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Abstract

Despite the growing emphasis on integrated STEM (Science, Technology, Engineering, and Mathematics) education in K-12 settings, little research has examined how teachers within Career and Technical Education (CTE) contexts perceive and implement integrated STEM education. This qualitative case study investigates the perceptions and experiences of five STEM pathway teachers at four metro area Regional Career Technical Centers (CareerTechs) in Oklahoma. Grounded in Dewey's theory of experiential education and Bandura's Social Cognitive Theory, this study examines how CareerTech STEM pathway teachers understand integrated STEM education, perceive their own content knowledge and instructional capacity, and identify the barriers and supports for implementation. Data was collected through a demographic survey and semi-structured interviews and analyzed using an inductive approach. Findings reveal that participants held a shared vision of integrated STEM education as rigorous, experiential, and collaboratively enacted. Participants consistently rejected superficial or standardized approaches. Teachers' confidence in STEM content knowledge was grounded primarily in technical and professional experience rather than formal preparation, and all participants demonstrated awareness of uneven confidence across STEM domains. Teachers felt capable of providing integrated STEM education when instruction emphasized inquiry-based, hands-on real-world tasks, and CareerTechs' institutional infrastructure. Recommendations focused on sustained funding, reduced lab class sizes, expanded work-based learning access, content-rich professional development, and mechanisms to elevate teacher voice in governance.

Keywords: integrated STEM education, Career and Technical Education, STEM pathway teacher self-efficacy, barriers to STEM implementation

Chapter 1: Introduction

In this chapter, I will discuss the background and context of this study and provide an overview of the research. This overview includes the purpose of the study and the research questions.

Background Of the Study

Research consistently highlights that "STEM education needs revamping" (McNally, 2012, p. 49), yet many aspects of STEM (Science, Technology, Engineering, and Mathematics) education remain intensely debated. Two of the most contested areas are 1) the definition of STEM education and 2) its implementation. At a broad level, Gonzalez and Kuenzi (2012) defined STEM education as teaching and learning in science, technology, engineering, and mathematics. However, Kennedy and Odell (2014) argued that "STEM education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers between these subjects and instead focuses on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies" (p. 246). This meta-discipline approach is referred to as integrated STEM education throughout this study.

Many researchers advocate for an interdisciplinary approach to STEM education, emphasizing that it better prepares students for STEM careers by fostering real-world connections (English, 2017; You, 2017). Firat (2020) found that science teachers' perceptions significantly influence their implementation of curriculum and are critical when integrating STEM education. However, little research has examined these perceptions within the Career and Technical Education (CTE) setting. CTE has the potential to contextualize STEM content areas, helping students better grasp key concepts (Stone, 2011). This understanding of how CTE teachers contextualize STEM education can inform how we implement integrated STEM education in many settings.

Problem Statement

During the 2019–2020 school year, 7.6 million secondary students across the U.S. participated in CTE courses (Association for Career and Technical Education, 2021). In 2022, 12.3 million students are enrolled in secondary CTE programs, including 147,913 students in Oklahoma (Advance CTE, 2022). These Oklahoma students represent the future workforce and deserve an education that equips them with career skills and the academic foundation necessary to critically evaluate information and use that information effectively within careers.

Kazis (2005) emphasized that for significant improvements in high school education, CTE must be included in reform efforts. In 2026, Oklahoma CareerTech reached a record enrollment of more than 151,000 students, representing nearly half of all Oklahoma high school students (Dowers, 2026). These students participate in both traditional public education and CTE, meaning the two systems have direct influence on each other. What works in one setting has implications for the other, and each can learn from the other. When nearly half of a state's high school population is served through CTE, the quality of instruction in those programs is not a niche concern. It is a public education concern. What happens in CareerTech classrooms shapes workforce readiness, postsecondary access, and economic opportunity for hundreds of thousands of Oklahoma students and families. CTE cannot be treated as separate from the broader educational landscape because, at this scale, it is the educational landscape for a significant portion of Oklahoma's students. To effectively implement STEM education within a CTE context, we must consider STEM education and CTE together rather than in silos.

Integrated STEM education in CTE contexts breaks down the division between academic knowledge and practical application while fostering connections among STEM disciplines.

STEM education has historically been driven by two central goals: preparing students for the workforce and ensuring the United States remains globally competitive in STEM fields (Roberts, 2012; National Research Council, 2011). CTE shares these same goals, making the two systems natural partners in preparing students for the demands of a modern economy (Asunda, 2012; Stone, 2014). The U.S. Department of Education organizes CTE programs into sixteen Career Clusters, these are broad industry sectors that guide the development of programs of study (pathways), within each cluster. STEM content is embedded across all sixteen clusters, meaning that integrated STEM education is not limited to pathways within the cluster explicitly labeled as STEM. Many students across a wide range of career pathways would benefit from high-quality integrated STEM education. Thus, understanding teachers' perceptions of STEM education within the CTE setting is vital. This study examines their experiences, the barriers they face in implementing integrated STEM education, and the supports needed to succeed.

Purpose Of the Study

While research indicates that both STEM education and academically enriched CTE improve student achievement (Pearson et al., 2013; Seage & Türegün, 2020; Stone et al., 2006), implementing integrated STEM education faces numerous barriers. One recurring issue is that K-12 teachers often feel ill-prepared to plan and deliver integrated STEM education instruction. Firat (2020) found that teachers with inadequate STEM content knowledge had negative perceptions of integrated STEM education. Similarly, Smith et al. (2015) reported that agriculture teachers who lacked confidence in certain STEM domains often deemed those areas unimportant to implement. These barriers frequently lead teachers to revert to traditional methods or adopt a “STEM veneer,” a superficial integration of STEM disciplines lacking genuine interdisciplinary connections (Shaughnessy, 2013, p. 324).

To address these challenges, research underscores the need for robust professional development (Nadelson et al., 2013; Parker et al., 2015). While traditional professional development builds content knowledge, Eun (2019) argued that teachers also require practical support to implement these strategies effectively. This study explores how STEM pathway teachers in CTE perceive and implement integrated STEM education. Insights from this research will inform efforts to support CareerTech STEM pathway teachers by identifying the conditions, experiences, and professional development approaches that build confidence and sustain integrated STEM implementation in CTE settings. At the same time, because CTE and traditional public education are deeply interconnected, these findings offer a window into what effective STEM teacher support can look like more broadly. Understanding what helps CareerTech teachers feel confident and capable in integrated STEM instruction can point to strategies for building that same confidence in K-12 STEM teachers across the state.

Research Questions

This study seeks to understand the lived experiences of CTE teachers and how these experiences shape their self-efficacy and beliefs about integrated STEM education. The research focuses on teachers’ perceptions and practices within the CTE setting:

1. What are CareerTech STEM pathway teachers’ beliefs regarding integrated STEM education?

2. What are CareerTech STEM pathway teachers' perceptions of their STEM content knowledge?
3. To what extent do CareerTech STEM pathway teachers perceive themselves as being able to provide integrated STEM education?
4. Based on supports and barriers, what are the CareerTech STEM pathway teachers' suggestions regarding integrated STEM education?

These questions aim to uncover the experiences of CareerTech STEM pathway teachers and clarify their beliefs and practices. By identifying barriers to effective implementation, this study will contribute to strategies for supporting teachers in delivering integrated STEM education.

Operational Definitions

For the purpose of this study, the following operational definitions are used.

Integrated STEM Education

For the purposes of this study, integrated STEM education refers to an interdisciplinary instructional approach that intentionally connects two or more of the STEM disciplines through authentic, problem-based learning contexts. This definition draws from Kelley and Knowles (2016), who defined integrated STEM education as "an approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context, for the purpose of connecting these subjects to enhance student learning" (p. 3). Throughout this study, integrated STEM education is distinguished from siloed or discipline-specific instruction, which addresses individual subject areas independently without deliberate interdisciplinary connection.

STEM Education

The term STEM education is used in two distinct ways throughout this study. First, STEM education is used in contrast to integrated STEM education when a source's definition or approach does not align with the intentional interdisciplinary framework described above. In these instances, the term reflects a broader or discipline-specific conception of STEM that does not meet the criteria for integrated STEM education as defined in this study. Second, STEM education is used as an umbrella term when an integrated STEM framework had not yet been established as the analytic lens (as was the case in the initial teacher interview protocol) or when referring to the full range of STEM instructional approaches regardless of the degree of disciplinary integration. In these contexts, STEM education encompasses both integrated and non-integrated forms of STEM instruction.

STEM

When used alone, the term STEM in this study refers strictly to the content acronym, encompassing subject matter that falls within the classification of science, technology, engineering, or mathematics. This is distinct from integrated STEM education, which refers to the intentional interdisciplinary approach described above.

Career and Technical Education (CTE)

Career and Technical Education refers to a structured system of secondary and postsecondary programs that provide students with both academic knowledge and technical skills aligned with specific career pathways. CTE programs are governed at the federal level by the Carl D. Perkins Career and Technical Education Act (Advance CTE, 2018), which emphasizes academic knowledge, technical and employability skills, and college and career readiness. In this study, CTE refers specifically to secondary-level programs offered through Oklahoma's

CareerTech system whether housed at a Regional Career Technical Center (CareerTech) or within a traditional high school (Stone, 2011).

Regional Career Technical Center (CareerTech)

A Regional Career Technical Center, referred to throughout this study as a CareerTech, is a specialized educational institution within Oklahoma's Career and Technical Education system that serves high school students from multiple sending school districts (Goble, 2004). Students attend on a part-time or full-time basis to participate in specialized programs not typically available at their home high schools. CareerTechs in Oklahoma also serve adult learners and industry professionals seeking workforce development. For this study, we will focus on the portion of the CareerTech that serves high school students.

Career Clusters

Career Clusters are the sixteen nationally recognized organizing frameworks established by the U.S. Department of Education that group related occupations and industries to guide the development of CTE programs of study (McCaslin & Parks, 2002; Solares, n.d.). Each cluster represents a broad industry sector, and together they encompass virtually all areas of the modern workforce. STEM content is embedded across multiple Career Clusters, meaning that integrated STEM education is relevant beyond pathways within the cluster explicitly labeled as STEM.

STEM Pathways

STEM pathways, also referred to as programs of study, are structured sequences of academic and CTE courses within the Career Cluster framework that prepare students for postsecondary education and careers in STEM-related fields (McCaslin & Parks, 2002; Solares, n.d.). For the purposes of this study, a STEM pathway is any CareerTech program of study in which STEM content is central to the curriculum. This includes programs housed within the Science, Technology, Engineering, and Mathematics Career Cluster as well as programs in other clusters where STEM content plays a primary instructional role. For example, the Health Science Career Cluster contains multiple pathways, including Biotechnology Research and Development, Diagnostic Services, Health Informatics, and Support Services. Each of these pathways requires significant STEM content knowledge even though they are not housed within the STEM Career Cluster itself (Solares, n.d.).

STEM Pathway Teacher

A STEM pathway teacher, as used in this study, is a CareerTech teacher who teaches at least one course within a designated STEM pathway program of study. This includes teachers across a range of career clusters whose courses require the substantive application of STEM content, regardless of whether their program is housed within the STEM Career Cluster specifically.

Chapter 2: Review of the Literature

In this chapter, I will explore the theoretical framework and current literature that inform this study. My research is grounded in the works of John Dewey and Albert Bandura. Dewey's theories on experiential learning, vision of the ideal school, and pragmatic philosophy offer a foundational perspective on the importance of hands-on, integrated learning experiences, a view supported by STEM education research. Bandura's Social Cognitive Theory, with its focus on self-efficacy and the role of social influences in learning, complements Dewey's work by shedding light on how teachers' experiences shape their perceptions of barriers and necessary supports for the successful implementation of STEM education in CareerTech settings.

Following the discussion of the theoretical foundations, I will review the existing literature on STEM pathway teachers in CareerTechs. This review examines two key components: K-12 STEM education and Career and Technical Education (CTE). The K-12 STEM education literature covers the definition of STEM education, the historical context that has driven the push for integrated STEM education, the benefits of STEM education, and teachers' perceptions of the barriers and supports needed for effective STEM education implementation. The CTE literature also examines the historical development of CTE both nationwide and in Oklahoma.

Finally, I will address the gap in the literature that this study aims to address. Despite the increasing focus on STEM education, there remains a lack of research examining the perspectives of STEM pathway teachers in CTE settings, including CareerTechs. Existing studies in this area mainly focused on recruiting and retaining CTE teachers, rather than exploring how they perceive the implementation of integrated STEM education. This study seeks to fill that gap by examining how CTE teachers perceive their role in implementing integrated STEM education. The goal is to contribute to a broader understanding of how integrated STEM education can be effectively implemented in specialized educational environments like CareerTechs.

Theoretical Framework

CTE and STEM education share several key goals and practices, making CTE settings important contexts for integrated STEM education implementation. These shared goals and practices are grounded in Dewey's vision of the ideal school (Schiro, 2013). Dewey's ideal school emphasized exploration and understanding over memorization and rote learning. His theory of education stressed that schools should foster not only intellectual development but also social, emotional, and moral growth (Dimitriadis & Kamberelis, 2006). This perspective aligns with Bandura's Social Cognitive Theory, which focuses on the social dimensions of learning and the importance of self-efficacy in the learning process.

Dewey's Theory of Education

John Dewey is widely regarded as one of the most influential educational philosophers, recognized for his work on pragmatic epistemology and instrumentalism. Instrumentalism, as Dewey defined it, asserts that organisms interact with their environments through self-guided activities. This idea laid the groundwork for what would become the theory of constructivism in education (Archambault, 1964).

Experiential Learning. Dewey's *My Pedagogic Creed*, published in 1897, articulated his core educational beliefs. In the first article, Dewey (1897/2017) argued that education is shaped by social situations that demand action from the learner, a belief that echoes his emphasis on self-guided activities and experiential teaching methods. Dewey further explored how schools and their curricula offer opportunities for students to engage meaningfully with social experiences. For Dewey, subjects like cooking and manual training serve as entry points into formal academic disciplines, reflecting the shared values between STEM education and CTE (Dewey, 1897/2017).

Dewey's pragmatic approach to education positioned learning as an active, experiential process, where teachers guide students to engage meaningfully with their environments (Archambault, 1964). Pragmatism asserted that education should be intertwined with life, utilizing teaching methods that offer authentic, real-world experiences. Central to this philosophy is Dewey's view of knowledge as a tool that emerges through solving real-world problems, not as a static endpoint. A focus on inquiry and problem-solving underpinned Dewey's adaptive curriculum model, which emphasized flexibility to meet the needs of both students and the situations they confront (Archambault, 1964). Dewey's theory of inquiry further emphasized that education should foster critical thinking through engagement with meaningful problems, providing a framework that aligns well with STEM education and CTE practices. The concept of inquiry in Dewey's philosophy is defined by three phases: a problematic situation, identification of its parameters, and reflection on those parameters. This resonates with the inquiry-based approaches found in both STEM education and CTE (Dimitriadis & Kamberelis, 2006).

The Perfect School. In *Experience and Education* (1938), Dewey contrasted traditional and progressive educational models. He defined traditional education as one that imposes facts from above, whereas progressive education emphasized cultivating individuality and learning through experiences. Dewey's view aligned with his theory of inquiry and his broader pragmatic philosophy, which continues to influence constructivist educational approaches today.

Bandura's Social Cognitive Theory

Albert Bandura's Social Cognitive Theory, introduced in Social Foundations of Thought and Action: A Social Cognitive Theory (Bandura, 1986), explains human behavior through triadic reciprocal causation**,** the dynamic interaction among personal, behavioral, and environmental influences (Pajares, 2004; Eun, 2019). Within this framework, individuals are understood as proactive, self-reflective, and self-regulating agents rather than passive responders to external conditions. This theoretical stance positioned efficacy belief as central mechanisms guiding motivation, persistence, and behavioral choice.

Bandura (1997) later identified self-efficacy as the core construct of social cognitive theory, defining it as an individual's belief in their capacity to organize and execute actions required to achieve desired outcomes. Self-efficacy operates through multiple psychological processes, including cognitive goal setting, motivational regulation, emotional control, and resilience in the face of obstacles. Individuals with strong efficacy beliefs approach challenges as tasks to be mastered, sustain effort during difficulty, and recover more rapidly following setbacks, whereas those with weaker efficacy beliefs are more likely to avoid challenges, experience stress, and disengage from effortful tasks (Bandura, 1997).

Within educational settings, efficacy beliefs are especially consequential because teaching requires sustained motivation, adaptive decision-making, and persistence under complex contextual demands (Bandura, 1997; Lesha, 2017). Teacher self-efficacy has been consistently associated with instructional quality, persistence, enthusiasm, and professional commitment, as well as student achievement, motivation, and students' own efficacy beliefs (Tschannen-Moran & Woolfolk Hoy, 2001). Teachers with stronger efficacy beliefs demonstrated greater planning, openness to innovative pedagogy, and resilience when instruction does not proceed as expected (Lesha, 2017).

Teacher Self-Efficacy and Professional Identity. Beyond classroom practice, teacher self-efficacy is closely intertwined with teachers' professional identity, including job satisfaction, occupational commitment, and motivation. These constructs collectively reflect how teachers perceive themselves within their professional roles and shape their long-term persistence in the profession. Empirical research demonstrated that self-efficacy contributes positively to motivation, job satisfaction, and occupational commitment, positioning efficacy beliefs as foundational to teachers' professional engagement (Canrinus et al., 2012).

Importantly, professional identity is dynamic rather than fixed, shaped through continuous interaction between the individual teacher and contextual conditions such as school environment, policy expectations, and career stage. As teachers accumulated experience and encountered new influences, their efficacy beliefs and related identity constructs evolved over time (Canrinus et al., 2012). This dynamic perspective aligns directly with Bandura's reciprocal causation model, reinforcing the theoretical relevance of social cognitive theory for understanding teachers' professional development trajectories.

Teacher Self-Efficacy, Teaching Quality, and CareerTech Contexts. Research further demonstrated that teacher self-efficacy is strongly related to teaching quality and student engagement, particularly in applied and career-focused learning environments. Higher levels of teacher self-efficacy are associated with innovative instructional strategies, effective classroom management, and improved student engagement and achievement (Duncan et al., 2013; Lesha, 2017). In CTE contexts specifically, teachers with stronger efficacy beliefs reported greater confidence in instructional practices, technology integration, and classroom management, all of which contribute to effective teaching and learning environments (Duncan et al., 2013).

Because CareerTech and STEM-focused settings emphasize practical skill development, adaptability, and real-world application, teacher efficacy may play an especially significant role in these instructional contexts. At the same time, STEM teachers in traditional public schools frequently reported lower self-efficacy linked to limited confidence in content knowledge or implementation capacity**,** which can hinder effective instruction (Firat, 2020; Nadelson et al., 2013; Parker et al., 2015). Bandura's theory suggested that efficacy develops through mastery experiences, social modeling, verbal persuasion, and emotional regulation, implying that targeted professional supports and modeled instructional practices are necessary to strengthen STEM teachers' confidence and implementation success (Bandura, 1997). Without such supports or incentives, even knowledgeable teachers may struggle to enact instructional change, underscoring the importance of systemic and contextual supports within CareerTech environments.

Review Of Literature

Definition Of STEM Education

Bybee (2013) presented an intriguing paradox: "Many request a definition, and few agree with the one when it is presented" (p. x). STEM education is no exception, with definitions varying from those focused on the four individual subject areas to a fully integrated approach. While STEM stands for Science, Technology, Engineering, and Mathematics (Jayarajah et al., 2014), STEM education is more concerned with how these subjects are taught in schools, with most research leaning toward integrated methods of implementation (Corlu et al., 2014; Shernoff et al., 2017). Kennedy and Odell (2014) explained that "STEM education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers between these subjects, focusing instead on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies" (p. 246).

Kelley and Knowles (2016) defined integrated STEM education as "an approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context, for the purpose of connecting these subjects to enhance student learning" (p. 3). This leads to a key debate about how many STEM domains must be integrated to be considered truly STEM education. Bybee (2013) noted that some definitions emphasize only one discipline or treat the STEM domains as separate but equal, while others, like Shaughnessy (2013), argued for the integration of all four content areas. Shaughnessy defined STEM education as "solving problems that draw on concepts and procedures from mathematics and science while incorporating the teamwork and design methodology of engineering and using appropriate technology" (p. 324).

This raises the question: if all four content areas are incorporated, should they all receive equal focus? English (2017) addressed this by highlighting the challenge of effectively integrating the disciplines while maintaining the integrity of each. In practice, engineering and mathematics often become overshadowed by science and technology (English, 2017). This exclusion or imbalance, which Shaughnessy (2013) referred to as a "STEM veneer," fails to meaningfully integrate the subjects and potentially leaves out important learning.

Some researchers also suggested expanding the STEM framework to include additional disciplines, such as the integration of art for a STEAM approach (Shernoff et al., 2017). Charette (2013) warned that focusing solely on STEM education risks narrowing students' worldviews and career options, as they may lack grounding in the arts, literature, and history. He argued that such an approach reinforces the idea that STEM problems are, in essence, literacy problems.

While these definitions outlined the interdisciplinary nature of STEM education, they did not fully capture the pedagogical approaches that support integrated STEM education in classrooms. It is important to examine the pedagogical strategies used to engage students personally with the content. These approaches include inquiry-based learning, project- and problem-based learning, and real-world connections. Zeng et al. (2018) found that incorporating these pedagogical methods enhanced the effectiveness of STEM education. Roberts (2012) emphasized that STEM programs should focus on core principles from the STEM disciplines, enabling students to apply prior knowledge to solve problems. He explained that "when incorporated properly, it should inspire creativity, inquisitive thinking, and teamwork" (p. 4). These characteristics of quality STEM education aligned with the use of the engineering design process in project-based approaches, which accomplishes these goals. Margot and Kettler (2019) identified six key tenets of quality K-12 STEM education:

1. Inclusion of math and science content,
2. Student-centered pedagogy,
3. Lessons situated in engaging and motivating contexts,
4. Inclusion of engineering design or redesign challenges,
5. Students learning from making mistakes, and

6. Emphasis on teamwork.

These elements stressed that an integrated STEM education approach is synonymous with quality STEM education, and that pedagogy is critical for effective integrated STEM education implementation.

Historical Context

Education's close relationship with society has led to world events shaping educational goals and practices. In the 1800s, for example, there was societal pressure for education to focus on morality (Rillero, 2010), and children were expected to stay within their communities and take over family businesses. As a result, subjects like science were sidelined. As society has evolved, so has education, and understanding the historical context of STEM education and CTE helps explain their integration.

STEM Education. The first significant reform in science and mathematics education came after World War II, driven by concerns about losing military superiority, which led to the establishment of the National Science Foundation (NSF). This shift in focus moved curriculum development from local needs to federal reform (Duschl et al., 2007). In the 1950s, the launch of Sputnik prompted an expansion of science education, with an emphasis on excellence in science and technology.

The 1980s marked another reform in science education as national priorities shifted once again, this time to address economic and technological challenges. New frameworks for science and mathematics emphasized preparing future scientists and engineers. STEM education became central to the next wave of science education reform in the early 2000s (Duschl et al., 2007; McNally, 2012), sparked by concerns about a shortage of STEM career workers in the U.S.

(Charette, 2013). This led to an influx of STEM workers from abroad, but the U.S. government believed that improving STEM education was essential to remain globally competitive (Roberts, 2012; Epstein & Miller, 2011; You, 2017; National Research Council, 2011).

The push for STEM education also included an emphasis on 21st-century skills, as seen in the Common Core Math Standards (2010) and the Next Generation Science Standards (2013), which focus on problem-solving, model development, and using scientific and mathematical tools. Charette (2013) argued that “the real STEM crisis is one of literacy” (p. 3), meaning that increasing students’ STEM content knowledge would benefit society beyond career prospects, influencing public policy debates as well.

This drive for STEM education continues with recent legislation, such as the CHIPS and Science Act (2022), which aims to strengthen manufacturing and national security by expanding STEM opportunities, particularly in rural areas, and providing $200 million over five years to support educational initiatives in the semiconductor workforce.

CTE Education. The history of CTE mirrors many aspects of STEM education, particularly the belief that such education would enhance the American workforce (Asunda, 2012; Stone, 2011). The first CTE school in the U.S. opened in 1879 at Washington University in St. Louis as a manual training school (Goble, 2004). Initially, these schools offered a curriculum divided between academic subjects and manual training. Over time, labor unions and management raised objections, with the former fearing that these schools would undermine apprenticeships, and the latter worried about labor unrest. This resistance led to the development of industrial arts, which emphasized manual training at the expense of academics.

The Smith-Hughes Act of 1917 established a more cohesive approach to vocational education, requiring states to develop plans for vocational education, particularly in agriculture and trade, while focusing on practical skills. Subsequent acts, such as the George-Reed Act and the Vocational Education Act of 1963, further expanded CTE offerings, including business and health occupations. In 2006, the Carl D. Perkins Act redefined vocational education as Career and Technical Education (CTE), emphasizing academic rigor and expanding access to special populations.

The current version of the Perkins Act, Perkins V (Advance CTE, 2018), calls for the development of both academic knowledge and employability skills, strengthening CTE's connection with academic standards. CTE is delivered through various settings, including CTE high schools, traditional high schools with CTE programs, and CareerTechs. In these settings, CTE provides both academic and technical education, with students often selecting courses based on their career interests (Stone, 2011).

In Oklahoma, CTE programs are offered through Regional Career Technical Centers (CareerTech), which provide opportunities for students from various home schools to attend specialized programs (Goble, 2004). The CareerTech model will be explored in this study.

Implementation of Integrated STEM Education

Understanding how teachers perceive integrated STEM education matters because perception shapes practice. Teachers bring beliefs, attitudes, and prior experiences into their classrooms, and those factors actively influence the instructional decisions they make. Research consistently showed that teachers broadly value STEM education, citing its potential to increase student engagement, develop critical thinking, and connect learning to real-world contexts

(Margot & Kettler, 2019). However, valuing STEM education and feeling prepared to implement it are not the same thing. Teachers who feel confident in their STEM content knowledge approached integration more willingly and sustain it more consistently over time (Kelley et al., 2020; Stohlmann et al., 2012). Firat (2020) found that teachers who felt inadequately prepared in STEM concepts held more negative perceptions of integration overall and were more likely to treat STEM education as an add-on rather than a genuine reorganization of practice. Experience with integration itself appeared to shift this. Teachers who regularly engaged in interdisciplinary practice expressed stronger confidence and more expansive views of what STEM education could accomplish (Sormunen et al., 2021; Wang et al., 2011).

This study focuses on understanding teachers' perceptions of integrated STEM education, specifically the barriers they encounter and the supports they believe facilitate success. According to Fixsen et al. (2005), implementation refers to the "specified set of activities designed to put into practice an activity or program of known dimensions." In the case of integrated STEM education, barriers to implementation are common. Without full implementation, positive outcomes are unlikely (Fixsen & Blasé, 1993).

Barriers to STEM Education. K-12 teachers often struggled with implementing STEM education because they feel unprepared to teach STEM content (Banilower et al., 2018). Firat (2020) found that teachers who felt inadequately prepared in STEM concepts had negative perceptions of integrated STEM education. This challenge was particularly evident at the elementary level, where teachers must serve as subject-matter experts across multiple disciplines. Lesseig et al. (2018) echoed these concerns, emphasizing the need for better preparation for STEM education.

Secondary teachers faced similar challenges, with many lacking formal preparation in multiple STEM domains (Honey et al., 2014). Research on teacher self-efficacy showed that teachers who feel prepared are more effective in the classroom (Stohlmann et al., 2012). Professional development that exposed teachers to STEM concepts and engineering design principles are a key solution (Nadelson et al., 2013; Parker et al., 2015). Long-term solutions involved shifting teacher preparation programs to better align with STEM career practices and integrated STEM education pedagogies into teacher preparation (Lynch et al., 2014).

Supports for STEM Education. In addition to professional development, teachers identified institutional support as a key factor in STEM education implementation (Shernoff et al., 2017). Effective STEM education programs required access to resources, including funding, curriculum materials, and collaboration time (Parker et al., 2015). The integration of STEM education into CareerTechs may provide a model for overcoming these barriers and supporting implementation.

STEM Education in CTE Settings

Pedagogical approaches represent another way that CTE and STEM education align well. Project-based and problem-based learning are referenced in both STEM and CTE literature to help students build problem solving skills, develop employability skills, and garner a deeper understanding of the content area. (Nadelson et al., 2013; Parker et al., 2015; Stone 2011). Stone (2011) defined project-based learning as a process of repeated inquiry that students engage in to make sense of a complex challenge. Problem-based learning is similar to project-based learning but centers on diagnosing and working through a specific challenge rather than producing a culminating product or artifact. Both approaches engage students in inquiry and real-world application, though problem-based learning typically presents a defined problem scenario while project-based learning organizes learning around the creation of something demonstrable. In addition, Stone (2011) detailed Work-Based Learning that allows for supervised learning experiences in a workplace environment.

The U.S. Department of Education established 16 Career clusters that guide the development of the career pathways or programs of study offered within CTE schools (McCaslin & Parks, 2002; Solares, n.d.). The 16 clusters include:

1. Agriculture, Food and Natural Resources
2. Architecture and Construction
3. Arts, A/V and Communications
4. Business Management and Administration
5. Education and Training
6. Finance
7. Government and Public Administration
8. Health Science
9. Hospitality and Tourism
10. Human services
11. Information technology
12. Law, Public Safety, Corrections, and Security
13. Manufacturing
14. Marketing, Sales, and Service
15. Science, Technology, Engineering, and Mathematics

16. Transportation, Distribution and Logistics

Within each of these clusters are multiple career pathways (also called “programs of study”) which detail what academic and CTE courses are needed to prepare students for a career in the given cluster. The pathway also includes necessary or recommended post-secondary education (McCaslin & Parks, 2002; Solares, n.d.; Stone, 2014). While every career cluster incorporates the STEM content areas, it does not mean that every pathway incorporates integrated STEM education.

Researchers studied an enhanced math learning approach that focused on strengthening the connections in CTE courses to Mathematics standards (Stone et al., 2006). The researchers studied the Math-in-CTE model developed by the National Research Center for Career and Technical Education (NRCCTE). This model included professional development and a detailed pedagogical approach to incorporating math standards into their CTE courses. The teachers who participated in this study came from five of the career clusters: agriculture, business management, health science, information technology, and transportation. CTE and math teachers worked together to develop enhanced mathematics lessons incorporating the following seven elements.

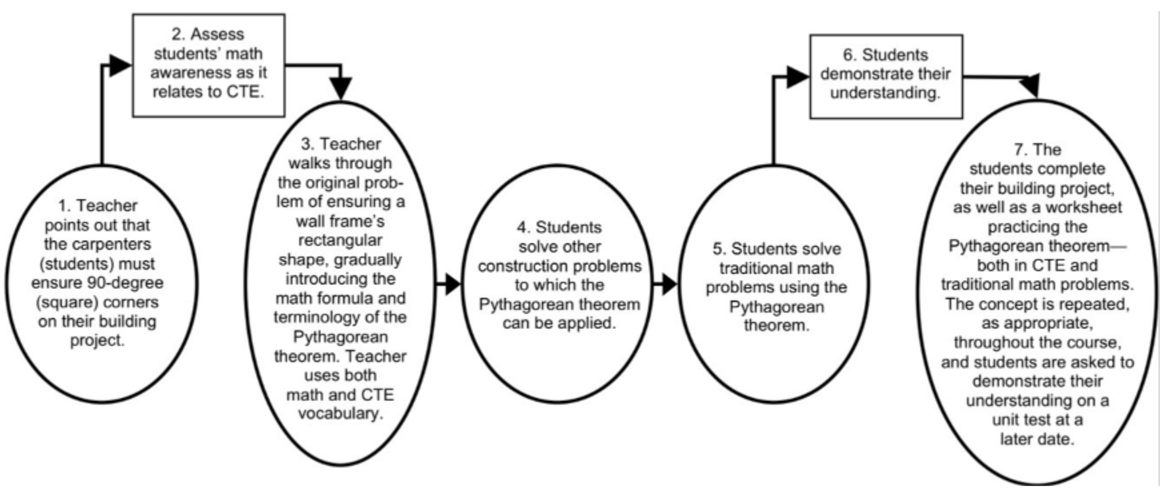
1. Introduce the CTE lesson
2. Assess students’ math awareness as it relates to CTE
3. Work through the math examples embedded in the CTE lesson.
4. Work through related contextual math-in-CTE examples.
5. Work through traditional math examples.
6. Students demonstrate their understanding

7. Formal assessment

This model allows students to interact with math standards through a relevant application to their career interests. Figure 1 shows a sample of the kinds of lessons that were created. This example delves into the Pythagorean theorem used in carpentry. Researchers found that after a year of exposure to CTE lessons that follow the Math-in-CTE model, students performed significantly better on math ability assessment than their counterparts without the enhanced mathematics lessons.

Figure 1

Math-in-CTE Sample Lesson



Driven by the success of the Math-in-CTE research, a pilot study of science-in-CTE was conducted by Pearson et al. (2013). The research design used in Math-in-CTE (Stone et al., 2006) was replicated with 29 agriculture education teachers and focused on the implementation of explicit science (Pearson et al., 2013). Explicit science includes science concepts, nature of science, and scientific inquiry. After a semester of exposure to explicit science lessons in the agricultural courses, students in the 2nd, 3rd, and 4th quartiles of the pre-test performed significantly better on the post-test than their peers who had not received the explicit science instruction. Based on these two studies, we conclude that integration of STEM education into CTE career pathways will lead to improved student achievement on content area tests (Pearson et al., 2013; Stone et al., 2006). This study will focus on the teacher's self-efficacy in implementing strategies like those found in the Math-in-CTE and science-in-CTE studies.

Identified Research Gap

While research on STEM education and CTE is abundant, there is a notable gap in studies exploring the intersection between the two fields. Existing research primarily focuses on student outcomes and curricula that support the implementation of STEM in CTE settings. However, there is a lack of research examining CTE teachers' perceptions of STEM education. Given what the literature tells us about teacher preparation, self-efficacy, and the goals of CTE, it is logical to assume that CTE is an ideal context for incorporating STEM education, and that CTE teachers' beliefs about STEM implementation may influence their effectiveness.

One of the closest studies addressing this gap examines agriculture teachers' perceptions and self-efficacy regarding the integration of STEM education into CTE courses (Smith et al., 2015). This research found that agriculture teachers viewed science as the most critical STEM domain to implement, while engineering was considered the least important domain to implement. Additionally, teachers reported feeling most comfortable with science and least comfortable with engineering. Correspondingly, agriculture teachers tended to use lecture-based instruction most frequently and role-playing the least, aligning their teaching methods with their comfort level in each area.

This study will expand this research in multiple ways. First, it will involve CTE teachers from a variety of STEM pathways across the Career Clusters, rather than focusing on a single discipline. Second, it will employ qualitative methods to gain a deeper understanding of how teachers lived experiences shape their perceptions of STEM education. Finally, this research will consider both individual STEM content areas and the integration of these areas into CTE settings.

Conclusion

Summary Of Key Literature Findings

This study addresses a critical gap in the literature by exploring CTE teachers' perceptions of integrated STEM education and its implementation in CareerTechs. Existing research on STEM education and CTE tends to focus on student outcomes and curriculum design rather than teachers' beliefs and practices. Key findings from the literature reveal:

1. Teachers who are well-prepared are more effective (Darling-Hammond, 1990).
2. Teachers' self-efficacy significantly impacts their instructional performance (Bandura, 1982).
3. A STEM content knowledge crisis exists, highlighting the need for robust foundational understanding in STEM concepts (Charette, 2013).
4. The primary goal of CTE is to enhance student achievement and technical literacy, aligning it as an ideal setting for STEM education (Bottoms, 2005).

Studies like Smith et al. (2015) highlight variability in CTE teachers' perceptions of STEM education. For example, agriculture teachers prioritize science while undervaluing engineering and aligning their instructional strategies with their comfort level. However, these findings are limited in scope, focusing on a single discipline and neglecting integrated STEM education approaches.

This study broadens the understanding of these issues by including CareerTech STEM pathway teachers across various career clusters and utilizing qualitative methods to delve into how their lived experiences shape their perceptions and practices. By examining individual STEM content areas and integrated approaches, this study contributes to the growing body of knowledge on effective STEM education in specialized educational settings like CTE.

Final Reflections

This study underscores the significant role that teacher perceptions and self-efficacy play in the effective implementation of integrated STEM education in a CareerTech setting. The integration of STEM education into CTE holds immense potential for addressing workforce needs and fostering student success, yet this potential is contingent upon the preparation, beliefs, and practices of teachers.

The theoretical foundations provided by John Dewey and Albert Bandura reinforce the importance of experiential learning, self-efficacy, and the social dimensions of education. Dewey's emphasis on inquiry-based learning and the pragmatic integration of real-world problems resonates with the goals of both STEM education and CTE. Similarly, Bandura's Social Cognitive Theory highlights the importance of self-belief and modeled support for teachers to succeed in implementing innovative practices.

Research emphasized the need for professional development tailored to building teacher self-efficacy with the content. Equally important is the alignment of teacher beliefs with classroom practices, supported by observations and targeted interventions. By addressing these needs, CTE can better serve as a bridge between education and industry, preparing students for the demands of a STEM-driven world.

Ultimately, this research contributes to the ongoing conversation about how to effectively implement integrated STEM education in specialized settings. It provides actionable insights for policymakers, administrators, and teacher educators, aiming to foster environments where both teachers and students thrive in STEM education.

Chapter 3: Methodology

In this chapter, I outline the qualitative case study methodology utilized for this research study, which examines teacher perceptions of barriers and supports needed to implement integrated STEM education in CareerTechs. First, I provide a rationale for utilizing a qualitative case study design and discuss its appropriateness for addressing the research questions. Next, I describe the research setting, participant selection process, and data collection methods. I then explain the procedures used for data analysis, detailing the coding and thematic analysis processes inherent to qualitative research. Additionally, I address ethical considerations, including informed consent, confidentiality, and the protection of participants' rights. Finally, I discuss measures taken to ensure trustworthiness and credibility in the findings, such as triangulation, member checking, and reflexivity. This chapter establishes the foundation for collecting and analyzing data to answer the study's central research questions within the qualitative case study framework.

Research Questions

This study aims to understand how teachers at a CareerTech perceive the barriers and supports needed when implementing integrated STEM education in their classrooms. This study supports the development of STEM education resources and increases insight into working more effectively with teachers implementing integrated STEM education programs. The questions guiding this study are:

1. What are CareerTech STEM pathway teachers' beliefs regarding integrated STEM education?

2. What are CareerTech STEM pathway teachers' perceptions of their STEM content knowledge?
3. To what extent do CareerTech STEM pathway teachers perceive themselves as being able to provide integrated STEM education?
4. Based on supports and barriers, what are the CareerTech STEM pathway teachers' suggestions regarding integrated STEM education?

Research Design

To understand how teachers at a CareerTech interpret their experiences implementing integrated STEM education, this research uses case study as a methodology. Case study research is particularly well suited for studies that seek to understand the how and why of a phenomenon within a real-world context (Yin, 2003). Rather than measuring outcomes across a large population, case study allows the researcher to go deep within a bounded setting, capturing the nuances, contradictions, and complexities of lived experience that surveys or quantitative measures would miss. Because this study is concerned with how teachers make sense of their experiences implementing integrated STEM education, and because those experiences are shaped by the specific institutional context of CareerTech, case study is the most appropriate design. Based on the goal to make sense of lived experiences in a single bounded case, the case study aligns with this research (Merriam & Tisdell, 2016; Creswell & Poth, 2018).

This is a single instrumental case study that aims to develop a general understanding of one bounded case (Creswell & Poth, 2018). An instrumental case study is appropriate here because the goal is not to understand this particular group of teachers for their own sake, but to use their experiences as a window into the broader phenomenon of integrated STEM education implementation in CareerTech settings. In this instance, I aim for a general understanding of the barriers and supports STEM pathway teachers in a metro area CareerTech perceive within the bounds of a single state's CareerTechs. Data collection includes semi-structured interviews (Yin, 2003).

Settings

Merriam and Tisdell (2016) explain that "a case study is an intensive, holistic description and analysis of a single entity, phenomenon, or social unit" or a bounded system (Merriam & Tisdell, 2016, p. 46). The setting for this qualitative case study is bounded by an Oklahoma metro area CareerTech. The Oklahoma CareerTech system is a statewide network of Regional CareerTech centers. Oklahoma CareerTechs serve high school students, adult learners, and industry professionals. The selected sites provide a rich context for exploring teacher's perceptions of barriers and supports for integrated STEM education, as they operate within the unique constraints and opportunities presented by the CareerTech system. This bounded setting allows for an in-depth examination of the factors influencing integrated STEM education implementation.

Participants

This study uses a criterion sampling technique (Palinkas et al., 2015). Criterion sampling allows for specific groups of participants to be recruited within the study's parameters to gain insight from participants lived experiences that meet those criteria. For this study, inclusion criteria are as follows:

1. Participants must teach at a CareerTech in an Oklahoma Metro Area.
2. Participants must teach at least one STEM pathway Course.

This study aimed to have at least three STEM pathway teachers from at least three different CareerTechs participate in the research to gain a full understanding of how integrated STEM education is typically implemented within Oklahoma metro area CareerTechs. Nine participants from five different CareerTechs completed the initial survey, and five of those participants from four distinct CareerTechs completed the interview.

Data Collection

This study consisted of a survey to acquire demographic data and up to two semi-structured interviews that lasted approximately 60 minutes. Each participant completed the survey and at least one semi-structured interview with the possibility of a follow up interview if needed. The interviews were video and/or audio recorded. The video and audio recordings were destroyed once the interviews were transcribed and anonymized. Participants were encouraged to complete the interview outside of school time and off-site so that teachers can be open about their experiences with STEM education. However, all the participants who completed the interview indicated they felt comfortable and able to speak freely within school time and on-site at their CareerTech.

The survey (Appendix E) consisted of questions that included traditional demographic questions as well as the following open response questions related to the teachers' work and certification experiences:

1. What do you teach?
2. How long have you been a teacher?
3. Did you work somewhere in a business or industry related to the STEM field you currently teach before coming to the technology center?

Interviews consisted of semi-structured questions and probing follow-up questions to gain deeper insight into the participants' experiences. These interviews were based on Firat's (2020) study about science teachers' perceptions and beliefs about integrated STEM education in the science curriculum. The interview questions from Firat's study were adapted to fit CareerTech teachers (Appendix F). The questions were divided into four overarching areas: 1) questions following up on the demographic survey and their pathway to the CareerTech, 2) questions regarding understanding of STEM education, 3) questions surrounding the ability to teach STEM education, and 4) questions regarding barriers and supports for STEM education.

Questions following up on the demographic survey and their pathway to the CareerTech.

1. Describe your path to becoming a teacher.

Questions regarding understanding of STEM education explore effective STEM education and some of the questions include the following:

1. How would you define STEM education?
2. What makes something STEM education versus just science, or just math?
3. What would you say an ideal STEM education classroom would look like?
4. What do you see as the most effective ways to teach STEM content?
5. What role, if any, do you feel real world problems play in a STEM education classroom?
6. Please share an example of an effective way that you have taught or seen someone teach STEM content.

Questions surrounding the ability to teach integrated STEM education explore the teachers' self-efficacy and how comfortable teachers feel implementing integrated STEM education into their own courses. Some questions for this section include:

1. How comfortable or qualified do you feel implementing integrated STEM education in your classroom?
2. How comfortable do you feel about STEM content?
3. What experience did you have that made you feel comfortable with STEM content?
4. How comfortable do you feel about the pedagogy?
5. What other factors affect your comfort in the classroom other than the pedagogy and STEM content?
6. What areas of STEM content do you feel most confident in teaching?

Questions regarding barriers and supports for integrated STEM education explore the supports and experiences teachers have implementing integrated STEM education and some of the questions include the following:

1. What supports have helped you the most in implementing integrated STEM education in your classroom?
2. What supports do you feel like would make you feel even more comfortable teaching integrated STEM education?
3. What kinds of professional development or training do you feel would be helpful to you to become more comfortable?

4. Are there any things that you have experienced or seen other people experience that really harm your ability to be able to teach integrated STEM education?
5. Are there any challenges other than the ones you've spoken about that you faced integrating STEM content in your teaching?

Data Analysis Procedures

The data was analyzed through an inductive approach which allows research findings to emerge from raw data, without restraints (Thomas, 2006). I wanted to ensure that my own experiences in STEM education had a minimal impact on data analysis. Therefore, inductive analysis relies primarily on the natural themes in the transcripts and not my own perceptions, as deductive analysis may.

Interviews were transcribed through the zoom transcription feature. A backup transcription was completed through Microsoft's dictation feature. Each transcript was cleaned while listening to the video recording to ensure accurate transcriptions. Once transcripts were verified, interview notes and observations of participant behaviors were added to the transcription, and a second recording review was done to note inflection and align the interview notes with the transcript. This included adding notations for body language and facial expressions. Finally, the transcripts were anonymized with all participants and school names replaced with pseudonyms. One last review of the recordings was completed before the recordings were deleted. Inductive analysis was then used to find themes.

The steps of inductive analysis after data cleaning were a close reading of texts, creation of categories, overlapping coding, and continued revision (Thomas, 2006). During the close reading of the texts, the transcripts were open-coded through line-by-line analysis, with initial codes assigned to capture the meaning of each segment of data. The second round of coding allowed for codes to be grouped into categories through hierarchical coding, where related codes were collapsed together to identify broader patterns across participants. Once categories were established, they were examined in relation to each research question to determine which patterns spoke most directly to teachers' beliefs, perceptions, capacity, and suggestions regarding integrated STEM education.

To ensure validity, an additional researcher independently open-coded a selection of transcript segments without prior knowledge of the codes I had assigned. The two sets of codes were then compared and discussed until consensus was reached on any discrepancies. This process of negotiated agreement strengthened the credibility of the coding scheme and reduced the influence of my own assumptions on the analysis. Finally, participants were contacted to verify that the codes and emerging themes accurately captured their experiences, a process known as member checking. Overarching themes were then gathered from the interview data and organized by research question to form the findings presented in Chapter 4.

Subjectivity And Ethical Considerations

Structures built to support teachers have always been a focus of mine and can be seen in my work experiences. While in the classroom, I mentored new teachers, served as department, and focus team chairs, and presented conference sessions. I then moved into curriculum and professional development roles to help support teachers, and I now serve as a project director for a college and career readiness grant and plan an annual educational conference. My experience teaching high school science and mathematics focused my research on STEM education in grades 9-12. The combination of these interests led to my study of teacher perceptions of STEM education. My interest in CTE stems from my work with the Southern Regional Education Board and their work in the CTE field through Tech Centers That Work.

In my current role as a Project Director for a GEAR UP Grant, I support my team in developing resources for schools and teachers, work with school leaders in providing support to their students and staff, and work with students to understand their options after high school including CareerTech and/or STEM career pathways. This research helps me understand supports that leaders can provide to their teachers and teams that help grow their self-efficacy and in turn benefit the students we work with.

In my previous position as Professional Development Coordinator for a GEAR UP Grant, I created, published, and facilitated professional development (PD) sessions for teachers at participating schools, including STEM education PD and an integrated STEM curriculum. Understanding teacher needs allows me to better scaffold PD development and implementation and development of STEM resources.

My former role as a high school science and math teacher drives my interest in integrating the STEM subject areas to better support student understanding. During my doctoral residency, I have worked on research about STEM teacher resources, year-long job-embedded professional development, and instructional coaches' experiences moving to virtual coaching in a pandemic. I grew up in a family of teachers and their views on education and personalizing embedded PD have helped to shape my views of teacher support. This pushed me to focus on personalizing PD for the schools and teachers I work with and, in turn, inspired this research. Moving forward, I intend to continue working in professional development and supporting Science and Math teachers.

I believe my experience allows me to build rapport and better understand teacher perspectives of STEM education. I understand the challenges teachers face when implementing and sustaining a STEM program. In addition, I have become accustomed to delving into professional development feedback and identifying strengths and weaknesses. While my experience gives me a lot of contexts for my study and the data I gather, it also means I have assumptions and biases that I must monitor during my study. For example, I assume that teachers who do not believe STEM education is effective also do not truly understand integrated STEM education. While I assumed this was a trend I would see in my data, I must ensure I am not using it to confirm my biases. Finally, based on my expressive nature, I know I must be careful to control my facial expressions during interviews so that my opinions do not influence or skew my results.

There are a few ethical issues within this study. The participants are not members of high-risk groups. There is no connection between the researcher and the participant’s place of employment, and the study does not delve into sensitive topics. However, because the research is a case study bound within the region of the participants' workplace, they may be hesitant to share anything they believe would reflect the CareerTech negatively. As a researcher, I try to build relationships and clarify that I will not share results directly with their administrators, and all results will be as anonymous as possible to elicit honest responses.

Trustworthiness And Credibility

This study employs multiple techniques to ensure trustworthiness. First, this study aimed to recruit at least three STEM pathway teachers from at least three different CareerTechs as participants to ensure that the results represent a variety of perspectives. The study ended with five participants from four different CareerTechs. This sample size is appropriate for a qualitative case study, where the goal of sampling is purposeful selection of participants who can speak to the phenomenon under study rather than statistical representation of a population (Creswell & Poth, 2018; Merriam & Tisdell, 2016). The criterion sampling approach used in this study (Palinkas et al., 2015) was designed to capture variation across CareerTech sites, and the inclusion of participants from four different CareerTechs helped ensure that findings were not limited to a single institutional context. This sample was appropriate for a qualitative case study methodology and produced a strong pattern of saturation. Of the 16 themes identified across all four research questions, nine themes were present across all five participants ($n = 5$), six themes were present among four of five participants ($n = 4$), and only one theme was present among three of five participants ($n = 3$). This distribution reflects a high degree of thematic convergence across the participants of this study.

In addition, independent coding was completed. A second researcher blind-coded portions of the transcripts to ensure reliability. The two sets of codes were compared and discussed in order to reach consensus. For discrepancies that were unable to be resolved through discussion, member checking was used to determine the final code. When the researchers' codes did not match, participants were asked which code more closely reflected their meaning or if they would like to provide more information to better clarify their meaning. In addition to the member checking used for discrepancies between researchers, the final themes were sent to participants. Participants reviewed the themes to verify they captured their experiences accurately. Any discrepancies or clarifications offered by participants were incorporated into the final analysis.

Triangulation further strengthened the credibility of this study by drawing on multiple data sources. Specifically, this study triangulated data across the demographic survey and semi-structured interviews. Because both instruments were designed to address the same central research questions from different angles, convergence across these sources increased confidence in the findings. Where patterns appeared consistently across both data sources, those findings were treated as more robustly supported.

Limitations

This study is limited in a couple of important ways. First, the study sample was demographically homogeneous. All participants were white, aged 45 to 64, held graduate or bachelor's degrees, and held traditional certification obtained through either a traditional or alternative pathway. This limits the ability to examine how race, ethnicity, gender, career stage, or certification pathway intersect with teacher perceptions of integrated STEM education in CareerTech settings. This homogeneity is particularly noteworthy given that research has documented a significant racial gap between CTE learners and CTE teachers nationally, with 51% of secondary CTE concentrators identifying as learners of color compared to only 13% of CTE teachers (Advance CTE & ACTE, 2024). The demographic profile of participants in this study may reflect broader patterns in the CTE teacher workforce, as national data indicate that more than 80% of public-school teachers identified as white in 2020–21 (NCES, 2024). Future research should intentionally recruit more diverse participant samples and should include demographics of CareerTech teachers as a whole to determine if this sample is representative of the population. Diversifying the participant pool would allow researchers to examine how race, ethnicity, career stage, and certification pathway shape teacher perceptions of integrated STEM implementation in ways this study was unable to address. While this study attempted to include state-wide demographic data to contextualize the sample, that data was unavailable at the time of this writing.

Second, findings are based entirely on teacher self-report through interviews and surveys. The study did not include systematic classroom observations, which would allow for direct comparison between teachers' descriptions of their practice and what occurs instructionally in their classrooms. Teachers' perceptions of their own content knowledge, self-efficacy, and integration practices may differ from observable instructional behavior. This limitation is particularly relevant given that all participants held traditional certification through either a traditional or alternative pathway, meaning their formal preparation experiences varied considerably and may have shaped how they conceptualize and describe their own practice. Future research should incorporate classroom observations or other direct measures of instructional behavior to triangulate self-reported data and provide a more complete picture of how integrated STEM education is enacted in CareerTech settings.

Chapter 4: Findings

In this chapter, I describe the participants in this study and present the findings organized by research question. This study explores how STEM pathway teachers in Regional Career Technical Centers (CareerTechs) perceive integrated STEM education. The research focuses on teachers' perceptions, beliefs, and instructional practices within the Career and Technical Education (CTE) setting. The themes that emerged from this analysis are presented in the sections that follow. The following research questions guided this study:

1. What are CareerTech STEM pathway teachers' beliefs regarding integrated STEM education?
2. What are CareerTech STEM pathway teachers' perceptions of their STEM content knowledge?
3. To what extent do teachers perceive themselves as being able to provide integrated STEM education?
4. Based on supports and barriers, what are the CareerTech STEM pathway teachers' suggestions regarding integrated STEM education?

These questions aim to illuminate the experiences of CareerTech STEM pathway teachers and clarify how their beliefs and perceptions influence classroom practice. Understanding these perspectives provides insight into the barriers and supports that shape the implementation of integrated STEM education within CareerTech settings.

Data for this study was collected through a demographic survey and subsequent semi-structured interviews. Participants first completed a demographic survey, after which each participant was contacted to schedule a one-hour Zoom interview, with the option of a follow-up interview if clarification was needed. Interview transcripts were analyzed using inductive, line-by-line coding to identify patterns and themes. The themes that emerged from this analysis are presented in the sections that follow.

Participant Profiles

Nine participants from five different metro area CareerTechs completed the survey. While all nine participants said they were willing to be interviewed, only five responded to the request to schedule an interview. The five who chose to be interviewed are described in Table 1. Pseudonyms for participants and schools are used to protect participants' confidentiality.

Table 1

Demographic Characteristics of Interview Participants

Name	CareerTech	Age	Highest Degree	Certification	Years Teaching	Industry
Sarah	Maple CareerTech	45-54	Graduate	Traditional (Via Alternative)	21-30	Yes
Emily	Elm CareerTech	45-54	Graduate	Traditional (Via Alternative)	21-30	Yes
Megan	Oak CareerTech	45-54	Bachelors	Traditional	11-20	No
Nathan	Cedar CareerTech	45-54	Graduate	Traditional	21-30	No
Caleb	Cedar CareerTech	55-64	Graduate	Traditional (Via Alternative)	11-20	No

Certification Pathways

In Oklahoma, there are multiple pathways to becoming a teacher in any public-school setting. In addition to traditional and alternative certification routes offered through the Oklahoma State Department of Education, Oklahoma Department of CareerTechs provides an additional pathway to certification designed specifically for individuals entering teaching from industry backgrounds. These pathways exist in response to ongoing teacher shortages, particularly in career and technical education, where industry expertise is critical and traditional preparation pathways do not always align with workforce demands.

Traditional. The traditional teaching certification pathway is designed for teachers who have completed an approved teacher preparation program. This often includes attending an accredited college or university and obtaining a bachelor’s degree in education. In addition, candidates must successfully complete the required Oklahoma certification assessments. Traditional certification may also be obtained through completion of requirements within an alternative pathway or through out-of-state reciprocity if a candidate already holds a valid teaching certificate in another state (Oklahoma State Department of Education, n.d.).

Alternative. Alternative teaching certification pathways were created for teachers who did not complete traditional teacher preparation programs but do have a bachelor’s degree. Under this program, candidates must meet eligibility requirements based on academic credentials or relevant professional work experience, pass a state approved subject area examination prior to certification, and complete a background check. Once issued an initial teaching certificate, participants are permitted to serve as teachers of record while completing required professional education coursework in areas such as classroom management and pedagogical principles. All program requirements must be completed within three years in order to qualify for a traditional teaching certificate. This pathway allows individuals with content area expertise to transition into teaching while receiving structured support and oversight from the state (Oklahoma State Department of Education, 2025).

Provisional for CareerTech. Oklahoma Department of Career and Technology Education offers a provisional teacher certification pathway designed specifically for individuals entering the classroom from industry professions. This pathway allows individuals with significant occupational experience in their field to begin teaching while completing certification requirements. Candidates must demonstrate relevant work experience in their content area and meet eligibility requirements established by the Oklahoma Department of Career and Technology Education. Once approved, individuals may teach under a provisional certificate while completing required training and certification components. This pathway is intended to address workforce needs by allowing industry professionals to transition into teaching roles while maintaining connections to real-world applications within career and technical education programs (Oklahoma Department of Career and Technology Education, 2024).

Sarah

Sarah is a health teacher at Maple CareerTech. At the time of the study, Sarah was between 45 and 54 years of age and had between 21 and 30 years of teaching experience. She holds a graduate degree and a traditional teaching certification, although she initially obtained her certification through the alternative certification pathway.

In addition to her teaching credentials, Sarah has prior industry experience in the healthcare field, having worked as a certified nursing assistant for 11 years before entering the education profession. This professional background is common of CareerTech teachers and directly informs her instructional practices.

Sarah's pathway into teaching reflects a complex and nonlinear professional trajectory. After graduating high school in the early 90s, she initially pursued a bachelor's degree with the intention of entering the medical field and planned to later attend seminary with the goal of becoming a medical missionary. Following personal transitions, including marriage and divorce, she reassessed her career direction. Although she completed an initial degree in religion, she returned to higher education to earn a bachelor's degree in biology. Recognizing that medical school was no longer a feasible option, Sarah identified teaching as a meaningful avenue through which she could apply her scientific knowledge and professional experience.

Sarah began her teaching career at a public charter school focused on STEM education, where she simultaneously completed required education coursework and certification requirements. Her transition into CareerTech occurred several years later when a colleague encouraged her to apply for a position better aligned with her background and expertise. This interaction prompted her move to Maple CareerTech.

At Maple CareerTech, Sarah teaches Environmental Science, Project Lead the Way Medical Interventions, and Anatomy and Physiology. Her instructional role integrates academic science content with applied medical and environmental concepts, reflecting both her formal education and healthcare industry experience. Within the context of this case study, Sarah's professional journey illustrates how prior industry experience, alternative certification pathways, and professional networks influence career and technical education teaching trajectories.

Emily

Emily is a STEM teacher at Elm CareerTech. At the time of the study, Emily was between 45 and 54 years of age and reported between 21 and 30 years of teaching experience. She holds a graduate degree and a traditional teaching certification that she gained through the alternative pathway. Emily also brings prior industry and research experience to her teaching role, including laboratory work and graduate level research and teaching assistantships, which inform her instructional practice in advanced secondary science and mathematics courses.

Emily's pathway into teaching began during her secondary education and was rooted in early recognition of her strengths in mathematics and science. While in high school, she was identified by a teacher as having strong content knowledge and was asked to assist another student with advanced mathematics concepts. This experience served as an early introduction to teaching and contributed to her interest in STEM fields. She later attended a selective science and mathematics focused secondary program, which expanded her exposure to advanced coursework and reinforced her academic trajectory. Emily went on to complete a bachelor's degree in mathematics and a bachelor's degree in physics, followed by a master's degree in experimental physics.

Following the completion of her graduate degree, Emily initially pursued research focused work, including employment in a laboratory setting and serving as both a research assistant and teaching assistant during graduate school. When external factors interrupted her doctoral studies, she transitioned into secondary education. Emily entered the teaching profession through an alternative certification pathway in another state, where she began teaching at the high school level while completing certification requirements. This certification later transferred to Oklahoma.

Throughout her career, Emily has taught in multiple states and across a variety of school contexts. Much of her professional experience has occurred within environments connected to CTE, either through placement at CareerTech campuses or direct employment by CareerTech department. She has served in multiple instructional capacities and has taught a range of advanced and honors level STEM courses, including AP Physics, honors chemistry, engineering related coursework, and mathematics.

At Elm CareerTech, Emily currently teaches AP Physics 1, AP Physics 2, Honors Chemistry, and Geometry. Her instructional role emphasizes rigorous academic content, analytical reasoning, and applied problem solving, reflecting her extensive background in mathematics, physics, and scientific research. Within the context of this case study, Emily's professional journey highlights how deep content expertise, alternative certification obtained outside the state and varied educational settings shape long term careers in career and technical education STEM instruction.

Megan

Megan is a cybersecurity teacher at Oak CareerTech. At the time of the study, Megan was between 45 and 54 years of age and had between 11 and 20 years of teaching experience. She holds a bachelor's degree and entered the profession through a traditional certification pathway.

Megan's professional background is entirely within education, distinguishing her from many of the other participants who entered teaching from industry or research settings. She came from a family of teachers and knew from a young age that she wanted to be a teacher. She earned degrees in Elementary Education and Middle School Mathematics with the intention of becoming a middle school math teacher. Her early career reflects this goal, as she taught across the K–12 system, with the majority of her experience occurring at the middle school level.

Over time, Megan transitioned from teaching middle school mathematics to teaching computer science and cybersecurity at the middle school level, reflecting a shift toward STEM-related content areas. She later moved into CareerTech and is currently in her second-year teaching in a cybersecurity program at Oak CareerTech serving high school students and adult learners.

Within the context of this case study, Megan represents a more traditional educational trajectory, characterized by continuous experience within K–12 education and the absence of prior industry experience. She is also the only participant without a graduate degree. As a cybersecurity teacher, her pathway provides a contrast to participants whose instructional practices are informed by external professional or technical backgrounds and advanced academic preparation.

Nathan

Nathan is a teacher at Cedar CareerTech where he currently teaches STEM-related courses. At the time of the study, Nathan was between 45 and 54 years of age and had between 21 and 30 years of teaching experience. He holds a graduate degree and entered the profession through a traditional certification pathway.

Nathan described a direct and linear pathway into teaching, explaining that he made the decision during his freshman year of college to pursue science education. He completed his degree in science education and entered the classroom shortly after graduation. His early career consisted of teaching in traditional public high schools, where he worked for approximately 14 years across multiple school settings.

Nathan later transitioned to Cedar CareerTech. Although he did not enter teaching from a formal industry background, he identified informal, experience-based learning as influential in his preparedness to teach STEM content. Specifically, he described growing up working on cars with his father, who was a mechanic, and continuing this work independently for many years.

Within the context of this study, Nathan's profile highlights a traditionally prepared teacher whose instructional approach is supplemented by informal technical experiences rather than formal industry employment. As a STEM pathway teacher, his pathway provides insight into how experiential, non-professional learning can contribute to perceived readiness to teach applied STEM concepts.

Caleb

Caleb is teacher at Cedar CareerTech, where he teaches 3D Design and Modeling. At the time of the study, Caleb was between 55 and 64 years of age and had between 11 and 20 years of teaching experience. He holds a graduate degree and a traditional teaching certification obtained through an alternative certification pathway. Caleb began his career in education after retiring from the United States Air Force, where he served for 22 years, including 19 years as a teacher. He described teaching as a natural transition, explaining that it had always been something he wanted to pursue following his military career.

After completing the certification process through Troops to Teachers, Caleb began teaching 8th grade mathematics, including Algebra I for high school credit, at a public middle school, where he taught for six years. He later transitioned to a CareerTech center, where he initially taught in a pre-engineering program, including AP Calculus and Introduction to Engineering Design. Following programmatic changes and a partnership with a local college, Caleb developed and now teaches a 3D design and modeling program. In this role, he teaches students to use industry-relevant software and supports pathways in areas such as aerospace, automotive design, and architecture. Although Caleb did not come from a traditional industry background outside of education, his extensive experience as a military teacher and his development of technical programming contribute to his instructional approach.

Within the context of this case study, Caleb's professional trajectory reflects a transition from a highly structured instructional role in the military to secondary and CareerTech. As a 3D design and modeling teacher, his work emphasizes applied, technical skill development within STEM pathways. Although he did not enter teaching from a civilian industry background, his extensive experience as a military instructor and his leadership in developing technical programming contribute significantly to his instructional practice and perspective on STEM education.

Findings By Research Question

The findings are organized by research question and presented through themes that emerged from cross-case analysis. Table 2 provides an overview of the relationship among research questions, themes, and participant representation. This table is intended to illustrate patterns across cases rather than imply uniformity of experience. The identified themes reflect meaningful points of agreement across participants while also preserving variation in individual perspectives.

Table 2

Research Questions, Themes, and Participant Representation

Research Question	Theme	Participants	n
RQ 1. Teachers' beliefs regarding integrated STEM education	Integrated STEM education is robust, rigorous, and broad	All Participants	5
	Integrated STEM education is experiential rather than worksheet based	All Participants	5
	Collaboration across all STEM domains is essential	Emily, Megan, Caleb, Sarah	4
	Skepticism toward top-down standardization	Emily, Megan, Caleb, Sarah	4
RQ 2. Teachers' perceptions of their STEM content knowledge	Confidence Grounded in Prior Technical Experience	Emily, Sarah, Caleb, Megan	4
	Professional Development and Self-Directed Learning Build Knowledge	All Participants	5
	Uneven Confidence Across STEM Domains	All Participants	5
RQ 3. Teachers' Comfort Providing Integrated STEM Education	Integration through inquiry and facilitation	All Participants	5
	Hands-on, real-world tasks are the engine of integration.	All Participants	5
	CareerTech infrastructure enables integration	All Participants	5
	Post-COVID student behaviors complicate integration	Emily, Megan, Caleb, Sarah	4
RQ 4. Teachers' suggestions regarding	Increase and sustain funding and reduce lab class size	All Participants	5

Research Question	Theme	Participants	n
integrated STEM education	Provide autonomy and supportive leadership	Emily, Megan, Caleb, Sarah	4
	Expand shadowing, internships, and clinical access	Megan, Caleb, Sarah	3
	Offer advanced content rich professional development	All Participants	5
	Elevate teacher voice in governance and broaden accountability	Emily, Megan, Caleb, Sarah	4

The sections that follow present each research question with its associated themes, supported by participant evidence and illustrative quotations.

RQ 1. Teachers' Beliefs Regarding Integrated STEM Education

Research Question 1 examined teachers' beliefs about the nature of integrated STEM education within the CareerTech context. Analysis revealed four themes: integrated STEM education as robust, rigorous, and broad; integrated STEM education as experiential rather than worksheet-based; collaboration across STEM domains as essential; and skepticism toward top-down standardization. Collectively, participants articulated a shared vision of integrated STEM education grounded in authenticity, depth, and professional autonomy.

Before examining the themes that emerged regarding teachers' beliefs about integrated STEM education, it is worth considering how participants defined STEM education itself, what they believed distinguished it from single-discipline instruction, and the role they felt real-world problems played in that distinction. Participants' definitions varied in emphasis but converged around several key ideas.

Sarah described STEM education as something that "needs to be broad, rigorous, and robust," emphasizing its role in preparing students for the demands of postsecondary STEM pathways. When asked what made something truly STEM education rather than just science or math, she explained that "you really do need to kind of incorporate all the letters for it to be that robust," describing how she deliberately pulled engineering thinking, technology, and mathematics into her AP Environmental Science class. For Sarah, real-world problems were not supplementary but central, stating plainly that "STEM is not a book, it's not a computer, it's an experience."

Emily framed STEM education as fundamentally about "logic and problem solving" and teaching students "how to think critically about the world around them." For her, the distinction between STEM education and a single subject came down to connection across disciplines, explaining that "vectors appear in math, I talk vectors in computer science, we talk vectors in science. If we can bring these all together, it's not an isolated silo anymore." Emily described real-world integration as something she pursued spontaneously and creatively, pulling hot wheels tracks from a storage room to explore energy loss or dropping Barbies off banisters to teach linear extrapolation, explaining that these kinds of experiences were where "all of the pieces start clicking together."

Nathan kept his definition focused and direct, describing STEM education as preparing students for postsecondary STEM careers and stating that what makes something STEM education is "the integration of it all, not just one or the other." He grounded real-world relevance in project design, describing a capstone project where students built a disaster rescue robot, explaining that grounding projects in authentic scenarios was what gave students a reason to engage.

Caleb described STEM education as bringing together inquisitiveness about how things work, applied tools like computers and 3D printers, and mathematics embedded naturally through real problems rather than as isolated exercises. He emphasized that integration meant cross-curricular thinking in action, describing a collaborative project where his 3D design students and engineering students had to work together, noting that "they have to talk to each other, not just take directions." For Caleb, real-world problems were the engine of that integration, describing a project where students designed covers for electrical boxes in the building's conference center, explaining that "the students took ownership of it" precisely because the problem was genuine. He captured his broader view of STEM education simply: "there's more than one way to get there, but there is a right answer, and you have to use different tools to get it."

Megan described STEM education as involving "hands-on application of STEM concepts and theories," and when distinguishing STEM education from single-subject instruction, she pointed to both resources and authentic engagement, explaining that "until they actually do it themselves, it doesn't solidify."

Across participants, no one described STEM education as a collection of discrete subjects taught independently. Instead, all five defined it in terms of integration, authentic application, and real-world engagement. Importantly, participants arrived at these definitions not through formal study of STEM education theory, but through years of practice in CareerTech settings. These shared definitional foundations provide important context for the themes that follow, as participants' beliefs about what integrated STEM education should look like were grounded in clear understandings.

Theme 1. Integrated STEM Education is Robust, Rigorous, and Broad. All five participants expressed the belief that integrated STEM education should be robust, rigorous, and broad, particularly in preparing students for postsecondary pathways and careers. Teachers consistently rejected narrow or simplified conceptions of STEM education, instead emphasizing depth of understanding and genuine integration of the STEM domains.

Sarah articulated this belief most explicitly, stating that STEM education “needs to be broad, it needs to be rigorous, and it needs to be robust” because students often underestimate the academic demands of STEM careers. She emphasized that many students arrived with aspirations to become doctors or engineers but lacked awareness of the educational commitment required. For Sarah, integrated STEM education served as a reality setting experience that helped students understand what those pathways entail.

Emily echoed this emphasis on rigor, describing STEM education as inherently demanding and intellectually challenging. She noted that integrated STEM education required students to engage deeply with concepts rather than memorizing procedures, stating that “real STEM doesn’t let you stay on the surface very long.” She viewed integration as a way to strengthen student reasoning rather than dilute the components of each STEM domain.

Caleb similarly framed STEM education as broad and cognitively demanding. He described integration as exposing students to multiple ways of thinking about a single problem, explaining that “there’s not one right way to get there, but there is a right answer, and you have to use different tools to get it.” He emphasized that this multidimensional approach better reflected real engineering and design work.

Megan and Nathan also described STEM education as broad exposure rather than specialization too early. Megan noted that integration allowed students to “find their niche” over time rather than being prematurely tracked into narrow content areas.

Across participants, integrated STEM education was believed to require intellectual rigor and breadth, serving both as preparation and as a filtering experience that clarified students' interests and readiness.

Theme 2. STEM Education is Experiential Rather than Worksheet Based. Participants agreed that STEM education is fundamentally experiential and cannot be meaningfully implemented through worksheets or passive tasks. All five teachers described hands-on engagement as central to what distinguishes STEM from traditional instruction.

Sarah stated this belief directly, explaining, "STEM is not a book. It's not a computer. It's an experience." She emphasized that even high-achieving students struggled to develop understanding without physically engaging in labs, experiments, or applied investigations.

Caleb reinforced this view, describing hands-on work as the moment when integration truly occurred. He explained that when students were building, testing, and revising designs, "they stop asking what subject they're in and just focus on solving the problem." For him, experiential learning naturally dissolved disciplinary boundaries.

Megan similarly rejected worksheet driven instruction, especially in cybersecurity education. She explained that abstract explanations are insufficient, stating, "You can tell them the commands, but until they actually secure the machine themselves, it doesn't stick."

Emily also described experiential learning as essential, particularly in physics and mathematics. She noted that conceptual understanding improved when students could manipulate variables, test models, or visualize systems rather than complete static problem sets.

Across participants, STEM education was described as something students must do rather than complete on paper. Worksheets were viewed as inadequate for fostering integrated understanding because they isolated skills rather than engaging students in authentic application.

Theme 3. Collaboration Across STEM Domains is Essential. Four of the five participants explicitly identified collaboration across STEM domains as essential to effective integrated STEM education. Teachers emphasized that no single teacher could fully represent all STEM domains and that integration depended on professional collaboration.

Sarah described drawing on colleagues across CareerTech STEM pathways, noting that when she encountered mathematics, engineering, or physics questions beyond her comfort zone, she regularly consulted other teachers. She stated, “We have a really strong team, and if I need help, I can go to the math teacher or the engineering teacher.” She framed this collaboration as a professional strength rather than a limitation.

Caleb similarly emphasized interdisciplinary collaboration, describing joint projects between design and engineering students. He explained that students learned integration by observing professionals with different expertise working together, stating that “they have to talk to each other, not just take directions.”

Megan noted that collaboration occurred not only across teachers, but also through advisory boards and industry partners. She described community input as essential for keeping integrated STEM education aligned with real-world expectations.

Emily acknowledged collaboration as particularly important when teaching outside one’s primary specialization, emphasizing that integrated STEM education required humility and willingness to learn from others.

While Nathan did not emphasize collaboration as strongly as other participants, he noted that integrated STEM education inherently involved overlapping expertise and shared responsibility.

Overall, teachers viewed collaboration as a necessary condition for sustaining integrated STEM education, reinforcing the belief that integration is a collective rather than individual endeavor.

Theme 4. Skepticism Toward Top-Down Standardization. Participants consistently expressed skepticism toward top down or standardized approaches to integrated STEM education. Four of the five teachers articulated concerns that externally imposed definitions or programs risked oversimplifying or diluting authentic integrated STEM education.

Sarah was most explicit in this critique, arguing that many initiatives labeled as STEM education failed to capture its complexity. She stated, “When people don’t really understand what STEM is, they try to standardize it, and it ends up watering it down.” She emphasized that meaningful integrated STEM education could not be reduced to compliance checklists or superficial activities.

Emily similarly expressed concern about rigid frameworks that prioritized labeling over learning. She cautioned that standardized models often ignored the contextual and disciplinary nuance required for effective integration.

Caleb critiqued “one size fits all” approaches, explaining that integrated STEM education must remain flexible to reflect different industries, tools, and student pathways. He emphasized that professional judgment was critical to maintaining instructional integrity.

Megan raised related concerns about curriculum mandates, noting that externally imposed programs sometimes failed to align with student needs or industry realities.

Across participants, skepticism toward standardization reflected a belief that integrated STEM education is inherently contextual and cannot be prescribed uniformly without loss of quality.

Summary of RQ1 Findings. Findings from Research Question 1 indicate that CareerTech STEM pathways teachers believe integrated STEM education should be robust, rigorous, experiential, and collaborative. Teachers rejected worksheet based and overly standardized approaches, instead emphasizing authentic experiences, interdisciplinary cooperation, and professional autonomy. Collectively, participants articulated a shared belief that integrated STEM education functions best when grounded in real-world relevance and teacher expertise rather than top-down implementation.

RQ 2. Teachers' Perceptions of Their STEM Content Knowledge

Research Question 2 examined how CareerTech STEM pathway teachers perceived their knowledge of STEM content and the experiences that contributed to their confidence. Analysis across participants showed commonalities in how teachers described the development and limits of their STEM content knowledge, while also highlighting meaningful variation in the sources of that confidence. Three themes were identified: confidence grounded in prior technical experience, professional development, and opportunities for self-directed learning as mechanisms for knowledge building.

Across all five participants, confidence in STEM content knowledge was framed not as fixed or universal, but as shaped by experience, learning opportunities, and reflective awareness of content boundaries.

Theme 1. Confidence Grounded in Prior Technical Experience. A clear pattern emerged across participants indicating that confidence in STEM content knowledge was frequently grounded in experiences outside of traditional teacher preparation. Four of the five participants explicitly connected their STEM content confidence to prior technical, professional, or applied instructional experience, while the fifth described developing confidence through sustained applied practice.

Emily articulated strong confidence rooted in extensive academic training and research experience in physics and mathematics. She positioned her content knowledge as long standing and deeply embedded, stating, “I’ve been explaining these math concepts for well over thirty years” and later emphasizing, “I have a master’s in physics. How am I not qualified to teach physics?” Her comments reflected a perception that advanced academic preparation provided a source of her own self efficacy as well as a point of reassurance to of her understanding to her students.

Sarah similarly grounded her confidence in professional experience prior to teaching, drawing on over a decade working as a certified nursing assistant. She explained that this background allowed her to evaluate biomedical curriculum critically and guide students authentically toward health care careers. As she noted, “I was able to look at the curriculum or the videos and say, ‘that’s not really how we do it in a hospital.” She further described how students sought out her guidance because she could explain not only what content meant, but how it applied in real clinical settings.

Caleb described confidence emerging from a non-industry but highly technical pathway. With over twenty years in the United States Air Force, including nineteen years as an instructor, he framed teaching expertise as transferable across contexts. While he learned much of his current STEM content in recent years, he emphasized that confidence came from knowing how to learn complex systems. As he stated, “If I can learn this in the last six years, then I know I can help students through whatever stumbling blocks they hit.”

Megan presented a developing version of this theme. Although she did not enter teaching with formal industry experience in cybersecurity, she described years of participation in CyberPatriot competitions and applied coaching as foundational. She explained, “I didn’t go to school for cybersecurity… but after seven or eight years of doing CyberPatriot and teaching it, I feel pretty comfortable now.” Her experience suggests that sustained applied engagement can function similarly to traditional professional experience in building confidence. However, when discussing details of what she felt most comfortable and least comfortable with, she repeatedly referenced the curriculum she had used. Indicating her self-efficacy in STEM content knowledge is in the early stages where she relies on materials rather than her own knowledge.

Taken together, these findings indicate that confidence in STEM content knowledge was most strongly associated with applied experiences that extended beyond preservice preparation. Participants consistently described such experiences as providing credibility, practical perspective, and assurance when teaching advanced or interdisciplinary STEM content.

Theme 2. Professional Development and Self-Directed Learning Build Knowledge. In addition to prior experience, participants widely agreed that professional development and self-directed learning played a central role in developing and sustaining STEM content knowledge. All five participants described confidence as something that increased over time through intentional learning rather than something established at certification.

Sarah emphasized intensive professional development as foundational to her confidence, particularly through multiple Project Lead the Way trainings. She characterized these as immersive experiences, stating, “We covered an entire year’s curriculum in two weeks. We had homework just like the kids do.” She explicitly connected depth of content knowledge gained through training to instructional clarity, explaining that when she knew more than what she was required to teach, she felt better able to scaffold student understanding.

Megan similarly highlighted professional development experiences that allowed her to engage directly with content before teaching it. She described attending conferences where teachers “actually got to dive into the content ourselves,” noting that these experiences increased both content familiarity and instructional confidence. She emphasized the value of guided modeling, particularly in emerging areas where she was still developing expertise.

Caleb framed self-directed learning as a professional expectation in rapidly evolving STEM career fields. He described routinely reviewing software updates and revising curriculum, noting, “If I stopped learning, I’d lose that confidence pretty quickly.” He further emphasized that modeling continuous learning for students was an intentional instructional choice rather than a sign of weakness.

Emily, despite expressing high confidence overall, also described relying on professional networks when encountering new content or instructional challenges. She explained, “I know I can reach out and say, ‘I’m missing the hook here,’ and somebody will help me find it.” Her comments suggest that professional learning supported pedagogical refinement even when content knowledge was strong.

Across participants, professional development and self-directed learning were described as ongoing, necessary, and closely tied to confidence. Teachers consistently framed STEM content knowledge as evolving and responsive to both technological change and student needs.

Theme 3. Uneven Confidence Across STEM Domains. While participants described themselves as confident STEM pathway teachers, all five acknowledged uneven confidence across the individual STEM domains. This variability was described as expected and inherent in interdisciplinary teaching rather than as a deficit.

Emily noted that while she felt most confident in physics and mathematics, some content areas required additional effort to make engaging for students. She explained that discomfort was not rooted in lack of understanding, but in finding effective pedagogical entry points, stating that sometimes the challenge was “finding the right hook” rather than mastering the concept itself.

Sarah explicitly described strong confidence in biological and biomedical sciences, contrasted with lower confidence in advanced physics and specialized engineering topics. She stated, “If we’re doing broad stroke engineering, I’m comfortable. When it gets into the niche areas, that’s where I start struggling.” She emphasized relying on collaboration with colleagues and continued learning to support instruction in these areas.

Megan described greater comfort with technology and mathematics than with science content outside her primary area. She explained that curriculum simulations helped bridge gaps, stating, “The simulations include things I don’t yet feel qualified to build on my own, so I rely on them.”

Caleb framed uneven confidence as instructional leverage, noting that learning content alongside students allowed him to model persistence. He explained, “I share my failures with students so they can see that learning hard things takes time.”

Across participants, uneven confidence was universal and intentionally navigated. Teachers described leveraging collaboration, curriculum, and transparency with students to address variability across STEM domains.

Summary of RQ2 Findings. Findings from Research Question 2 indicate that CareerTech STEM pathway teachers perceived their STEM content knowledge as experience-based, continually developing, and contextually bounded. Confidence was most strongly grounded in applied technical experience and reinforced through professional development and self-directed learning. At the same time, participants demonstrated reflective awareness of uneven confidence across STEM domains, which informed instructional decisions rather than undermining self-efficacy. These findings suggest that CareerTech STEM pathway teachers conceptualize knowledge as dynamic and growth-oriented, aligning professional identity with lifelong learning rather than static expertise.

RQ 3. Teachers’ Comfort Providing Integrated STEM Education

Research Question 3 examined the extent to which CareerTech STEM pathway teachers felt able to provide integrated STEM education. Analysis across all five participants revealed that teachers generally felt capable of implementing integrated STEM education; however, this ability was contingent on pedagogical approach, task design, institutional context, and student factors. Four themes were identified: integration through inquiry and facilitation, hands-on real-world tasks as the engine of integration, CareerTech infrastructure as an enabling condition, and post-COVID student behaviors as a complicating factor.

Across participants, integrated STEM education was not described as a formal curriculum structure but as an instructional stance shaped by teacher decision-making and contextual supports.

Theme 1. Integration Through Inquiry and Facilitation. Participants agreed that integrated STEM education was best enacted through inquiry-based pedagogy and a facilitative teaching role rather than direct instruction. All five participants described integration as occurring when students engaged in questioning, problem-solving, and design, with teachers acting as guides rather than content deliverers.

Emily described integrated STEM education as emerging naturally when students were encouraged to explore problems that required multiple disciplinary perspectives. She explained that integration happened "when students are doing the thinking and I'm helping them make connections across math, physics, and technology, instead of giving them the answers." For her, integration was less about lesson structure and more about how students interacted with content.

Caleb similarly framed integration as a facilitative process, emphasizing the role of inquiry and iteration. He described showing students an end goal and then "breaking it down into pieces and letting them problem solve their way there." Integration occurred as students navigated design constraints, mathematical reasoning, and technological tools simultaneously.

Sarah emphasized that inquiry allowed her to intentionally integrate across pathways within the same classroom. Teaching AP Environmental Science to students from engineering, computer science, and biomedical pathways, she explained, required her to “stretch myself and bring in technology and engineering thinking, not just biology.” She noted that inquiry-based labs naturally encouraged these connections.

Megan described shifting into a facilitator role as essential for integration, particularly in cybersecurity. She stated, “They learn more when they’re actually doing it and figuring it out, and I’m just there to guide them.” Integration occurred as students independently navigated technical tasks, applying math, logic, and technology together.

Nathan echoed this pattern, noting that integrated STEM education required relinquishing control and allowing students to struggle productively. He emphasized that inquiry created space for disciplines to intersect organically rather than sequentially.

Taken together, participants described inquiry and facilitation as central mechanisms through which integrated STEM education became possible. Integration was presented as a pedagogical outcome rather than a prescriptive instructional format.

Theme 2. Hands-On, Real-World Tasks Are the Engine of Integration. All five participants strongly agreed that hands-on, real-world tasks were the primary drivers of integrated STEM education. Teachers consistently described integration as occurring when students worked on authentic problems requiring simultaneous application of multiple STEM domains.

Caleb provided detailed examples of design projects that required students to engage in engineering design, mathematical reasoning, and technological execution at once. He explained that when students designed and 3D printed functional components, “they don’t ask what subject they’re doing, they’re just trying to make it work.” Integration, for him, was a byproduct of authentic problem solving.

Sarah described real-world relevance as “almost central” to integrated STEM education, stating, “STEM isn’t a book or a computer. It’s an experience.” She emphasized that when students engaged with real environmental or biomedical problems, disciplinary boundaries faded because the work demanded integration.

Megan highlighted cybersecurity simulations as examples of integrated tasks. She explained that students had to apply logic, mathematical reasoning, and technological skills simultaneously, noting, “Until they actually do it themselves, it doesn’t really solidify.”

Emily similarly emphasized applied tasks, explaining that abstract concepts became integrated when students encountered them within meaningful contexts. She noted that hands-on modeling and experimentation created “those moments where math and physics stop being separate.”

Nathan described real-world tasks as essential for student buy in, explaining that integration was strongest when students understood why the problem mattered beyond the classroom.

Across participants, hands-on, real-world tasks were consistently described as the instructional engine of integration. Integration did not occur through symbolic alignment of content standards but through authentic work that required multiple disciplines at once.

Theme 3. CareerTech Infrastructure Enables Integration. Participants consistently identified CareerTech infrastructure as a critical enabling condition for integrated STEM education. All five teachers emphasized that access to funding, equipment, space, and institutional flexibility directly affected their ability to integrate STEM domains.

Megan explicitly contrasted CareerTech and traditional K–12 settings, stating, “The biggest difference is the budget. Having a budget allows hands-on learning, and hands-on learning allows STEM integration.” She described how curricular freedom and equipment access supported integrated instruction that would have been impossible in her previous setting.

Sarah echoed this sentiment strongly, stressing that “science is expensive” and describing how CareerTech funding allowed her to implement labs and activities that integrated biology, technology, and engineering. She emphasized that reduced class sizes and specialized facilities further supported integration.

Caleb highlighted institutional trust as equally important. He explained that administration support allowed him to invest in equipment intentionally and design long-term integrated projects without constant justification. He noted, “As long as I tie it back to student learning, they trust me to do it.”

Emily similarly pointed to scheduling flexibility, equipment access, and reduced testing pressures as factors that allowed her to design integrated learning experiences rather than isolated lessons.

Collectively, participants framed integration not solely as a pedagogical choice, but as something structurally enabled by CareerTech systems. Integration was sustained through material resources and organizational conditions that supported authentic integrated STEM education.

Theme 4. Post-COVID Student Behaviors Complicate Integration. While participants generally felt capable of providing integrated STEM education, four of the five explicitly described post-COVID student behaviors as complicating integration efforts. Teachers reported challenges related to attention, persistence, and student readiness for open-ended tasks.

Megan described noticeable declines in attention span and increased device dependence, stating, “The attention span is awful… the phones are glued to their hands.” She explained that integration through inquiry was more challenging when students resisted sustained problem-solving.

Caleb noted that while his own instructional flexibility improved post-COVID, students often struggled with self-management and perseverance. He emphasized that integrated projects required students to navigate uncertainty, which some found uncomfortable after prolonged periods of structured or virtual learning.

Sarah acknowledged similar challenges but noted that CareerTech student choice mitigated some behavioral issues. She explained that students being “here by choice” improved engagement, though rebuilding stamina for complex tasks remained necessary.

Emily and Nathan discussed the need to reteach collaboration and productive struggle skills, particularly for students unused to extended inquiry.

Although CareerTech mitigated some post-COVID challenges through structure and choice, participants agreed that integration required additional scaffolding to support students’ readiness for interdisciplinary and inquiry-based work.

Summary of RQ3 Findings. Findings from Research Question 3 indicate that CareerTech STEM pathway teachers largely feel able to provide integrated STEM education when pedagogical approaches, task design, and institutional supports align. Integration was most strongly associated with inquiry-based facilitation, hands-on real-world tasks, and CareerTech infrastructure. However, post-COVID student behaviors complicated implementation, requiring additional scaffolding and intentional instructional design. Overall, integrated STEM education was described as achievable but context dependent, emerging through interaction between teacher practice and structural conditions.

RQ4. Teachers' Suggestions Regarding Integrated STEM Education

Research Question 4 examined teachers' suggestions for strengthening the implementation and sustainability of integrated STEM education in CareerTech settings. Across all five participants, teachers offered concrete and system level recommendations grounded in their daily instructional experiences. Analysis revealed five themes: increasing and sustaining funding while reducing lab class sizes; providing autonomy and supportive leadership; expanding shadowing, internships, and clinical access; offering advanced, content rich professional development; and elevating teacher voice in governance while broadening accountability measures.

Collectively, participants' suggestions emphasized structural conditions rather than individual teacher effort as the primary levers for improving integrated STEM education.

Theme 1. Increase And Sustain Funding and Reduce Lab Class Sizes. All five participants identified sustained funding as a foundational requirement for effective integrated STEM education. Teachers emphasized that integration depends on access to equipment, consumable materials, and appropriately sized instructional spaces, particularly in laboratory settings.

Sarah articulated this concern most forcefully, stating, “Science is expensive. People don’t understand how expensive it really is until they try to run a program like this.” She explained that meaningful integration required funding not just for initial purchases but for ongoing maintenance, replacements, and supplies. She also emphasized concerns about safety and instructional quality, arguing that lab-based STEM courses should not enroll large numbers of students, noting that “there is absolutely no reason to have thirty kids in a lab science class.”

Megan similarly highlighted the role of funding in enabling hands-on instruction, explaining that integration was only possible because CareerTech programs have budgets that allowed teachers to purchase equipment without personal financial burden. Comparing her current CareerTech and her previous experience in a traditional high school, she stated, “The biggest difference is the budget. The budget lets you do the hands-on things, and that’s what makes STEM actually work.”

Caleb supported this perspective, emphasizing the importance of sustained funding rather than one-time grants. He cautioned that equipment failures and consumable needs required ongoing investment and noted that without long-term funding plans, integrated projects would quickly become unsustainable.

Emily and Nathan echoed concerns about class size and resource strain, noting that integration becomes more difficult when physical space and materials must be shared among too many students.

Across participants, funding and class size limits were framed as non-negotiable pre-requisites for authentic integrated STEM education rather than optional enhancements.

Theme 2. Provide Autonomy and Supportive Leadership. Participants consistently emphasized the importance of autonomy and supportive leadership in enabling integrated STEM education. Four of the five participants explicitly identified administrative trust as a critical condition that allowed them to innovate and adapt instruction.

Sarah described leadership support as one of the strongest facilitators of her instructional confidence. She explained that her director took a hands-off approach, stating, "He's basically told me, 'You know what needs to be done. Go do it.'" She emphasized that this trust allowed her to implement integrated projects without fear of micromanagement.

Caleb similarly highlighted supportive leadership, explaining that administrators were receptive to equipment requests and professional development when proposals were tied to student learning outcomes. He stated, "If you can connect it back to student learning, they really don't have a reason to say no."

Megan contrasted her CareerTech experience with prior K–12 settings, noting that autonomy over curriculum pacing and instructional choices allowed her to respond flexibly to student needs. She explained that feeling trusted to select curriculum and shape learning experiences was both empowering and motivating.

Emily echoed this sentiment, emphasizing that integrated STEM education required professional judgment that could not be scripted. She noted that leadership support created space for disciplinary integration rather than forcing rigid curricular alignment.

Collectively, participants suggested that integrated STEM education flourishes when teachers are treated as professionals with expertise rather than implementers of externally mandated programs.

Theme 3. Expand Shadowing, Internships, and Clinical Access. Three of the five participants strongly advocated for expanding student access to work-based learning opportunities, including shadowing, internships, and clinical experiences. Teachers described these opportunities as critical for reinforcing integrated STEM education learning and sustaining student motivation.

Sarah described significant frustration with barriers to clinical experiences for biomedical students. She explained that students often left advanced biomedical STEM pathways for CNA pathways because those programs offered tangible clinical access, stating, “They get to wear scrubs and go out to clinicals, and my kids are like, ‘I want that.’” She questioned age and regulatory restrictions that limited access, asking, “Why do they have to be eighteen? Why can’t we figure this out?”

Caleb emphasized internships as a motivational tool, explaining that many students prioritized employment over coursework. He suggested that guaranteed or paid internships would incentivize deeper engagement with STEM content.

Megan also highlighted the value of industry partnerships, noting that students responded positively when they could see how integrated skills translated into workforce expectations.

Emily and Nathan acknowledged fewer formal partnerships but supported expanded access, describing exposure to real workplaces as essential for helping students understand the relevance of interdisciplinary learning.

Across participants, expanded work-based learning was positioned as both a structural support and an instructional extension of integrated STEM education.

Theme 4. Offer Advanced Content Rich Professional Development. All five participants recommended professional development that prioritized advanced content knowledge rather than generalized instructional strategies. Teachers emphasized that deeper knowledge enhanced both confidence and instructional effectiveness.

Sarah articulated this belief explicitly, stating, "When I have more knowledge than what I'm having to teach, it helps me teach it better." She described past experiences with advanced scientific professional development as reaffirming her identity as a STEM pathway teacher.

Caleb similarly emphasized content embedded learning, explaining that attending industry conferences exposed him to emerging applications and helped keep curriculum current.

Megan expressed a desire for professional development that included modeling and hands-on exploration of tools and equipment, particularly in areas outside her strongest expertise.

Emily noted that content rich learning allowed teachers to make more meaningful interdisciplinary connections, particularly when teaching outside their primary domain.

Collectively, participants suggested shifting professional development away from abstract pedagogy toward immersive, content centered experiences aligned with real STEM career practices.

Theme 5. Elevate Teacher Voice in Governance and Broaden Accountability. Participants expressed strong agreement that teacher voice should play a larger role in decision-making related to education. Four of the five explicitly critiqued governance structures that prioritized test-based accountability over program outcomes.

Caleb framed CareerTech success as stemming from a focus on placement and readiness rather than test scores, stating that students should be viewed as “customers we’re preparing for the workforce.”

Sarah echoed this critique, expressing concern that biomedical STEM pathways were undervalued because they did not lead directly to immediate employment. She argued that long-term outcomes, such as college completion and professional advancement, should be recognized as markers of success.

Emily similarly cautioned against narrow accountability measures, emphasizing that integrated STEM education outcomes often emerged over time rather than through standardized assessments.

Megan described the importance of advisory boards and practitioner input, suggesting that governance structures should consistently incorporate teacher perspectives to remain responsive and relevant.

Across participants, elevating teacher's voice and broadening accountability were framed as necessary steps for sustaining meaningful integrated STEM education.

Summary of RQ4 Findings. Findings from Research Question 4 indicate that CareerTech STEM pathway teachers’ recommendations focus on systemic and structural conditions rather than teacher level change. Participants emphasized sustained funding, supportive leadership, expanded work-based learning opportunities, advanced professional development, and increased teacher voice in governance as critical for strengthening integrated STEM education. These suggestions reflect a shared belief that integrated STEM education depends on institutional commitment and professional trust rather than individual resilience.

Cross Case Synthesis

Across the five cases, a coherent pattern of integrated STEM education implementation emerged. Although participants varied in disciplinary background, professional pathways, and instructional contexts, findings converged around shared understandings of integrated STEM education as an experiential, inquiry-driven practice shaped by both teacher expertise and institutional conditions. Variation across cases reflected contextual differences rather than fundamentally different conceptions of integrated STEM education teaching and learning.

Three cross-cutting patterns extend across the four research questions. These patterns synthesize findings across research questions, which are presented individually in Table 3.

Table 3

Cross-Case Thematic Alignment by Research Question

Research Question	Theme	Cross-Case Pattern
RQ 1. Teachers' beliefs regarding integrated STEM education	Beliefs about the nature of integrated STEM education	Integrated STEM education is rigorous, experiential, and grounded in collaboration and professional autonomy
RQ 2. Teachers' perceptions of their STEM content knowledge	Teacher capacity	STEM content knowledge is experience-driven, continuously developed, and contextually bounded
RQ 3. Teachers' Comfort Providing Integrated STEM Education	Instructional orientation	Integration is enacted through inquiry, facilitation, and authentic problem-solving
RQ 4. Teachers' suggestions regarding integrated STEM education	Structural supports	Integrated STEM education is sustained through funding, leadership, and systemic conditions rather than individual effort

First, integrated STEM education was consistently understood as an instructional orientation rather than a prescribed model. Teachers did not describe integration as adherence to a set of standards or a formalized curriculum structure. Instead, integration emerged through inquiry-based pedagogy, the teacher positioning themselves as a facilitator, and engagement in authentic problem solving. Across cases, integration occurred when students were positioned as active participants working through complex, real-world tasks that required the simultaneous application of multiple STEM domains.

Second, teacher capacity to enact integrated STEM education was grounded in experience and shaped by context. Across participants, confidence in STEM content knowledge and instructional ability developed through prior technical experience, sustained professional learning, and ongoing self-directed growth. Teachers demonstrated clear awareness of uneven expertise across STEM domains and navigated these differences through collaboration, resource use, and continued learning. Capacity was not described as a fixed individual trait but as responsive to environmental conditions.

Third, the sustainability of integrated STEM education was consistently framed as dependent on structural and systemic conditions rather than individual teacher effort. Across cases, participants emphasized that funding, lab resources, class size, leadership support, and access to work-based learning opportunities directly influenced the quality and feasibility of integration. Teachers also identified the importance of professional autonomy and the inclusion of teacher voice in decision-making processes.

Taken together, these patterns indicate that integrated STEM education in CareerTech settings is best understood as a relational system connecting pedagogy, teacher expertise, and organizational context. These findings demonstrate that the themes presented by research question (Table 3) are not discrete but collectively contribute to a broader system shaping integrated STEM education teaching and learning.

These cross-case patterns provide a foundation for the interpretive analysis in Chapter 5, where findings are examined in relation to existing literature on integrated STEM, teacher self-efficacy, and CareerTech education, as well as their implications for policy, practice, and future research.

Summary

Through four research questions, the study explored how teachers understand their STEM content knowledge, enact integration in practice, conceptualize integrated STEM education, and propose improvements to support its implementation.

Across cases, teachers' perceptions of STEM content knowledge were grounded in experience, strengthened through ongoing learning, and characterized by reflective awareness of disciplinary limits. Teachers generally felt capable of providing integrated STEM education when instruction emphasized inquiry, hands-on real-world tasks, and facilitative teaching. However, implementation was shaped by contextual factors, including post-COVID student behaviors and available institutional supports.

Teachers' beliefs regarding integrated STEM education reflect a shared vision of rigor, authenticity, and interdisciplinarity. Participants rejected worksheet driven and overly standardized approaches, instead emphasizing experiential learning, collaboration, and professional judgment. Their suggestions for strengthening integrated STEM education focused on systemic conditions, including funding, leadership, work based learning access, professional development, and governance structures that elevate teacher voice and broaden accountability beyond testing metrics.

Overall, findings indicate that integrated STEM education within CareerTech settings is not experienced as a discrete program but as an instructional philosophy supported or constrained by institutional context. The consistency of themes across diverse cases suggests strong pattern saturation and underscores the importance of structural alignment in sustaining integrated STEM education.

Chapter 5: Discussion

In this chapter, I will interpret the findings of this study examining CareerTech STEM pathway teachers' perceptions, capacities, beliefs, and recommendations regarding integrated STEM education. Building on the results presented in Chapter 4, this discussion moves beyond description to explore what those findings mean for integrated STEM education practice, policy, and research.

Interpretation Of Findings by Research Question

RQ 1. Interpreting Beliefs Regarding Integrated STEM Education

Findings from Research Question 1 reveal that CareerTech STEM pathway teachers hold a clear and demanding vision of what integrated STEM education should be. Across all five participants, STEM education was described as rigorous, experiential, broad, and collaboratively enacted, which aligns with integrated STEM education. These beliefs were not incidental. They reflect deeply held professional values shaped by years of applied experience in both industry and education.

Participants consistently defined integrated STEM education and that is more than a collection of subject-area content. For them, it was an instructional philosophy oriented toward authentic problem solving, disciplinary interconnection, and the kind of intellectual challenge that mirrors real-world STEM careers work. This aligns with Kennedy and Odell's (2014) conception of integrated STEM education as a meta-discipline focused on innovation and applied problem solving. It also stands in notable contrast to the findings of Firat (2020), whose study of secondary science teachers found that teachers held fragmented and inconsistent conceptions of

STEM education. Many of Firat's participants could not articulate what integration required beyond surface-level descriptions of the four disciplines. Where those teachers were responding to a newly mandated curriculum they had not been prepared for, the CareerTech teachers in this study had developed their conceptions through years of applied practice, industry experience, and sustained professional engagement. Rather than uncertainty about what STEM is, participants here expressed conviction about what it should be and skepticism toward anything that fell short of that standard.

Participants also unanimously rejected worksheet-driven, passive, or overly standardized approaches to STEM education. This skepticism reflects a broader concern in the literature: that externally imposed definitions of STEM education often dilute authentic practice by prioritizing compliance over genuine interdisciplinary learning (Margot & Kettler, 2019). Emily cautioned that rigid frameworks "prioritize labeling over learning," while Sarah argued that attempts to standardize STEM education without deep understanding of what it requires tend to "water it down." This resonates with Fixsen et al.'s (2005) finding that implementation without sufficient fidelity produces poor outcomes, and with Eun's (2019) observation that teachers need practical, contextual support, not just content knowledge, to enact meaningful instructional change.

Dewey's (1897/2017; 1938) philosophical framework helps explain these beliefs. Participants' emphasis on experiential, inquiry-driven, problem-based learning closely mirrors Dewey's pragmatic conception of education as rooted in real-world engagement and active sense-making. Caleb's description of integration captures this well: "There's not one right way to get there, but there is a right answer, and you have to use different tools to get it." Teachers in this study did not view STEM education as content to be delivered. They viewed it as an experience to be facilitated, which aligns directly with Dewey's emphasis on learning as participation in meaningful, socially situated problems (Dimitriadis & Kamberelis, 2006).

Four of five participants also identified collaboration across disciplines as essential, not optional. This reinforces Kelley and Knowles's (2016) framework of integrated STEM education as reliant on shared expertise and collective professional practice. Teachers drew on colleagues, advisory boards, and industry partners to sustain integration across content areas where their own expertise was bounded. This suggests that sustainable integrated STEM depends on building interdisciplinary professional communities, not just preparing individual teachers.

RQ 2. Interpreting Teachers' Perceptions of STEM Content Knowledge

Findings from Research Question 2 indicate that CareerTech STEM pathway teachers perceive their content knowledge as grounded in experience, continuously developing, and shaped by honest awareness of their disciplinary limits. Four of five participants connected their confidence directly to prior technical, professional, or applied instructional experience outside of traditional teacher preparation. For these teachers, confidence was not primarily conferred by degrees or certifications. It was earned through doing, which aligns with Bandura's (1997) identification of mastery experience as the most powerful source of self-efficacy.

Emily's confidence in physics and mathematics was rooted in over thirty years of explaining those concepts, beginning as a high school student tutoring peers and continuing through laboratory research and graduate teaching assistantships. She framed her qualifications as a lived history of engagement: "I have a master's in physics. How am I not qualified to teach physics?" Sarah's confidence in biomedical sciences drew from eleven years as a certified nursing assistant, which allowed her to evaluate curriculum critically and guide students from a position of authentic professional authority. She noted that she was "able to look at the curriculum or the videos and say, 'that's not really how we do it in a hospital.'" Caleb, despite having learned his 3D design content primarily in the last six years, framed that trajectory as evidence of confidence: "If I can learn this in the last six years, then I know I can help students through whatever stumbling blocks they hit."

These patterns extend Firat's (2020) work in an important direction. In that study, most teachers considered themselves inadequately prepared for integrated STEM education. Even teachers with adequate STEM concept knowledge still felt unqualified because they lacked implementation knowledge. In the present study, participants' confidence was not anchored in curriculum familiarity or formal STEM training. It was built through applied, real-world mastery, exactly the kind of experience Bandura (1997) identifies as the strongest source of efficacy. The CareerTech context, which draws teachers from industry and rewards practical expertise, appears to create conditions where this form of experience-based confidence can develop and be sustained in ways that according to participants, traditional school settings may not support.

Canrinus et al. (2012) noted that teacher self-efficacy is closely intertwined with professional identity and that both evolve dynamically through interaction with contextual conditions. The participants in this study reflect that dynamic model. Their confidence was not a fixed attribute. It was a developing relationship between their experiences and their instructional environments.

Megan's case presents a distinct pattern worth examining more closely. Unlike her colleagues, Megan entered CareerTech without formal industry experience in cybersecurity and described her content confidence as substantially dependent on the curriculum she used. She explained that "the simulations include things I don't yet feel qualified to build on my own, so I rely on them." This reflects what Forbes and Davis (2008) described as curricular role identity, the dimension of a teacher's professional identity organized around the use of curriculum materials. Forbes and Davis found that teachers often begin by closely identifying with curriculum as a tool that mediates their relationship to content, and that over time, more experienced teachers develop the autonomy to adapt and move beyond those materials. Megan's reliance on curriculum suggests her identity is still in an early, material-dependent stage.

Feille (2025) extends this thinking in her investigation of preservice elementary science teachers, finding that science teaching self-efficacy and professional identity develop through a layered process shaped by mastery moments, course experiences, and ongoing reflection. Applied to Megan's case, this framing suggests that her reliance on curriculum is not a deficit but a developmental marker. Teachers at this stage benefit less from abstract instructional strategies and more from direct, scaffolded engagement with STEM content alongside mentors who model expertise in action.

All five participants also acknowledged uneven confidence across the STEM domains. This was described as expected and able to improve rather than disqualifying. Sarah was direct: "If we're doing broad stroke engineering, I'm comfortable. When it gets into the niche areas, that's where I start struggling." Caleb framed uneven confidence as pedagogically useful, noting that sharing his own learning failures with students modeled persistence. This transparency reflects Bandura's (1997) concept of resilience under uncertainty and aligns with the broader finding that these teachers view professional expertise as dynamic and growth-oriented rather than fixed.

RQ 3. Teachers' Comfort Providing Integrated STEM Education

Findings from Research Question 3 indicate that CareerTech STEM pathway teachers generally felt capable of providing integrated STEM education, but that this capacity was not unconditional. It was consistently framed as dependent on the alignment of pedagogical approach, task design, institutional infrastructure, and student readiness. For these teachers, integration did not happen because of a curriculum or a standard. It happened when the right conditions were in place.

The most consistent finding was that integration emerged through inquiry-based facilitation rather than direct instruction. All five participants described repositioning themselves as guides while students engaged in active problem solving. Nathan captured this directly saying, "Ask a bunch of questions, make them think through it and reach for it; you facilitate it and let them figure it out, because otherwise it's not as much fun for them." Megan described a similar shift: "They learn more when they're actually doing it and figuring it out, and I'm just there to guide them." The stance that the teacher fills the role of facilitator is central to what Kelley and Knowles (2016) described as integrated STEM education pedagogy and aligns with Dewey's (1938) vision of the teacher as someone who structures meaningful encounters with problems rather than delivering predetermined answers.

Watson (2019) provides a useful counterpoint here. He argues that in-the-moment instructional choices are often governed by algorithmic reasoning, habituated routines that teachers invoke to manage the complexity of classroom life. When uncertainty or pressure arises, teachers tend to default to teacher-centered practices even when they hold reform-oriented beliefs. This helps explain why integration, though valued by all participants, was described as context-dependent rather than automatic. Without adequate time, equipment, administrative support, and student readiness, the pressure toward more directive instruction increased. One such condition that four participants explained made integration harder to sustain was student behavior, especially post-COVID. These behavior challenges included declining attention spans, increased device dependence, and reduced tolerance for productive struggle.

CareerTech infrastructure emerged as a decisive enabling condition which improves their own efficacy as well as their ability to integrate STEMdomains. Participants consistently contrasted their current CareerTech contexts with their prior experiences in traditional public schools, framing the difference primarily in terms of funding, flexibility, and institutional trust. Megan, reflecting on her own experiences in both a traditional high school and CareerTech stated directly: "The biggest difference is the budget. The budget lets you do the hands-on things, and that's what makes STEM actually work." Sarah echoed this about her own experiences: "Science is expensive. People don't understand how expensive it really is until you try to run a program like this." These accounts reinforce Parker et al.'s (2015) finding that institutional resource conditions, not just teacher preparation, are central to effective STEM education implementation.

Caleb's description of administrative trust was equally telling. As long as he could connect a request to student learning outcomes, he explained, "they really don't have a reason to say no." That kind of institutional trust created what Bandura (1997) refers to as an enabling environment for self-efficacy, one where teachers are treated as professional decision makers rather than compliance agents. Duncan et al. (2013) found that CareerTech teachers with higher self-efficacy reported greater confidence in instructional innovation, classroom management, and technology integration, all of which were evident across the participants in this study.

RQ 4. Interpreting Suggestions Regarding Integrated STEM Education

Findings from Research Question 4 reveal that participants' recommendations were overwhelmingly structural and systemic rather than individually focused. Participants were not asking for more motivation or generic instructional training. They were asking for sustained funding, smaller lab class sizes, expanded work-based learning access, content-rich professional development, supportive leadership, and mechanisms to elevate teacher voice in governance. This reflects a systems-level understanding of integrated STEM education implementation that the literature has increasingly emphasized but that policy responses have often failed to match (Shernoff et al., 2017; Nadelson et al., 2013).

The emphasis on content-rich professional development stands out. Sarah articulated the logic clearly: "When I have more knowledge than what I'm having to teach, it helps me teach it better." This aligns with Bandura's (1997) model, in which deepened mastery strengthens self-efficacy, and with Eun's (2019) finding that teachers need substantive content engagement, not just pedagogical strategies, to enact meaningful change. Generic professional development was consistently viewed as insufficient. Caleb described attending an industry conference as transformative precisely because it exposed him to authentic applications of the tools and content he taught. Professional development for STEM pathway teachers, the data suggest, should be embedded in real-world disciplinary practice wherever possible.

These recommendations converge with Firat's (2020) finding that teachers in that study also prioritized active, hands-on, experience-based training as their top recommendation. The alignment across two very different educational contexts, Turkish secondary schools and Oklahoma CareerTechs, strengthens the argument that content-rich applied professional development is not a context-specific preference but a consistent need among STEM pathway teachers. Where the two studies diverge most sharply is in the structural conditions teachers identified. Firat's participants focused on equipment shortages, curriculum mandates, and time constraints within a newly imposed policy framework. Participants in this study emphasized sustained funding, expanded work-based learning, and governance structures that elevate teachers' voices. These concerns reflect a more mature implementation context where the question is no longer whether to integrate STEM education but how to sustain and deepen it.

The call for expanded shadowing, internships, and clinical access reflects a deeper structural concern about the alignment between classroom experience and industry reality. Sarah expressed significant frustration that students in the biomedical pathway could not access hospital or clinical settings as easily as students in the CNA program: "They get to wear scrubs and go out to clinicals, and my kids are like, 'I want that.'" Caleb similarly argued that guaranteed or paid internships would incentivize deeper student engagement with STEM content, reinforcing the literature on work-based learning as a central mechanism of effective CTE-STEM integration (Stone, 2011; Stone et al., 2006).

Participants also called for accountability measures that recognize long-term outcomes, including college completion, career placement, and professional advancement, as meaningful indicators of program success rather than test scores alone. Caleb framed this in terms of viewing students as "customers we're preparing for the workforce," while Nathan argued for teacher's voices to shape standards rather than simply receive them. These recommendations align with Fixsen et al.'s (2005) framework, which emphasizes that sustainable educational change requires systemic conditions, including accountability structures that reflect program goals, not just individual teacher development.

Cross Cutting Themes

Across all four research questions, three cross-cutting patterns emerged that help explain how integrated STEM education functions and is sustained or constrained within CareerTech settings.

First, integrated STEM education was consistently understood as an instructional orientation rather than a prescribed curriculum model. Participants did not describe integration as adherence to standards or a scripted sequence of activities. It emerged through teacher positioning, inquiry-based task design, and authentic engagement with real-world problems requiring multiple disciplines at once. This reinforces Kelley and Knowles's (2016) framework and extends it by demonstrating that in CareerTech settings, the conditions for integration are as much institutional as they are pedagogical.

Second, teacher capacity to enact integrated STEM education was grounded in experience and shaped by context. Confidence developed primarily through prior technical experience, professional development, and sustained self-directed learning, not through formal preparation alone. Teachers demonstrated consistent awareness of their disciplinary limits and navigated those limits through collaboration, strategic use of curriculum, and transparency with students. The data suggest a developmental trajectory in which less experienced teachers, like

Megan, organize their professional identity around curriculum materials, while more experienced teachers, like Emily and Sarah, develop the autonomy to adapt and move beyond those materials. This pattern is consistent with Forbes and Davis (2008) and further illuminated by Feille's (2025) model of teacher identity development.

Third, the sustainability of integrated STEM education was consistently framed as dependent on structural and systemic conditions rather than individual effort. Funding, lab resources, class size, leadership support, and access to work-based learning directly determined the feasibility of integration. Participants framed their ability to provide authentic, rigorous, experiential integrated STEM education not as a function of personal motivation but as a function of institutional alignment. This has direct implications for how policymakers and administrators understand what makes integrated STEM education possible and sustainable.

Implications

Policy

At the most immediate level, findings support sustained, flexible funding models for CareerTech STEM pathways rather than episodic grant-based support. Caleb cautioned directly against one-time funding: "You can't just buy it one time and then expect that everything's going to work; parts break, things don't work like you thought they would." This reflects Shernoff et al.'s (2017) emphasis that resource conditions are prerequisites for effective STEM education implementation, not optional enhancements.

Findings also support reducing lab class sizes. Sarah argued that there is "absolutely no reason to have thirty kids in a lab science class," a position supported by both safety concerns and research on student engagement in STEM education environments (Parker et al., 2015).

Accountability structures also warrant reconsideration. Participants consistently argued that program success in CareerTech STEM pathways are better measured by long-term indicators, including postsecondary enrollment, degree completion, and career placement, then by standardized assessment performance. This aligns with Stone's (2014) argument that the value of high-quality CTE is best evaluated through the workforce and academic trajectories it enables.

Finally, policy related to work-based learning access needs direct attention. Current regulatory barriers, including age restrictions, liability concerns, and HIPAA requirements, significantly limit clinical and shadowing experiences for students in biomedical and health-focused STEM pathways. Policies that create structured, supervised pathways for high school students in these areas would address a critical motivational and experiential gap that participants identified consistently.

Teacher Education and Professional Development

The pattern across participants is clear: confidence in integrated STEM education pedagogy was built through direct engagement with content in applied, authentic contexts, not through abstract pedagogical training. Nadelson et al. (2013) and Parker et al. (2015) have similarly emphasized that effective professional development must build genuine content knowledge alongside instructional capacity.

Feille's (2025) work on preservice elementary science teacher identity offers an important connection here. Her finding that science teaching self-efficacy increases when teachers are given mastery experiences, opportunities for reflection, and direct engagement with science in everyday contexts suggests that professional development for CareerTech STEM pathway teachers should follow a similar logic: immersive, content-centered, reflective, and situated in authentic disciplinary practice. For teachers like Megan, whose curricular role identity is still developing (Forbes & Davis, 2008), professional development that includes side-by-side mentoring and modeled expertise may be particularly effective.

Watson's (2019) framework also has implications here. Because teachers under pressure tend to default to teacher-centered routines, professional development aimed at sustaining integration must do more than expand theoretical repertoires. It must build new instructional habits through repeated, supported practice. This points to the value of intensive, embedded, long-term professional development over single workshop experiences, a finding consistent with Eun (2019).

Equity And Access

CareerTech integrated STEM pathways represent a meaningful access point for rigorous STEM education, particularly for students underserved in traditional K-12 settings. Sarah's account of students who entered the biomedical academy without family resources or institutional support but went on to complete doctoral programs, earn full-ride scholarships, and enter health professions illustrates the transformative potential of these programs. At the same time, equitable implementation requires deliberate attention to conditions that are unevenly distributed: funding, class size, work-based learning access, and the quality of teacher expertise available to students across different CareerTech contexts.

Recommendations

For STEM Pathway Teachers

STEM pathway teachers in CareerTech settings are encouraged to continue prioritizing inquiry-based facilitation, hands-on real-world task design, and interdisciplinary collaboration as the foundations of effective integrated STEM education practices. Integration is most powerful when enacted through authentic problem solving rather than mandated through curriculum compliance. Investing in professional networks, with colleagues across STEM disciplines, with industry partners through advisory boards, and with professional organizations, strengthens both content knowledge and instructional support.

Teachers at earlier stages of their professional identity development, particularly those who entered CareerTech from non-industry backgrounds, are encouraged to seek mentored professional learning experiences that place them in direct contact with STEM content in authentic applied contexts. For teachers like Megan, whose confidence is currently organized around curriculum materials, the goal is not to abandon those materials but to develop the autonomy to adapt, supplement, and move beyond them over time. This developmental trajectory is consistent with Forbes and Davis (2008) and elaborated in Feille's (2025) teacher identity research.

For Oklahoma CareerTech

Oklahoma CareerTech is encouraged to sustain and expand the structural conditions that participants consistently identified as enabling effective integration: dedicated and renewable program budgets, reasonable lab class sizes, administrative trust and instructional autonomy, access to industry advisory boards, and pathways for students to engage in internships, shadowing, and clinical experiences. Participants described these not as amenities but as the conditions without which authentic integrated STEM education is not feasible.

Professional development should prioritize advanced, content-rich experiences that deepen subject matter expertise rather than generic instructional strategies. Wherever possible, it should connect teachers with practitioners in relevant industries. CareerTech should also formalize structures through which teacher voices are incorporated into decisions about curriculum, accountability, and program design. Participants who felt trusted and heard were more confident, more innovative, and more committed to their programs.

For Future Research

This study offers a starting point, but several important questions remain. The most natural extension of this work would expand the participant pool to focus on CareerTech teachers who hold provisional certificates through the Oklahoma CareerTech certification pathway. All five participants in this study held traditional or alternative certifications, meaning the experiences of industry professionals who enter the classroom through the provisional pathway were not represented. Those teachers bring a distinctly different set of experiences, knowledge bases, and professional identity trajectories that may shape how they perceive and implement integrated STEM education in meaningful ways. Future research that centers provisional certificate holders would provide a more complete picture of who is teaching STEM pathway courses in CareerTechs and how their certification pathway influences their practice.

Relatedly, this study would benefit from replication across a wider range of teaching experience levels. Participants here were largely veteran teachers with over a decade in the classroom and advanced degrees. Including early career teachers, mid-career teachers making transitions from industry, and those nearing retirement would allow researchers to examine how perceptions of integrated STEM, self-efficacy, and professional identity shift across a career span. The developmental patterns suggested by participants' varied trajectories, particularly the contrast between Megan's curriculum-dependent confidence and the more autonomous expertise of Emily and Sarah, point to the value of a longitudinal or cross-sectional design that captures teachers at multiple career stages.

A comparative case study between CareerTech and traditional high school settings represents another important direction. This study consistently found that participants credited CareerTech infrastructure, including dedicated budgets, smaller class sizes, industry advisory boards, and institutional autonomy, as central to their ability to implement integrated STEM education. However, because all participants came from CareerTech settings, it is not possible to determine from this study alone whether those structural conditions produce meaningfully different outcomes than what occurs in well-resourced traditional high schools. A comparative design that examines both teacher self-efficacy and student outcomes across CareerTech and traditional high school STEM education programs would begin to answer that question. Such a study could explore whether the confidence and instructional autonomy CareerTech teachers describe translates into measurable differences in student engagement, achievement, and career readiness, and whether similar structural conditions in traditional high schools produce comparable results. This kind of comparative work would strengthen the evidence base for CareerTech as a model for integrated STEM education delivery and help identify which features of the CareerTech context are transferable to other settings.

Conclusion

This study contributes to a growing body of literature on integrated STEM education by centering the lived experiences, perceptions, and recommendations of teachers who enact that integration daily in CareerTech settings. Findings suggest that successful integrated STEM education is not primarily a function of individual teacher talent or motivation. It depends on the alignment between teacher expertise, pedagogical approach, and institutional infrastructure. When those conditions align, integrated STEM education becomes achievable, meaningful, and transformative for students.

Integrated STEM education thrives in CareerTech when it is understood as a philosophy rather than a program, enacted through inquiry and facilitation rather than prescription, and sustained by institutional commitment rather than individual resilience. It is grounded in the kind of real-world, applied engagement that Dewey (1938) envisioned as the heart of meaningful education. Bandura's (1997) framework reminds us that efficacy is built through mastery, supported through modeling, and nurtured through environments that trust teachers as professionals. The voices in this study offer a compelling case that when those conditions are in place, CareerTech STEM pathway teachers rise to meet them, and their students are better for it.

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Appendices

Appendix A: Recruitment Letter

Subject: Participants Needed: Research Study on STEM Education in Career Technical Centers

Dear [Potential Participant],

Are you a STEM pathway teacher at a Career Technical Center in an Oklahoma Metro Area? If so, I would like to invite you to participate in a research study exploring the lived experiences of Career Technical Education (CTE) teachers and how these experiences shape their self-efficacy and beliefs about STEM education.

About the Study: This study aims to understand CTE STEM pathway teachers' perceptions, beliefs, and practices related to integrated STEM education. By identifying barriers to effective implementation, the research will contribute to strategies for supporting teachers in delivering STEM instruction.

To participate, begin by completing this 10-minute survey: LINK

To be eligible, you must:

- Be 18 years of age or older
- Currently, I teach at least one STEM pathway course.
- Currently teach at one of the following Career Technical Centers:
  - Birch CareerTech
  - Cedar CareerTech
  - Elm CareerTech
  - Maple CareerTech

  - Oak CareerTech
  - Willow CareerTech

What's Involved: Participants will be asked to:

- Complete a 10-minute online survey
- Participate in **up to two 60-minute interviews** (video recorded)

To participate, begin by completing this 10-minute survey: LINK

If you have questions about this research, please contact: Mariah Warren at MWarren@ou.edu or (405) 325-3056 and Kelly Feille at Feille@ou.edu.

The University of Oklahoma is an equal opportunity institution.

Best regards,

Mariah Warren

Appendix B: Recruitment Follow-Up Email

Subject: Reminder: Research Study on STEM Education in CTE - Your Participation

Dear [Participant],

Thank you for considering participating in our research study! We are seeking **STEM pathway teachers** from **Career Technical Centers in an Oklahoma Metro Area** to share their experiences and insights into STEM education.

If you haven't already signed up and would like to participate, here's a quick reminder of the details:

To participate, begin by completing this 10-minute survey: LINK

To be eligible, you must:

- Be 18 years of age or older
- Currently, I teach at least one STEM pathway course.
- Currently teach at one of the following Career Technical Centers:
    - Birch CareerTech
    - Cedar CareerTech
    - Elm CareerTech
    - Maple CareerTech
    - Oak CareerTech
    - Willow CareerTech

What's Involved: Participants will be asked to:

- Complete a 10-minute online survey
- Participate in **up to two 60-minute interviews** (video recorded)

To participate, begin by completing this 10-minute survey: LINK

If you have questions about this research, please contact: Mariah Warren at MWarren@ou.edu or (405) 325-3056 and Kelly Feille at Feille@ou.edu.

Thank you again for your consideration!

Best regards,

Mariah Warren

Appendix C: Online Participant Consent Form

You are invited to participate in research about STEM Education in the Career Technical Setting.

If you agree to participate, you will complete a 10-minute online survey and up to two 60-minute interviews that will be video recorded.

You may experience these risks:

Data collected online or by a device and transmitted electronically: You will be asked to complete an online survey as part of this research. The organization hosting the data collection platform has its own privacy and security policies for keeping your information confidential. There is a risk that the external organization, which is not part of the research team, may gain access to or retain your data or your IP address which could be used to re-identify you. No assurance can be made as to their use of the data you provide for purposes other than this research.

Collection of demographic or geographic location data that could lead to deductive re-identification: You will be asked to provide demographic information that describes you. We may also gather information about your geographic location in this research. Different combinations of personal and geographic information may make it possible for your identity to be guessed by someone who was given, or gained access, to our research records. To minimize the risk of deductive re-identification, we will not combine identifying variables nor analyze and report results for small groups of people with specific demographic characteristics.

There are no benefits for participating in this research.

Your participation is voluntary, and your responses will be confidential.

We might share your de-identified data with other researchers or use it in future research without obtaining additional assent from you.

Even if you choose to participate now, you may stop participating at any time and for any reason.

If you have questions about this research, please contact: Mariah Warren at MWarren@ou.edu or (405) 325-3056 and Kelly Feille at Feille@ou.edu.

You can also contact the University of Oklahoma – Norman Campus Institutional Review Board at 405-325-8110 or irb@ou.edu with questions, concerns or complaints about your rights as a research participant, or if you don't want to talk to the researcher.

Please print this document for your records. By providing information to the researcher(s), I am agreeing to participate in this research.

Are you 18 years of age or older? ___ Yes ___ No (If no – cannot participate)

Are you a STEM pathway teacher? ___ Yes ___ No (If no – cannot participate)

Are you currently teaching at one of the following CareerTech Center (Birch CareerTech, Cedar CareerTech, Elm CareerTech, Maple CareerTech, Oak CareerTech, Willow CareerTech)?

___ Yes ___ No (If no – cannot participate)

Appendix D: Oral Participant Consent Form

You are invited to participate in research about STEM Education in the Career Technical Setting.

If you agree to participate, you will complete a 10-minute online survey and up to two 60-minute interviews that will be video recorded.

You may experience these risks:

Data collected online or by a device and transmitted electronically: You will be asked to complete an online survey as part of this research. The organization hosting the data collection platform has its own privacy and security policies for keeping your information confidential. There is a risk that the external organization, which is not part of the research team, may gain access to or retain your data or your IP address which could be used to re-identify you. No assurance can be made as to their use of the data you provide for purposes other than this research.

Collection of demographic or geographic location data that could lead to deductive re-identification: You will be asked to provide demographic information that describes you. We may also gather information about your geographic location in this research. Different combinations of personal and geographic information may make it possible for your identity to be guessed by someone who was given, or gained access, to our research records. To minimize the risk of deductive re-identification, we will not combine identifying variables nor analyze and report results for small groups of people with specific demographic characteristics.

There are no benefits for participating in this research.

Your participation is voluntary, and your responses will be confidential.

We might share your de-identified data with other researchers or use it in future research without obtaining additional assent from you.

I will be asking some questions to find out how you want me to report your ideas. You can refuse any that you do not like without any penalty.

Do you agree to being quoted directly, without the use of your name? ___ Yes ___ No

Do you consent to video recording? ___ Yes ___ No

May I contact you to gather additional data or recruit you for new research? ___ Yes ___ No

Even if you choose to participate now, you may stop participating at any time and for any reason.

If you have questions about this research, please contact:

Mariah Warren at MWarren@ou.edu or (405) 325-3056 and Kelly Feille at Feille@ou.edu.

You can also contact the University of Oklahoma – Norman Campus Institutional Review Board at 405-325-8110 or irb@ou.edu with questions, concerns or complaints about your rights as a research participant, or if you don't want to talk to the researcher.

Do you agree to participate in this research? ___ Yes ___ No

Finally, would you like a printed or electronic copy of the information we have just reviewed?

____________________ (note response)

Date of interview: ___________________________________

Name of Interviewee: ________________________________

Mailing or Email address for electronic consent copy: ____________________________

Name of Researcher and Date of the Consent Process: __________________________

Signature of the Researcher: ____

Appendix E: Demographics Survey

Eligibility Questions

Q1. Are you 18 years of age or older?

- Yes / No (If no – cannot participate)

Q2. Are you currently teaching at one of the following CareerTech Centers (Birch CareerTech, Cedar CareerTech, Elm CareerTech, Maple CareerTech, Oak CareerTech, Willow CareerTech)?

- Yes / No (If no – cannot participate)

Q3. Do you teach at least one STEM Pathway Course?

- Yes / No (If no – cannot participate)

Demographics

Q4. Name (First / Last)

Q5. Preferred Email Address

Q6. How old are you?

- 18–24 years old
- 25–34 years old
- 35–44 years old
- 45–54 years old
- 55–64 years old
- 65+ years old

Q7. How do you describe yourself?

- Male

- Female
- Non-binary / third gender
- Prefer to self-describe
- Prefer not to say

Q8. Choose one or more races that you consider yourself to be:

- White or Caucasian
- Black or African American
- American Indian/Native American or Alaska Native
- Asian
- Native Hawaiian or Other Pacific Islander
- Other
- Prefer not to say

Q9. What is the highest level of education you have completed?

- High school diploma or GED
- Some college, but no degree
- Associate's or technical degree
- Bachelor's degree
- Graduate or professional degree (MA, MS, MBA, PhD, JD, MD, DDS, etc.)
- Prefer not to say

Teaching Experience

Q10. Which Regional Career Technical Center do you currently work at?

Q11. How long have you been a teacher?

- 1–5 years
- 6–10 years
- 11–20 years
- 21–30 years
- 31+ years

Q12. What educational certification do you currently hold?

Q13. What was your teaching assignment for the 2024–2025 school year?

Q14. What will be your teaching assignment for the 2025–2026 school year?

Q15. Did you work somewhere in a business or industry related to the STEM field you currently teach before coming to teaching?

- Yes
- No

Q16. Provide a brief description of your pathway to teaching.

Additional Participation

Q17. Are you willing to be contacted for interviews about STEM education in CareerTech Centers?

- Yes
- No

Q18. Do you know someone who meets these requirements that we should contact?

- Yes
- No

Additional Participants

Q19. First Participant Recommendation Name

Q20. First Participant Recommendation Email

Q21. Do you know someone who meets these requirements that we should contact?

- Yes
- No

Q22. Second Participant Recommendation Name

Q23. Second Participant Recommendation Email

Q24. Do you know someone else who meets these requirements that we should contact?

- Yes
- No

Q25. Third Participant Recommendation Name

Q26. Third Participant Recommendation Email

Appendix F: Interview Protocol

Consent

Section 1 Professional Background and Pathway

1. Can you describe your path to becoming a teacher?
    1. What experiences influenced your decision to teach?
    2. How did you arrive in your current teaching role?
2. How do students enter or choose your program or pathway?
    1. At what grade levels do you teach students?
    2. Is your program structured for one year or multiple years?

Section 2 Conceptions of STEM Education

1. How would you define STEM education?
2. What makes something STEM versus just science or math?
3. How do you think about extensions such as STEAM or other models?
4. What would an ideal STEM classroom look like?
5. What do you see as the most effective ways to teach STEM?
6. What role, if any, do real world problems play in STEM instruction?
7. Please share an example of an effective way you have taught a STEM concept.
    1. What made it effective?
    2. What would have made it more effective?

Section 3 Self Efficacy Content and Pedagogy

1. How comfortable or qualified do you feel implementing STEM education in your classroom?

    1. How comfortable or qualified do you feel about the STEM content you teach?
    2. How comfortable or qualified do you feel about the teaching or pedagogical side of your work?
    3. Are there other factors that affect how qualified you feel in the classroom?
2. What experiences have made you feel most comfortable with the content?
    1. What experiences have made you feel most comfortable with pedagogy?

Section 4 Challenges and Supports

1. What challenges have you faced in teaching STEM?
    1. Have you noticed changes in students or teaching since COVID-19?
2. What aspects of your current role feel most supportive?
3. What supports have helped you most in implementing STEM education?
    1. Are those supports content specific or more general?
4. In a perfect world, what supports would you want?
    1. What supports could ensure teachers feel competent in STEM education?
5. Are there specific content areas where support would help you feel more confident?

Section 5 CareerTech and Comparative Contexts

1. What role does industry or professional expertise play in supporting you?
    1. Do you feel that coming from industry versus education affects comfort in teaching?
    2. How is STEM in a CareerTech setting different from traditional schools?

2. What should someone know about implementing STEM education in CareerTech
3. Do you have any additional thoughts about STEM teaching?