
teachers from other grade levels and increase the duration to be year-long with opportunities for summer workshops.

Additionally, I would explore the inclusion of additional researchers within the field of STEM education and other contexts not limited to the location that this study took place. This would offset some of the components that would normally fall under one researcher to provide an opportunity to collect and view data in the lens of multiple perspectives. Inviting outside researchers that have varying experiences with STEM education could strengthen findings, identify gaps in analysis, and increase validity.

Although this study was specific to exploring integrative STEM education, I am curious as to how this model could be applied to other learning pedagogy that are identified as student-centered approaches to learning. It would be worth exploring how this experiential learning cycle and intentional PD design could affect teacher confidence and competence towards the application of project-based learning.

One unanticipated result that emerged from the data was the conflict between STEM and media teacher and the classroom teachers during the focus group discussion as discussed in the previous chapter. The frustrations led to conflict during the interview I found the minor conflict between the classroom teachers and the media and STEM teachers noteworthy. It is interesting that the STEM teacher posed this question to her peers. This conversation during the focus group addresses the purpose of my study; it highlights the importance and need for training of integrative STEM to provide all teachers, including subject
areas such as music, PE, and art, a foundational understanding of this student-centered approach. In addition, this dialogue between the classroom teachers and the media and STEM teacher uncovered several points that I am curious to explore further: the need to establish how STEM teachers can help support classroom teachers in integrating STEM into their classroom practices and establishing how STEM teachers and building-level STEM advocates can effectively collaborate with classroom teachers to help plan STEM activities. This could provide more learning opportunities to work with other adults, learn from one another, and seeing connections between multiple curriculum areas.

Ultimately, all educators work towards the same goal of providing students with learning opportunities that help them become STEM-literate members of society. Exploring ways to maximize the expertise of a STEM teacher and STEM advocates through collaboration provides different perspectives, which could lead to different ideas of implementation.

As an extension of this study, I am interested in exploring the interpretations and implementations of integrative STEM education across the United States. During my research and experiences in my professional context, I’ve experienced more teachers throughout the country asking for help because they’ve been asked to teach STEM and have zero experience in what STEM is. This is an issue that could potentially add to the already existing confusion and lack of structure for STEM education in K-12 school districts, and further solidifies the need for additional studies pertaining to integrative STEM education and professional development.
Conclusion

The findings that emerged from the focus group, classroom observations, teacher reflection journals, and post-study Google form survey shaped the overall themes that holistically encompass the study’s aim and purpose. The intentional instructional design for PD provides support needed to address barriers that exist pertaining to the planning and implementation of integrative STEM. Through addressing these barriers through multiple cycles of experiential learning PD, transformation of barriers toward this student-centered learning approach can occur that would ultimately lead to an increase of confidence and competence to apply what they learned.

One key takeaway relevant to my professional context as a district STEM coordinator is the alarming number of educators that are expected to teach or lead STEM activities without having an accurate understanding of what exactly integrative STEM is. This has been observed contributing to confusion and inaccuracy across the K-12 realm. As a STEM advocate, I intend to address this within my own school district, starting with the upcoming school year. My current plan is to establish a district STEM academy and require administration from each school building to send one teacher to represent their school. They will be encouraged to send teachers that are diverse in population, demographics, educational background, and educational experiences. I intend on expanding this study to all grade levels K-12 and recreating this experiential learning PD cycle within this academy with changes that would reflect some of the limitations provided in this chapter. In addition to designing and implementing the district
STEM academy, I plan to present my findings and experiences at state and national conferences. My hope is that this initiative will help provide a model PD plan to pave a path for future district and state leaders for K-12 STEM education. This would empower educators to advocate for and implement integrative STEM instruction as part of their regular instruction, which would expose K-12 students to more STEM opportunities.
References


[https://doi.org/10.18260/1-2--15533](https://doi.org/10.18260/1-2--15533)


Lin, K. Y., Wu, Y. T., Hsu, Y. T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop


Appendix A: Consent Form

By signing this document, I:

- Am voluntarily agreeing to participate in this research study.
- Understand that I have the choice to withdraw my participation at any time.
- Have the choice to refrain from answering questions asked.
- Have had the purpose of the study explained to me and that I understand the nature of it.
- Understand that participation involves attending PD, being an active participant in learning, being observed, being interviewed, and being asked questions.
- Agree for my interview to be audio recorded.
- Understand that the information I provide will be confidential to protect my identity.
- Understand that if I am interviewed that the researcher can use direct quotes that I share.
- Understand that data will be collected to be shared in settings such as, but not limited to conferences, reports, published papers, etc.

Signature of Participant: _____________________ Date: ________
Signature of Researcher: _____________________ Date: ________
Appendix B: Focus Group Script

Good afternoon! I want to begin our session by thanking each of you for being a part of this experience. My name is Christine Mitchell, and I am currently a student at the University of South Carolina where I am pursuing a doctorate in STEM Education. I am looking forward to chatting with you all to record information about your experiences and attitudes towards integrative STEM education using a design-based model. You were invited to be a part of the focus group because of your interest in learning about the integrative STEM approach for your classroom.

During our chat, there are no right or wrong answers. Please feel free to openly share your point of view with me and the others in the focus group. This includes positive and negative experiences, thoughts, and feelings. Since we are in a safe space, please be mindful of others as they are sharing out. We want to ensure that all of you feel that your opinions and views have been heard.

This interview session will be recorded. The purpose of this is for me to understand any of your thoughts and feelings that you choose to share with me. This will allow me to stay focused and present with you all here and provide accurate information to stay true to what you have shared. I assure you that your identity will be kept confidential. We will not use your names in any documentation that is to be included in this submission. In fact, if you would like to choose a pseudonym to represent yourself, that will be helpful. I will place a notecard at the front of your seat so that I am able to call you by your pseudonym name for our study.

After sharing this information, you are completely free to opt-out of this interview now and at any given time. If you are currently feeling uncomfortable and would not like to participate, please let me know.

Let us begin! Let us start by going around to each of you to state your name and the grade that you currently teach.
Appendix C: Focus Group Questions

1. What are your thoughts about this entire PD experience?

2. Think back to the experience. How has your attitude toward integrative STEM changed, if at all?

3. How has your instructional practice changed since before the study and after?

4. How did you perceive student outcomes when you changed your instructional approach?

5. Give an example of the PD experience that you liked best.

6. Take a few seconds to reflect on your participation in this PD. Please share your thoughts.

7. What is something we can do to improve the program?

Ending Questions

1. Out of our conversation this afternoon, what would you say would be the most important?

2. If you had one thing to share about your experience with a teacher that did not participate, what would you share?

3. What, if anything, would you like to share about the PD experience, integrative STEM education, or this interview?

4. Is there anything else you would like to share?
Appendix D: Classroom Observation Template

Participant # ____
Date: ________
Time: ________

<table>
<thead>
<tr>
<th>Factual Observations</th>
<th>Interpretive Notes</th>
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Appendix E: Teacher Reflection Journal Prompts

1: What is your current attitude towards integrative STEM educational approaches? Describe, if any, what hands-on activities your students engaged in this week.

2: In what ways, if any, do you take an integrative STEM approach when planning your lessons and teaching? Provide specific examples.

3: What were some challenges that arose as you implemented a design challenge with your students this week? How did you and your students overcome them?

4: Reflecting on your instructional planning and implementation, what changes, if any, have you seen in your students’ outcomes in learning? Give specific examples.

5: How has your instructional practice changed since week 1? Give specific examples.

6: What is your current attitude towards integrative STEM educational approaches? Describe, if any, what hands-on activities your students engaged in this week.
Appendix F: 3\textsuperscript{rd} Grade Worksheet

3rd Grade Force and Motion Investigation

Make a Prediction!
Out of the six tracks, which do you think will cause your car to:

- move the fastest?
- move the slowest?
- change direction?
- get stuck on the track?

<table>
<thead>
<tr>
<th>Track</th>
<th>Time Trial 1</th>
<th>Time Trial 2</th>
<th>Observations (What happened with your car? Did it change direction? Was it slow or fast?)</th>
</tr>
</thead>
<tbody>
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</table>

Reflection

What surprised you the most?

What did you learn today about speed, force, and direction?

If you were to build a car to yield better results, how would you design it? Why?

Figure F.1 Third Grade Force and Motion Worksheet
Appendix G: 4/5th Grades Worksheet

4th/5th Grade Force and Motion Investigation

Make a Prediction!

Which track is mostly likely to change the direction of your car? Why?

What will cause your car to move faster: no block, green block, or purple block?

Out of the six tests, which will give you the FASTEST results?

Out of the six tests, which will give you the SLOWEST results?

<table>
<thead>
<tr>
<th></th>
<th>Smooth Track (no block)</th>
<th>Smooth Track (Green Block)</th>
<th>Smooth Track (Purple Block)</th>
<th>Bumpy Track (no block)</th>
<th>Bumpy Track (Green Block)</th>
<th>Bumpy Track (Purple Block)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Time</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Distance</td>
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</table>

Observations

|       | 2nd Test                |                             |                             |                        |                           |                             |
|-------| Time                    |                             |                             |                        |                           |                             |
|       | Distance                |                             |                             |                        |                           |                             |

Observations

Reflection

What surprised you the most?

What did you learn today about speed, change in mass, and direction?

If you were to build a car to yield better results, how would you design it? Why?

Figure G.1 Fourth/Fifth Grade Force and Motion Worksheet
Appendix H: Engineering Design Process Map

Figure H.1 Graphic Map of Engineering Design Process
## Appendix I: Definitions of Codes and Exemplars

Table I.1 Definitions of Codes and Exemplars

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Coding Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract Conceptualization</td>
<td>Participants reconstruct their own understanding of integrative STEM.</td>
<td>“I have also reflected more on my lessons and will make some changes for the rest of the school year. I want them to record data down themselves and not just have me write it on the board for everyone to see. This would allow them to compare and analyze more.”</td>
</tr>
<tr>
<td>Active Experimentation</td>
<td>Participants implement integrative STEM activities in their classroom and adjust their instruction.</td>
<td>“After doing the 3rd/5th grade friction lesson PD with teachers I decided to come up with a modified lesson for K.”</td>
</tr>
<tr>
<td>Activities</td>
<td>Participants engaged in activities as a learner or facilitator.</td>
<td>“I enjoyed the hands-on activities and the chance to implement them”</td>
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<tr>
<td>Adapting</td>
<td>Participants make differentiated decisions for their student needs.</td>
<td>“When I saw that and I haven’t done a lot of prediction stuff with my kids, yet. It really encouraged me to try to find ways to implement stem in a way that they could do it”</td>
</tr>
<tr>
<td>Barriers</td>
<td>Participants mentioning possibilities of why integrative STEM is not a part of their instruction.</td>
<td>“I honestly have trouble even doing my STEM lessons in that amount of time”</td>
</tr>
<tr>
<td>Behaviors</td>
<td>Positive or negative classroom management observations.</td>
<td>“she tried it out and she felt so good about herself…she was laughing and smiling with her group, which I’ve never seen before.”</td>
</tr>
<tr>
<td>Change in Instructional Practices</td>
<td>Evidence of change in instructional practices.</td>
<td>“K-2nd grade planning has been a challenge for me so I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons for those grades.”</td>
</tr>
<tr>
<td>Class Discourse</td>
<td>Student discussions between students and the teacher.</td>
<td>“What the difference between notebook paper, construction paper, and cardstock?” “it’s heavier”</td>
</tr>
<tr>
<td>Communication</td>
<td>Communication or questioning between teacher and students.</td>
<td>Teacher also reviewed each step of the EDP with students and asked students what they thought the problem/challenge is.</td>
</tr>
<tr>
<td>Concrete Experience</td>
<td>Participants immersed in integrative STEM training as learners.</td>
<td>“I always find it really helpful to kind of do a STEM activity as a participant versus the teacher”</td>
</tr>
<tr>
<td>Confidence</td>
<td>Teachers and students feel a lack of confidence or a boost in confidence.</td>
<td>“And then I felt more confident in teaching that with my kids and getting them to do it”</td>
</tr>
<tr>
<td>Conflict</td>
<td>Conflict between two of the participants with differing opinions.</td>
<td>“Have a different viewpoint. Hmm. I would say, you know, as from the classroom perspective, you need to have someone in the school. That is talking it up and this showing these teachers, because if you bring me in, and I don’t care a thing about stem, and I’ve got this many things on my plate, you can put me at that table, but I’m not gonna buy into it.”</td>
</tr>
<tr>
<td>Creativity</td>
<td>Mention of students’ creativity during the integrative STEM learning approach.</td>
<td>“they really enjoyed the activity, and I enjoyed their creative approach to the challenge. It gave me the opportunity to see a different side of my students.”</td>
</tr>
<tr>
<td>Cross Curricular</td>
<td>Making connections to more than one disciplinary area.</td>
<td>“stem is a great way to build academic vocabulary that background knowledge in an easy way and you can just make that interdisciplinary connection”</td>
</tr>
<tr>
<td>Design Process</td>
<td>Any mention and/or implementation of the engineering design process.</td>
<td>“I know I had done some PD with you before on the engineering design process and I understood it but I don't know. This really helped me take each step. Because I guess, because we did it here first, and it helped me really see it”</td>
</tr>
<tr>
<td>Engagement</td>
<td>Increased or lack of engagement observed or mentioned.</td>
<td>“Then as they started the activity she was given the task by her partner as being the time keeper. She struggled with pressing the start and stop button on her own so I tried to help the group by giving a few suggestions of how to make it work. They tried it out and she felt so good about herself. Then when I came back around they were laughing and smiling and were still on task which I have never seen her do before.”</td>
</tr>
<tr>
<td>Excitement</td>
<td>Any indication of the excitement of learning for integrative STEM from teachers and students.</td>
<td>“But then it's nice because that means that they want to learn and like, they're excited about learning and they're engaged”</td>
</tr>
<tr>
<td>Fear</td>
<td>Teachers and students indicate a feeling of fear.</td>
<td>“I think they're scared because like they didn't grow up with it. I think that's a big part of it and it's scary”</td>
</tr>
<tr>
<td>Implementation</td>
<td>Evidence of integrative STEM implementation.</td>
<td>“My students completed the airplane challenge this week. They really enjoyed the activity and I enjoyed their creative approach to the challenge.”</td>
</tr>
<tr>
<td>Modeling</td>
<td>The need for modeling a new learning approach.</td>
<td>“I am a hands on learner so actually doing the activity provided me with the visuals I need to understand the topic,”</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Extracted Text</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PD</td>
<td>Any mention of professional development.</td>
<td>“I've noticed that if I do like a STEM PD or I do just a stem activity acting as the student, that I do better”</td>
</tr>
<tr>
<td>Planning</td>
<td>The need for more time to plan integrative STEM activities and the importance of planning collaboratively.</td>
<td>“Being as I am just teaching science, I plan each unit around a formal assessment (MasteryConnect) and an informal assessment (STEM activity)”</td>
</tr>
<tr>
<td>Reflection</td>
<td>Participants reflect on their own learning and experiences.</td>
<td>“And you don't get a chance to reflect, I mean, you know, we always struggle with that.”</td>
</tr>
<tr>
<td>Resources</td>
<td>Resources that are needed for integrative STEM implementation but are not available.</td>
<td>“we have to find that activity we have to purchase or provide all the materials for the stem activity”</td>
</tr>
<tr>
<td>Scheduling</td>
<td>The school schedule hinders the implementation of integrative STEM consistently.</td>
<td>“we don't teach science and we don't harp on it the way we do with math and reading and there isn't time”</td>
</tr>
<tr>
<td>SEL</td>
<td>Integrative STEM experiences promoting social and emotional learning.</td>
<td>“Then as they started the activity she was given the task by her partner as being the time keeper. She struggled with pressing the start and stop button on her own so I tried to help the group by giving a few suggestions of how to make it work. They tried it out and she felt so good about herself. Then when I came back around they were laughing and smiling and were still on task which I have never seen her do before.”</td>
</tr>
<tr>
<td>Structure</td>
<td>School structure that affect STEM implementation.</td>
<td>“The third grade curriculum is so packed that I don’t seem to have time to complete everything”</td>
</tr>
<tr>
<td>Student Outcomes</td>
<td>Any mention of positive or negative student outcomes.</td>
<td>“A great outcome I have seen when implementing STEM activities is student engagement. They are very focused and determined to figure it out.”</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Time</td>
<td>Participants indicated not having enough time to plan or implement integrative STEM in their instruction.</td>
<td>“we don't teach science and we don't harp on it the way we do with math and reading and there isn't time”</td>
</tr>
<tr>
<td>Training</td>
<td>Participants indicate the need for more training for all teachers.</td>
<td>“training to show them how easy it is to implement and it'll inexpensive it can be”</td>
</tr>
</tbody>
</table>
Appendix J: PD 1 Outline

Objectives:

- Review what STEM represents in WCS
- Hands-on activity on force and motion
- Overview of the engineering design process

Today’s Presentation

<table>
<thead>
<tr>
<th>Introductions</th>
<th>5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is STEM?</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Investigative Activity - Force and Motion</td>
<td>30 minutes</td>
</tr>
<tr>
<td><strong>Activity Sheets</strong></td>
<td></td>
</tr>
<tr>
<td>Activity Reflection</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Overview of the Engineering Design Process</td>
<td>15 minutes</td>
</tr>
</tbody>
</table>

Next Steps:

- Please complete this [Google form](#) before you leave

- Email me a date and time next week (or the week after) that will work best for your implementation/observation of this activity.

- I will send STEM kits through the courier and email copies of the digital sheets.

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Appendix K: PD 2 Outline

Objectives:
- What is the Engineering Design Process?
- How can you apply the EDP using a STEM activity?

Today’s Presentation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>AnswerGarden Reflection</td>
<td>5 minutes</td>
</tr>
<tr>
<td>What is the Engineering Design Process?</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Investigative Activity - Paper Planes</td>
<td>45 minutes</td>
</tr>
<tr>
<td>Activity Sheet 1</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td></td>
</tr>
<tr>
<td>Activity Reflection – Think Pair Share</td>
<td>15 minutes</td>
</tr>
</tbody>
</table>

Next Steps:
- Email Christine a date and time to come observe.
- Make sure you're up to date on your teacher reflection journals.
Appendix L: Paper Plane STEM Shop Worksheet

Name: ________________________ Date: ___________ 

PAPER PLANE STEM SHOP

You have a budget of $2. Spend wisely!

- Notebook Paper: $0.50
- Cardstock: $0.50
- Construction Paper: $0.50
- Masking Tape: $0.50/ft
- Paper Clip: $0.05
- 2nd Throw: $1.00

<table>
<thead>
<tr>
<th>Item</th>
<th>Price of Item</th>
<th>Amount of Money Leftover (show your work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notebook Paper</td>
<td>$0.50</td>
<td></td>
</tr>
<tr>
<td>Cardstock</td>
<td>$0.50</td>
<td></td>
</tr>
<tr>
<td>Construction Paper</td>
<td>$0.50</td>
<td></td>
</tr>
<tr>
<td>Masking Tape</td>
<td>$0.50/ft</td>
<td></td>
</tr>
<tr>
<td>Paper Clip</td>
<td>$0.05</td>
<td></td>
</tr>
<tr>
<td>2nd Throw</td>
<td>$1.00</td>
<td></td>
</tr>
</tbody>
</table>

Figure L.1 Paper Plane STEM Shop Worksheet

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**PAPER PLANE STEM ACTIVITY**

Make a prediction: Which design and paper will fly the furthest.

Which paper will you use?
What plane design will you use?

Test 1

<table>
<thead>
<tr>
<th>Flight Distance (in)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test 2 - Improved Design

<table>
<thead>
<tr>
<th>Flight Distance (in)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was your prediction correct? Yes No

What improvements did you make to your plane?

How did the 2nd plane's performance compare to the first?
Why do you think that happened?

How does weight and gravity relate to today's activity?

Figure L.2 Paper Plane STEM Activity
Appendix M: After Study Google Form

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did you like about this STEM PD experience?</td>
<td></td>
</tr>
<tr>
<td>Your answer</td>
<td></td>
</tr>
<tr>
<td>What are some things you would have liked more of to make the experience better?</td>
<td></td>
</tr>
<tr>
<td>Your answer</td>
<td></td>
</tr>
<tr>
<td>Do you plan on integrating STEM into your classroom more after participating in this study?</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Yes/No options" /></td>
<td></td>
</tr>
<tr>
<td>What part of the STEM study do you think made the most impact in your understanding of STEM integration? (Check all that apply)</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Options" /></td>
<td></td>
</tr>
</tbody>
</table>

Figure M.1 Google Form Part 1
If you chose any options in the question above, please example how and why that made the most impact for you.

Your answer

<table>
<thead>
<tr>
<th>Would you ever be interested in attending any future STEM related PD as they are offered in person and/or asynchronously?</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Yes</td>
</tr>
<tr>
<td>☐ No</td>
</tr>
<tr>
<td>☐ Maybe</td>
</tr>
</tbody>
</table>

How has your understanding of integrative STEM changed, if at all, as a result of this study? Give specific examples if possible.

Your answer

What are some needs that would help you incorporate STEM into your classrooms? List any and all things that come to mind.

Your answer

Figure M.2 Google Form Part 2
Appendix N: Themes and Supporting Quotations

Theme 1: Instructional Design for Integrative STEM Education PD

“I really think having them plan using the engineering design process helps with thinking through what their design needs to be and how to use the materials effectively. It also allows them to work as a group when making decisions. In the past when I didn’t use this planning sheet, students would just jump into making something without thinking about it and there was not as much collaboration, just one person using their idea. I have also noticed that students don’t know how to think.” -Molly

“even if we’re having a problem like we had one in PE today or last week where we’re getting frustrated, they’re getting upset. So, we talked through it. What is the problem? What can we try? Let's try it. Let's see if it works. Came back together and talk about the strategy.” -Maggie

“as a class, we are more cognizant of the process rather than the final product. We are looking at the how instead of just the what.” -Maggie

“it [EDP] helps me allow them to reflect while they were doing it versus at the end. Even if it's giving them time to think and to process.” -Lola
“I’ve noticed that if I do a STEM PD or I do just a STEM activity acting as a student…I know what the student is supposed to be thinking about.” -Lola

“I liked being able to take the PD activities and use them with my students. Putting myself in the place of the students helped me with guiding questions in the classroom.” -Maggie

“I am a hands-on learner so actually doing the activity provided me with the visuals I need to understand the topic, steps, and expectations of teaching the activity. I enjoyed completing the activity myself with other adult learners.” -Jane

“each component of the STEM study was powerful and important. Rarely do teachers get a chance to implement what they learn – especially hands-on.” -Piper

“this really helped me take each step…we did it here first, and it helped me really see it. And then I felt more confident in teaching that with my kids and getting them to do it.” -Jane

“I have become very aware of ways that I can try to differentiate some of my instruction to help meet the needs of all of my students… STEM is great because it encourages students to become independent and active learners.” -Lola
“I think this helped me to process the steps and understand how to break down the steps for my students so they can be successful.” -Maggie

**Theme 2: Transformation of Barriers Relevant to Integrative STEM Education**

“Starting in kindergarten…We got all this mandatory reading and math training. There needs to be some mandatory science training.” -Molly

“more support is needed for science, there needs to be some mandatory training, PD, workshops, something in small groups.” -Maggie

“they’ll say oh, I tried this. It was cool, why don’t you try? This is what my kids got out of it. It would be more impactful coming from someone that I know.” -Molly

“the book helps with literacy to hit on those standards as well. An example, the 4th grade lesson involves perimeter, which is what math skills they are working on in the classroom.”-Jane

“It can be difficult to plan and execute activities that merge science, math, reading, writing, and technology.” -Maggie

“training to show … how you can tie it in [to other subject areas].” -Molly
“they’re [teachers] scared because they didn’t grow up with it… I think that’ll [PD and training] help a lot of teachers too because they’re scared to do it.” -Molly

“you have to let go of that control…with STEM I don't really know exactly what's going on…You don't know what's going to happen. It can make you anxious, it can make you a little worried.” -Piper

“I would tell my students, you're not going to get this right the first time. And that is okay, this is a safe place for you to fail. Try again, try, that's fine. You know, all your emotions are fine. But you got to try again. That's hard. Like it is hard…we as adults… don't have those skills.” -Lola

“I felt a little more confident in what I was doing because I had played around with it and had time to practice it.” -Molly

“we don't always know all the resources that are available to us.” -Maggie

“they were like, really? I was like, well let me tell you! You could use these activities and consumables that will make STEM easier for you and use if you want to!” -Molly

“it would be great to continue adding activities to go with standards.” -Jane
“I have 45 [minutes] … I know other specialty areas teachers are like, oh, I don't care if they're 10 minutes late. I do because if they're 10 minutes late I'm cutting out something. Whether it's a mini lesson, whether it's vocabulary, whether it's our reflection piece, they don't have as much time to create or design and like, for me, it's [time] all precious. And so, time is very, very hard for me. I wish that my special time was longer. I always run out of time.”  -Lola

“don’t teach science and don’t harp on it the way we do with math and reading – there isn’t enough time.”  -Lola

“I've got so much to do, and I've got to fit this in, and I've got to do this and it sometimes it becomes more of a problem…I do see the value.”  -Maggie

**Theme 3: Increase Confidence and Competence for Integrative STEM Application**

“I am also building my knowledge on doing STEM with lower grades. K-2nd grade planning has been a challenge for me so I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons for those grades.”  -Jane
“Students responded eagerly and enthusiastically when I taught STEM…they were engaged… Being able to touch, explore, use, and see results in real time led to more active and concrete learning. They were better able to retain what they were experiencing and apply that knowledge in other areas”. -Piper

“I really liked the activity stuck with them and we could have those conversations and they were so into it…Mine have actually taken paper to lunch [to make] the airplane…They’re continuing it outside of the classroom setting”. -Maggie

“They really enjoyed the activity, and I enjoyed their creative approach to the challenge. It gave me the opportunity to see a different side of my students.” -Maggie

“Some of my students struggle with academic subjects, such as reading and math, but I found that they are very creative with problem solving activities. I loved seeing that part of their brain being used in the classroom setting. I love integrating the STEM with science, math, reading, etc.” -Maggie

“They are very focused and determine to figure it out.” -Jane

“She tried it out and she felt so good about herself…she was laughing and smiling with her group, which I’ve never seen before.” -Jane
“I was always second guessing myself and I think it's because I didn’t have as much experience with it. I feel like from the beginning to now, I’m a bit more confident in doing my own lessons and creating them myself.” -Piper

“I have learned more during this experience that has made me see elements that I didn’t really see before and has opened my mind on how to create and plan better STEM lessons. I am now also building my knowledge on doing this with my lower grades classes.” -Jane

“I felt a little more confident in what I was doing because I had played around with it and had time to practice it. And I think that’ll help a lot of teachers too because they’re scared to do it.” -Molly

“it [STEM activity] boosted their confidence. They’re like we want to do this, and I was like We're going to do more and that's what that's their learning style. They are hands-on and the boost of confidence for those students is amazing….it allows children who normally don't excel at like a standardized test to really show what they know and what they can do.” -Molly